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Deep Sea 2003: Conference on the Governance and Management of Deep-sea Fisheries

Part 2: Conference poster papers and workshop papers

Queenstown, New Zealand, 1–5 December 2003
Dunedin, New Zealand, 27–29 November 2003

Cover photo:
Stern view of the fishing trawler *Austral Leader* (owned by Austral Fisheries Pty Ltd, Perth) that was built in 1967 in Bordeaux, France. This photo was taken near Heard Island, Australia, in 1997.
Courtesy of Captain Geiri Petursson.

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Preface

Volume 2 of the Proceedings of the Deep Sea 2003 Conference both complement and supplement the papers that are presented in Volume 1 and underpin the Report on the Conference. Volume 1 ran to 718 pages and putting the papers that presenters developed from their posters and the papers and syntheses from the pre-Conference workshops into a second volume seemed the most practical approach.

The need for a poster session at the Queenstown Conference arose from the decision of the Programme Committee to avoid breakout sessions during the main period of the Conference. Not surprisingly there was great interest in presenting the results of deep-sea research and the results of related work on governance and it was decided that the most practical way to accommodate this desire was through a poster session. Those who presented posters at the Queenstown were invited to expand their presentations and the papers of those who wished to do so are presented in the first part of this second proceedings volume.

The Programme Committee had concluded that the four and a half days scheduled for the Conference would mean that discussions and treatment of issues and problems would necessarily be synoptic and thus render difficult addressing all issues in detail. Thus, it was decided to hold several separate workshops on topics of relevance to the Conference theme. Four such workshops addressed the topics of:

i. Assessment and Management of Deepwater Fisheries
ii. Management of Small-Scale Deep-Sea Fisheries
iii. Conservation and Management of Deepwater Chondrichthyan Fishes and
iv. Bioprospecting in the High Seas

These workshops were held in Dunedin at the University of Otago, from 27 to 29 November, just prior to DEEP SEA 2003. Because of the relevance of these workshops to the Conference's objectives, those presenting papers in the Dunedin meetings were invited to provide a paper based on their presentation for inclusion in the Conference Proceedings. While few papers have been provided by participants to the Workshop on Assessment and Management of Deepwater Fisheries there are many contributions from the other three workshops. The papers presented at the four workshops form the second part of this volume. Those interested in this topic and who have not read the contributions in the main Conference proceedings of Volume 1 are strongly encouraged to do so.

As for Volume 1, the task of preparing the various papers for publication as well as the follow-up correspondence with contributors has been undertaken through the endeavours of my secretary, Ms Marie-Thérèse Magnan, FIRM, FAO, Rome for which I am most grateful.

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Editor, Conference Proceedings
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[1] FAO 2005. Report on DEEP SEA 2003, an International Conference on Governance and Management of Deep-sea Fisheries. Queenstown, New Zealand, 1–5 December 2003. FAO Fisheries Report No. 772. Rome. 84pp.

Abstract

The second part of the Proceedings of the Conference on the Governance and Management of Deep-sea Fisheries that was held in Queenstown, New Zealand from 1 to 5 December 2003 contains papers developed from many of the posters that were presented in the Poster Session of the Conference. Not all poster presenters have expanded their papers for the Proceedings. Poster-papers presented in this volume address issues of deep-sea oceanography, ecology, fisheries management and governance.

The second part of Volume 2 of the Proceedings contains papers that were presented at the Workshops that were held in Dunedin, New Zealand, from 27 to 29 November, just prior to DEEP SEA 2003. There were four workshops that addressed the topics of:

i. Assessment and Management of Deepwater Fisheries
ii. Management of Small-Scale Deep-Sea Fisheries
iii. Conservation and Management of Deepwater Chondrichthyan Fishes and
iv. Bioprospecting in the High Seas.

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CONTENTS

Poster papers

Deep-sea fish diversity around Taiwan, Province of China

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1. INTRODUCTION

Taiwan, Province of China[1] is adjacent to the Taiwan Strait Shelf, the South China Sea Basin, the West Philippine Sea Basin and the Okinawa Trough (Figure 1). More than half of the sea territory of Taiwan are deep basins down to nearly 5 000 m and are the largest habitat around Taiwan. The shallow-water fishes of Taiwan have been well documented by Shen *et al.* (1993), but the deep-sea fish fauna are yet to be fully investigated. The same situation holds true for the fishes of the South China Sea. After the huge collections of shallow-water and deep-sea fishes by the U.S. research vessel *Albatross* in Philippine seas and adjacent waters during the years 1907–1910, the shallow-water fishes of the South China Sea have been relatively well documented (Randall and Lim 2000), but the data of deep-sea fishes are scarce. Okamura *et al.* (1984, 1985) provide a list of the shallow-water and deep-sea fishes of the Okinawa Trough. However, few samples were collected from the Taiwan area.

The 'water mass hypothesis' (Koslow, Bulman and Lyle 1994) explains the vertical and horizontal patterns of the deep-sea demersal fish communities. Therefore, the community structures of the deep-sea demersal fish are supposed to be different between the South China Sea and the adjacent waters.

To better understand the marine bioresource and diversity, it is critical to explore the deep-sea fauna in Taiwan. The short-term objective of this study is to explore the faunistical composition, abundance, biomass and diversity of deep-sea fishes in the waters around Taiwan. The long-term objectives are (a) to compare the community structure of deep-sea fishes inhabiting the South China Sea, the West Philippine Sea and the Okinawa Trough, (b) to detect the general trends in the distribution of the fish fauna in relation to the environmental variables and (c), to compare the boundaries between the faunal zones of deep-sea fishes with those water masses.

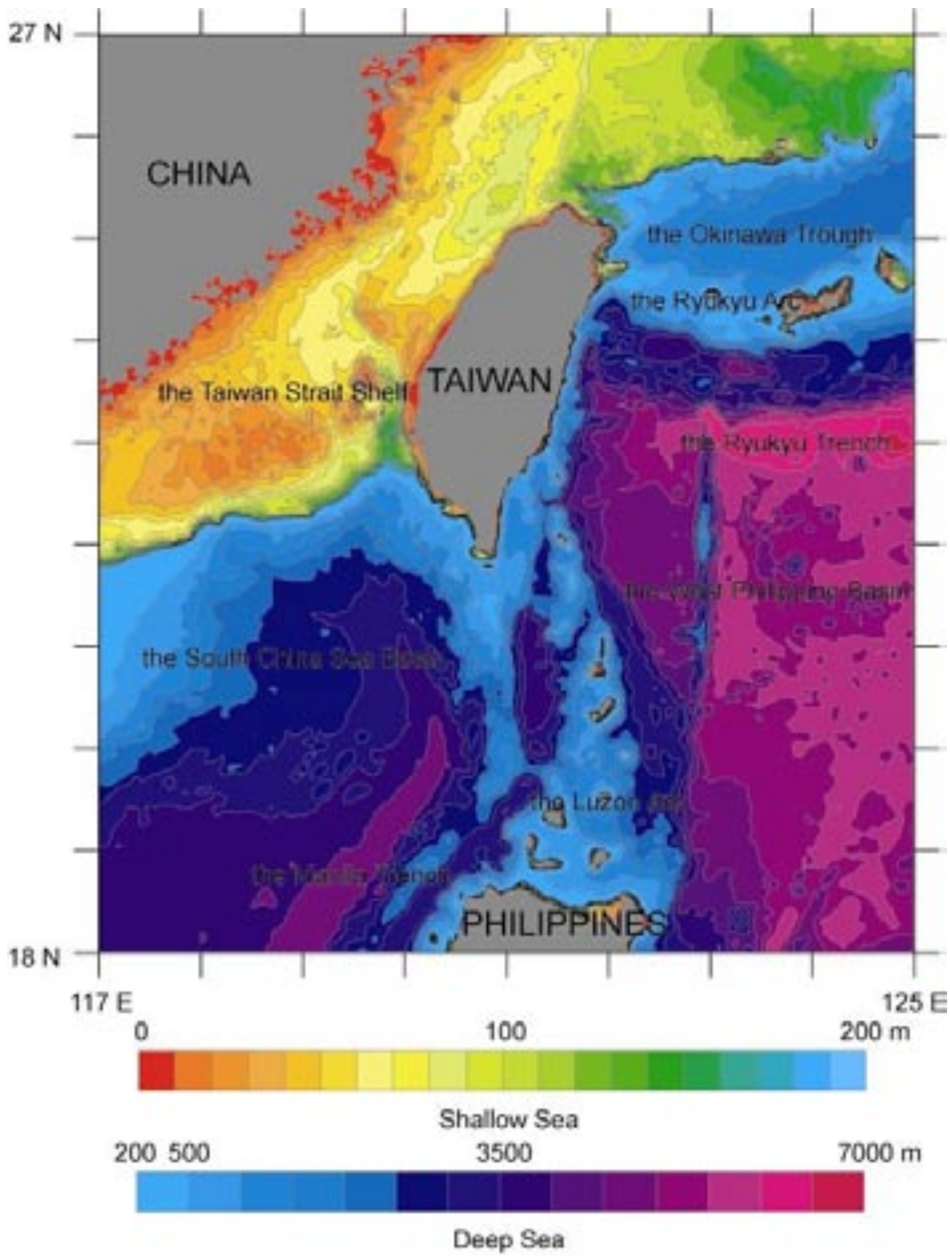
2. MATERIALS AND METHODS

The deep-sea fish fauna around Taiwan was investigated from the samples collected by the **R.V. Ocean Researcher I** under a three-year project (August 2002 – July 2004) of the National Science Council. Because of the limitation of the trawl wire length, only

[1] To facilitate reading of this report, "Taiwan, Province of China" will be subsequently referred to as "Taiwan".

depths less than 3 570 m were surveyed during the six cruises using a semi-balloon otter trawl with a 22 m headrope, a 2.5 cm stretched-mesh net body and a 1.3 cm stretched-mesh codend. A French type beam trawl of 4 m span, a rock dredge of 1 m span and Isaacs-Kidd midwater trawl (IKMT) were also used. One-hour tows were usually used for the operation of bottom trawl except when abnormally high tension of the tow wire was encountered during a trawl operation. The distance swept by the trawl was estimated from the position where the trawl contacted the sea bottom to where it left, using an integrated navigation system. The towing speed of otter trawl was kept between 1.5 and 2.5 knots over-the-ground speed and that of the beam trawl between 1.0 and 1.5 knots.

FIGURE 1
Sea floor topography around Taiwan



After recovery of the trawl, all of the samples were identified to main taxa. Fishes were preserved in a -20° C deep freezer. In the laboratory, the samples were identified to species if possible. The morphometric characters, e.g. size and weigh, of fish was measured and recorded. Specimens were then fixed in 10% neutralized formalin for more than 4 weeks. After fixing, the samples were rinsed with tap water and then preserved in 70% alcohol. The Shannon-Wiener index (natural logarithm base) was chosen to calculate fish diversity in each haul.

3. RESULTS AND CONCLUSIONS

A total of 21 otter trawl stations, 23 beam trawl stations, 7 dredge stations and eight IKMT stations were undertaken during the first two years (Figure 2). One thousand four hundred and seventy-five fishes belonging to 192 species were caught. Four new species (*Oneirodes pietschi*, *Bufoceratis shaoi*, *Caelorinchus sheni* and *Caelorinchus leptorhinus*), five possible new species (two Oneirodidae, one Gigantactinidae and one Dalatiidae – Figure 3) and 86 new records for Taiwan were added to the Taiwan fish fauna from the samples collected by these surveys. These

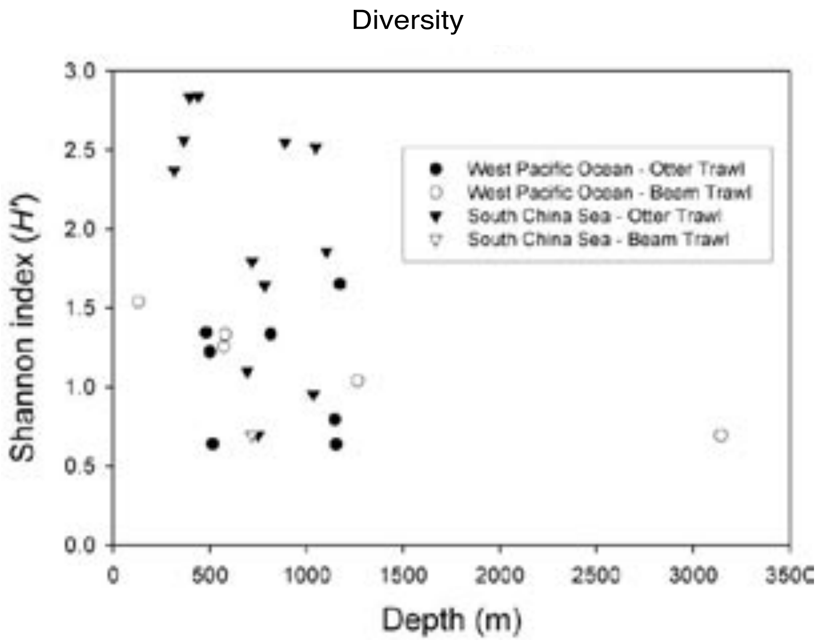
FIGURE 2
Location of sampling stations

FIGURE 3
New species and possibly new species

new records include three species of Rajidae (*Bathyraja* sp., *Bathyraja bergi* and *Pavoraja* sp.), two Dalatiids (*Centroscyllium kamohar* and *Etmopterus brachyurus*), a Scyliorhinidae (*Apristurus japonicus*), two Nettastomatids (*Venefica tentaculata* and *Nettastoma parviceps*), a Nemichthyid (*Avocettina infans*), a Muraenesocid (*Congresox talabonoides*), three Congrids (*Gnathophis nystromi ginanago, Rhechias retrotincta* and *Ariosoma meeki*), two Synaphobranchids (*Synaphobranchus* sp. and *S. brevidorsalis*), a Serrivomerid (*Serrivomer* sp.), seven Sternoptychids (*Argyropelecus gigas*, *A. hemigymnus, Polyipnus danae*, *P. triphanos complex*, *Sternoptyx diaphana, S. obscura* and *S. pseudobscura*), a Neoscopelid (*Neoscopelus porosus*), a Microstomatid (*Nansenia ardesiaca*), four Gonostomatids (*Cyclothone atraria, C. psendopallida*, *Sigmops atlanticum* and *S. elongatum*), six Stomiids (*Astronesthes lucifer, Flagellostomias* sp., *Stomias nebulosus, Photostomias guernei, Eustomias* sp., *Leptostomias* sp. and *Borostomias elucens*), a Phosichthyid (*Polymetme corythaeola*), five Alepocephalids (*Alepocephalus longiceps*, *Talismania okinawaensis*, *Conocara macroptera?*, *Rouleina guentheri* and *R. watasei*), two Melamphaids (*Poromitra oscitans* and *Scopeloberyx robustus*), a Ceratiid (*Ceratias* sp.), a Himantolophid (*Himantolophus* sp.), a Linophrynid (*Linophryne indica*), a Melanocetid (*Melanocetus murrayi*), two Oneirodids (*Oneirodes* sp.2 and *Oneirodes* sp.3), a Ipnopid (*Bathypterois guentheri*), a Halosaurid (*Halosauropsis macrochir*), 20 Macrourids (*Gadmus colletti*, *Bathygadus antrodes, B. nipponicus, B.garretti*, *Hymenogadus gracilis*, *Hymenocephalus lethonemus*, *Nezumia condylura*, *Pseudoctenurous septifer*, *Kumba japonica*, *Sphagemacrurus*, seven species of the genus Ventrifossa (*Ventrifossa longibarbata*, *V. macroptera*, *V. rhipidodorsalis*, *V. saikaiensis*, *V. lucifor*, *V. divergens*, *V. atherodon*) *Caelorinchus productus*, *C. longissimus*, *C. asteroids* and *Coryphaenoides microps*), a Morid (*Gadella jordani*), ten Ophidiids (*Monomitopus pallidus, M. kumae, Holcomycteronus* sp., *Alcockia rostrata*, *Bassozetus glutinosus*, *Bathyonus caudalis*, *Dicrolene tristis*, *Glyptophidium japonicum*, *Homostolus acer* and *Porogadus guentheri*), a Trachichthyid (*Hoplostethus melanopus*), aDiretmid (*Diretmoides pauciradiatus*), a Sebastid (*Helicolenus fedorovi*) an Ereuniid (*Ereunias grallator*) and a Zoarcid (*Bothrocara molle*). These data also filled the gaps in worldwide knowledge of the deep-sea fish fauna between Japan and Philippines.

Among the 192 species of deep-sea fishes, 121 species are demersal fishes and 71 species are midwater fishes. Only 31 species of demersal fishes were caught from the Western Pacific Ocean (WP), 72 species were from the South China Sea (SCS) and eighteen species were common in both seas (Table 1). The diversities of deep-sea demersal fishes in the South China Sea are about two times higher than those in the West Pacific Ocean in the depths less than 500 m. However, the diversities between the two seas are nearly the same when the depth is greater than 500 m (Figure 4). The faunal diversity in the South China Sea displays a dramatic decline with depth, but that in the Western Pacific Ocean displays only a general decline with depth. The higher diversity of deep-sea demersal fish found less than 500 m in depth and the dramatic decline of diversity in the South China Sea could be due to the shallower nutricline and the two-fold higher concentration of chlorophyll in the surface waters of the South China Sea compared to that of the Western Pacific Ocean (Liu *et al.* 2002). The thorough mixing of the South China Sea and the Western Pacific Ocean intermediate water (Chen and Huang 1996) could explain why the diversities of deep-sea demersal fish between the South China Sea and the Western Pacific Ocean in seas greater than 500 m depth are similar.

FIGURE 4
Diversities of demersal fish between the South China Sea and the West Pacific Ocean along the depth



The quantitative data of all collections as well as the specimen photos of almost all species were digitalized and archived in the web-accessible GIS database – Fauna and Distribution Database of Deep-sea Organism of Taiwan <*http://webgis.sinica.edu.tw/seafish/viewer.htm for public access*>. The database was also connected with Fish Database of Taiwan <*http://fishdb.sinica.edu.tw/*>.

In conclusion, four new species (*Oneirodes pietschi*, *Bufoceratis shaoi*, *Caelorinchus sheni* and *Caelorinchus leptorhinus*), five possible new species (two Oneirodids, one Gigantactinid and one Dalatiid) and 86 new records of Taiwan were added to the Taiwan fish fauna from the samples collected by the **R.V. Ocean Researcher I** during the three-year project (August 2002 – July 2004) of the National Science Council.

TABLE 1
Species of demersal fishes caught in the South China Sea (SCS) and the Western Pacific Ocean (WP)

Family	Species	SCS	WP	Family	Species	SCS	WP
Acropomatidae	*Synagrops japonicus*	*		Macrouridae	*Bathygadus* sp.	*	
Alepocephalidae	*Alepocephalus bicolor*	*	*		*Bathygadus spongiceps*		*
	Alepocephalus longiceps	*			*Caelorinchus aconcagus*	*	
	Bajacalifornia erimoensis	*			*Caelorinchus anatirostris*	*	
	Conocara sp. *(macroptera?)*		*		*Caelorinchus brevirostris*		*
	Rouleina guentheri		*		*Caelorinchus cingulatus*	*	
	Rouleina watasei	*			*Caelorinchus formosanus*	*	
	Talismania okinawaensis	*			*Caelorinchus kishinouyei*	*	
Anacanthobatidae	*Anacanthobatis borneensis*	*			*Caelorinchus macrorhychus*	*	
Aploactinidae	*Erisphex pottii*		*		*Caelorinchus occa*	*	
Bothidae	*Bothus myriaster*	*			*Caelorinchus smithi*	*	
Centrophoridae	*Deania calcea*		*		*Caelorinchus* sp.	*	*
Chaunacidae	*Chaunax abei*	*			*Cetonurus robustus*	*	
Chimaeridae	*Chimaera phantasma*		*		*Chalinura* sp.	*	*
Chlorophthalmidae	*Chlorophthalmus acutifrons*	*			*Coryphaenoides marginatus*	*	
Congridae	*Ariosoma meeki*	*			*Coryphaenoides microps*	*	*
	Gnathophis nystromi ginanago	*	*		*Coryphaenoides nasutus*		*
	Rhechias retrotincta		*		*Coryphaenoides* sp.	*	
	Bathycongrus retrotinctus	*			*Gadomus colletti*	*	
Cynoglossidae	*Symphurus hondoensis*	*			*Hymenocephalus lethonemus*	*	
	Symphurus novemfasciatus		*		*Hymenocephalus longiceps*	*	
	Symphurus strictus	*	*		*Hymenocephalus* sp.		*
Dalatiidae	*Centroscyllium kamohari*		*		*Hymenocephalus striatissimus*		*
	Etmopterus brachyurus	*			*Hymenogadus gracilis*	*	
	Etmopterus lucifer	*	*		*Malacocephalus laevis*	*	*
Diretmidae	*Diretmoides pauciradiatus*	*			*Mataeocephalus* sp.	*	
	Diretmus argenteus	*			*Nezumia condylura*	*	*
Ereuniidae	*Ereunias grallator*	*			*Nezumia sp.*	*	
Gonorynchidae	*Gonorynchus abbreviatus*		*		*Nezumia spinosa*	*	

Family	Species	SCS	WP	Family	Species	SCS	WP
Halosauridae	_Halosauropsis macrochir_	*	*		_Sphagemacrurus pumiliceps_		*
Ipnopidae	_Bathypterois guentheri_	*			_Sphagemacrurus richardi_	*	
Macrouridae	_Bathygadus antrodes_	*	*		_Squalogadus modificatus_	*	
	Bathygadus garretti	*			_Trachonurus_ sp.	*	
	Trachonurus sulctus	*		Ophidiidae	_Porogadus guentheri_		*
	Ventrifossa ctoenomelas	*			_Alcockia rostrata_	*	
	Ventrifossa garmani	*	*		_Homostolus acer_	*	
	Ventrifossa longibarbata	*		Paralichthyidae	_Pseudorhombus_ sp.	*	
	Ventrifossa macroptera	*		Peristediidae	_Peristedion orientale_	*	
	Ventrifossa nigrodorsalis	*			_Satyrichthys amiscus_	*	
	Ventrifossa rhipidodorsalis	*	*	Rajidae	_Bathyraja bergi_		*
	Ventrifossa saikaiensis	*			_Pavoraja_ sp.	*	
	Ventrifossa sp.	*			_Bathyraja_ sp.	*	*
Moridae	_Gadella jordani_	*	*	Scyliorhinidae	_Apristurus japonicus_		*
Muraenesocidae	_Congresox talabonoides_	*			_Apristurus macrorhynchus_		*
	Gavialiceps taiwanensis		*		_Galeus eastmani_	*	
Neoscopelidae	_Neoscopelus microchir_	*			_Galeus sauteri_	*	
	Neoscopelus porosus	*			_Parmaturus melanobranchus_	*	*
Nettastomatidae	_Saurenchelys fierasfer_		*	Sebastidae	_Helicolenus fedorovi_		*
	Venefica tentaculata		*		_Helicolenus hilgendorfii_		*
Ophichthidae	_Pisodonophis cancrivorus_	*		Setarchidae	_Setarches longimanus_	*	*
Ophidiidae	_Bassozetus glutinosus_		*	Sparidae	_Dentex tumifrons_		*
	Bathyonus caudalis	*		Synaphobranchidae	_Synaphobranchus affinis_		*
	Dicrolene tristis	*			_Synaphobranchus brevidorsalis_		*
	Glyptophidium japonicum	*			_Synaphobranchus kaupii_	*	
	Holcomycteronus sp.		*		_Synaphobranchus_ sp.		*
	Monomitopus kumae	*		Synodontidae	_Harpadon microchir_	*	*
	Monomitopus pallidus	*		Tetraodontidae	_Sphoeroides pachygaster_	*	
	Neobythites sivicola	*		Trachichthyidae	_Hoplostethus crassispinus_	*	
	Neobythites sp.	*			_Hoplostethus melanopus_	*	
	Neobythites sp.1	*		Zoarcidae	_Bothrocara molle_		*
	Neobythites stigmosus	*	*				

4. ACKNOWLEDGEMENTS

We thank the captain and crew of **R.V. Ocean Researcher I** for their cooperation and assistance during the cruises. We also acknowledge the support of the National Science Council for funding this three-year project.

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Distribution and length–weight compositions of some rare deep-sea fishes from Oreosomatidae, Notacanthidae, and Zoarcidae families in the Pacific waters off the northern Kuril islands and southeastern Kamchatka, Russia

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1. INTRODUCTION

Several research and fishing cruises were conducted off the North Kuril Islands and South East Kamchatka in 1993–2002. Data were collected on the composition of bottom fish communities in the lower part of the shelf and upper bathyal and on the distribution pattern and biology of local species. The occurrence of some rare ichthyofauna was also recorded. This paper presents information on the spatial and bathymetrical distribution, size and weight frequency data for four little-studied fish species: coster dory (*Allocyttus verrucosus,* Oreosomatidae), spiny eel (*Notacanthus chemnitzii*, Notacanthidae), (*Hadropogoonichthys lindbergi*) and tough eelpout (*Puzanovia rubra*, Zoarcidae).

2. MATERIAL AND METHODS

The material for this paper was collected during 44 research and fishing cruises on the Pacific side of the North Kuril Islands and South East Kamchatka (47° 50´–52° 10´ N, Figure 1) in April–December 1993–2002. Over 8 000 bottom trawl hauls at 100–850 m were made. The bottom temperature was measured during a trawling in most cruises. The hauls were made during the day and night using bottom trawls with a vertical and horizontal opening of 5–6 m and 25 m respectively. Average towing speed was 3.6 knots. Trawl opening was monitored using special equipment. Hauling duration varied between 0.5 and 10 hours so catches were then recalculated to a standard one-hour haul. The percentage presence of each species was analyzed by depth and bottom temperature. The size and weight data were based on length and weight measurements of 31 coster dory, 31 spiny eel, 8 *H. lindberg* and 7 tough eelpout.

FIGURE 1
Map of the study area

3. RESULTS AND DISCUSSION

The frequency of occurrence and catch volume data indicate that the abundance of all four species off the North Kuril Islands in the Pacific and near the South East Kamchatka is low (Table 1). Most often they jointly inhabit the sites with the more abundant species within the bathymetric range of their catches (Table 2).

TABLE 1
Quantitative indices characterizing the occurrence of the rare species Oreosomatidae, Notacanthidae, and Zoarcidae in the catches off the northern Kuril Islands and southeastern Kamchatka, 1993–2002

Species	% weight in catches	No. of individuals	No. per hour trawling	Total weight (kg)	Weight/h trawling (kg)	Number of trawls with specimens
Coster dory *(Allocyttus verrucosus)*	0-0.353 / <0.001	1-3 / 1.15	0-4 / 0.31	0-1.80 / 0.96	0-1.60 / 0.42	26
Spiny eel *(Notacanthus chemnitzii)*	0-1.156 / <0.001	1-5 / 1.35	0-4 / 0.50	0-2.00 / 0.56	0-3.00 / 0.44	26
Eelpout *(Hadropogonichthys lindbergi)*	0-0.256 / <0.001	1-2 / 1.14	0-1 / 0.28	0-0.12 / 0.08	0-0.10 / 0.03	7
Tough eelpout *(Puzanovia rubra)*	0-0.008 / <0.001	1 / 1.0	0-2 / 0.43	0-0.20 / 0.09	0-0.24 / 0.07	7

Note: Above line: minimum and maximum values, under line, mean value.

TABLE 2
Species composition of catches containing rare species of families Oreosomatidae, Notacanthidae, and Zoarcidae off the northern Kuril Islands and southeastern Kamchatka, 1993–2002

Species		A. verrucosus	N. chemnitzii	H. lindbergi	P. rubra
Aleutian skate	*Bathyraja aleutica*	57.7	+	+	+
Whiteblotched skate	*B. maculata*	+	57.7	100.0	57.1
Matsubara skate	*B. matsubarai*	+	53.8	+	+
Giant grenadier	*Albatrossia pectoralis*	84.6	80.8	57.1	+
Popeye grenadier	*Coryphaenoides cinereus*	73.1	88.5	-	+
Pacific flatnose	*Antimora microlepis*	65.4	+	+	-
Walleye pollock	*Theragra chalcogramma*	+	+	57.1	71.4
Atka mackerel	*Pleurogrammus monopterygius*	+	+	57.1	+
Pacific Ocean perch	*Sebastes alutus*	+	50.0	57.1	71.4
Shortraker rockfish	*S. borealis*	96.2	76.9	71.4	+
Shortspine thornyhead	*Sebastolobus alascanus*	80.8	50.0	+	-
Broadbanded thornyhead	*S. macrochir*	92.3	96.2	85.7	71.4
Whitebar eelpout	*Lycodes albolineatus*	57.7	+	85.7	+
Blackfin hooker sculpin	*Artediellichthys nigripinnis*	+	+	57.1	-
Longfin Irish lord	*Hemilepidotus zapus*	+	+	+	57.1
Blacknose sculpin	*Icelus canaliculatus*	+	65.4	57.1	-

Spectacled sculpin	*Triglops scepticus*	+	+	57.1	+
Darkfin sculpin	*Malacocottus zonurus*	84.6	92.3	100.0	85.7
Blackfin poacher	*Bathyagonus nigripinnis*	+	61.5	+	+
Sawback poacher	*Sarritor frenatus*	+	61.5	85.7	+
Unidentified snailfish	*Careproctus cf. cyclocephalus*	+	57.7	+	+
Forktail snailfish	*C. furcellus*	65.4	80.8	71.4	57.1
Round snailfish	*C. roseofuscus*	+	+	71.4	57.1
Snailfish	*Elassodiscus obscurus*	+	50.0	-	+
Dimdisc snailfish	*E. tremebundus*	65.4	80.8	100.0	+
Kamchatka flounder	*Atheresthes evermanni*	92.3	96.2	71.4	71.4
Roughscale sole	*Clidoderma asperrimum*	65.4	+	-	-
Pacific black halibut	*Reinhardtius hippoglossoides matsuurae*	88.5	73.1	-	+

Note: Table contains data only for species with frequency of occurrence in tows of 50% and more, «+» : less than 50%, «-» : the lack of species i catches.

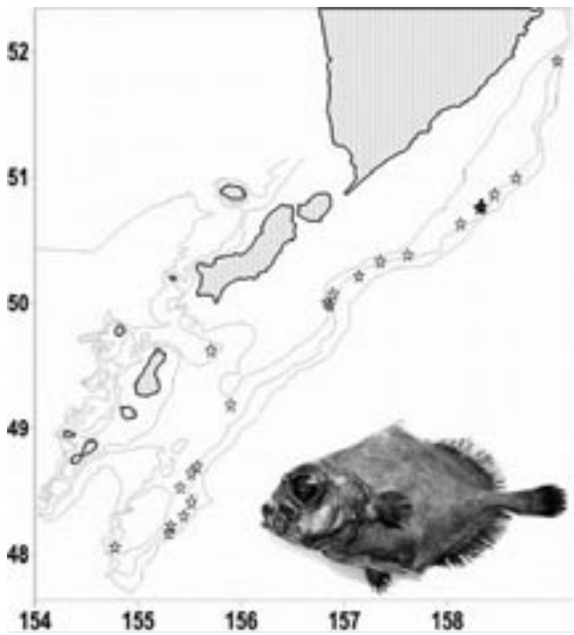
3.1 Occurrence and spatial/bathymetric distribution

Current data show coster dory to be widely distributed in world oceans (James, Inada and Nakomura 1988, Du Buitt and Quer 1993, Karrer 1990, Cabezas and Risso 1997, Quero, Du Buitt and Vayne 1997, 2000, Lindsay *et al.* 2000). In certain areas this species may be highly abundant and is considered a fishery target. In Australian waters coster dory is a common bycatch of orange roughy (*Hoplostethus atlanticus*) fisheries (Lyle, Riley and Kitchener 1992). Off New Zealand this species is fished with dories (Fincham, McMillan and Ito 1991). In the western Indian Ocean (off Aghullas banks) in the mid-1990s estimated biomass of coster dory was about 300 000 t and daily catches per vessel reached 35 to 50 tonnes. Annual available catch was estimated as 50 000 t (Budnichenko, Johnson and Hart 1998). In the North Pacific this species occurs from Honsu and California to the Gulf of Alaska and Bering Sea where it is caught occasionally (Welander, Johnson and Hart 1957, Kobayashi, Mikawa and Ito 1968, Maruyama 1970, Fedorov 1973, 2000, Eschmeyer, Herald and Hamman 1983, Masuda *et al.* 1984, Amaoka, Toyoshima and Inada 1995, Orlov 1998, Orlov, Moukhametov and Volodin 1998, Fedorov and Parin 1998, Moukhametov and Volodin 1999, Borets 2000, Sheiko and Fedorov 2000, Mecklenburg, Mecklenburg and Thorsteinson 2002). Coster dory is probably transported incidentally to these areas by deepwater currents during periods of warming.

In 1993–2002 the dory in the Pacific waters of the North Kuril Islands and South East Kamchatka was recorded nearly every year in the survey area, from 47° 50' to 52° 00' N (Figure 2) though its actual catches did not exceed 1 or 2 individuals during a 4–8 hour tow; only one catch of three of these species was recorded (Table 1). According to Sheiko and Fedorov (2000), coster dory is a mesopelagic species inhabiting depths down to 1800m. On the ocean side of the Kuril chain it occurs mostly near the bottom in the range 270–690 m (Fedorov 2000). The analysis of trawl catches showed that in April–December 1993–2002 coster dory was found in catches

FIGURE 2

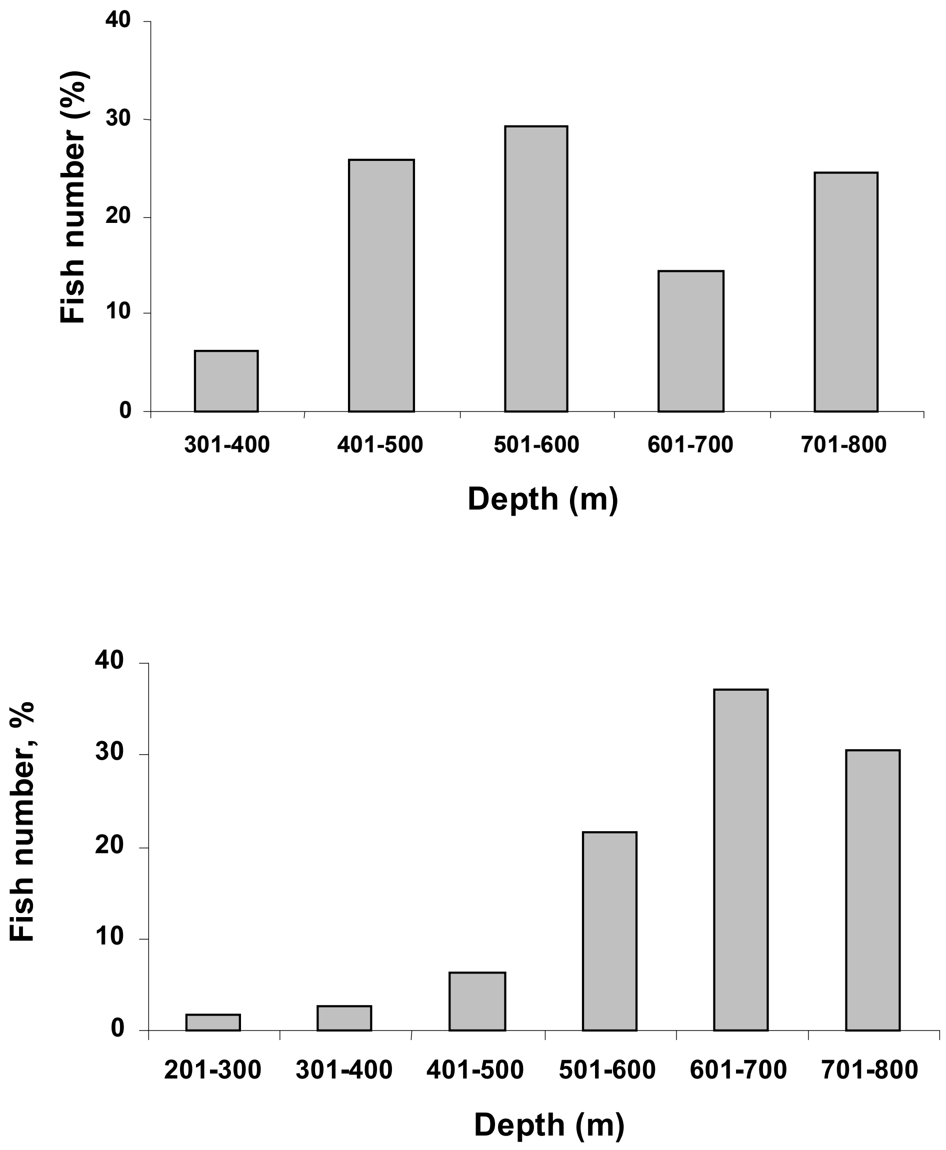
Capture sites of coster dory in the Pacific waters off the northern Kuril Islands and southeastern Kamchatcka, 1993–2002 (lines are 100, 200, 500 and 1 000 m isobaths)



on the Pacific side of the North Kurils and off the South East Kamchatka at depths of 310–750 m. Bottom temperatures were 2.3–3.6°C. However, over 55 percent of the fish came from the 400–600 m layer (Figure 3). Within Australian waters the maximum species abundance occurred in depths of 900–1 200 m (Lyle and Smith 1997). Such differences may relate to the limits of the bathymetric range investigated. In warmer Australian waters the range of coster dory may be shifted to greater depths.

Spiny eel is widely distributed in the world oceans (Blacker 1975, 1977, Jonsson 1976, Jonsson, Merrett 1981, Nakamura *et al.* 1986, Paxton *et al.* 1989, Paulin *et al.* 1989, Sulak 1990). In the North Pacific this species occurs in Asian waters from Hokkaido along the Kuril Islands (including the Sea of Okhotsk) to the East Kamchatka (Eschmeyer, Herald and Hamman 1983, Masuda, Amaoka and Araga 1984, Amaoka, Nakaya and Yabe 1995, Golovan *et al.* 1989, Golovan, Pakhorukov and Sysa 1990, Dudnik and

FIGURE 3
Bathymetric distribution of coster dory (upper panel) and spiny eel (lower panel) in the Pacific waters off the northern Kuril Islands and southeastern Kamchatka,1993–2002



Dolganov 1992, Orlov 1998, Orlov *et al.* 1998, Borets 2000, Fedorov 2000, Sheiko and Fedorov 2000). In American waters spiny eel is distributed from California to Oregon (Peden 1976, Eschmeyer, Herald and Hamman 1983, Lea and Rosenblatt 1987, Calliet, Andrews and Wakefield 1999, Mecklenburg, Mecklenburg and Thorsteinain 2002).

Only one specimen of spiny eel was found in 1993–2002, opposite the Fourth Kuril Strait; all other spiny eels were caught to the south, mostly over the slope of the underwater elevated plateau in the northern link of the outer Kuril chain ridge (Figure 4). Actual catches of spiny eel did not exceed 1–2 individuals per 4–8 hour tow; only once were five fish of this species caught (Table 1). Most researchers describe the spiny eel as a bathybenthal species inhabiting the near-bottom in a depth range of 126–3 285 m in the North Pacific (Fedorov 2000, Sheiko and Fedorov 2000, Mecklenburg *et al.* 2002).

It prefers muddy, muddy-sandy, or sandy grounds (Golovan, Pakhorukov and Sysa 1990). This species was recorded in catches off the North Kuril Islands in the Pacific (April–December, 1993-2002) at 210-790 m where bottom temperatures were 2.4–3.9° C. About 90 percent of fish were caught below 500 m (Figure 3), in temperatures over 3° C. *H. lindbergi* was first described in 1982 and was taken from the North Kuril waters (Fedorov 1982). This species was characterized as rare but widely distributed, mostly within Asian boreal waters from the northern Kuril Islands to Sagami Bay (Anderson 1994, Borets 2000, Fedorov 2000, Sheiko and Fedorov 2000), and also probably in the eastern Sea of Okhotsk (Anderson 1994). In 1993–2002 the eelpout was observed in catches in a limited part of the Fourth Kuril Strait (Figure 5), but only single individuals were caught except in one case when two fish were caught (Table 1).

The eelpout is a mesobenthal species found off the Kuril chain at 200–615 m (Fedorov 2000, Sheiko and Fedorov 2000) and in the south in a range of 340–1 400 m (Anderson 1994). In these studies it was recorded at 270–548 m, in bottom temperatures of 2.7–3.6 °C. Six of the eight individuals were found within 300–500 m at 3.4°–3.6°C. The tough eelpout was described in 1975 (Fedorov 1975) and is characterized as an Asian species with a wide boreal range, from the northwestern Pacific (Cape Navarin and Pribyloff Islands) off Bauers and Shirshov ridges) along the eastern Kamchatka and Kuril Islands to Hokkaido (Cape Erimo), in the sea of Okhotsk and off the Aleutian Islands (Amaoka *et al.* 1977, 1995, Masuda

FIGURE 4
Capture sites of spiny eel in the Pacific waters off the northern Kuril Islands and southeastern Kamchatka, 1993-2002 (legends are as for Figure 2)

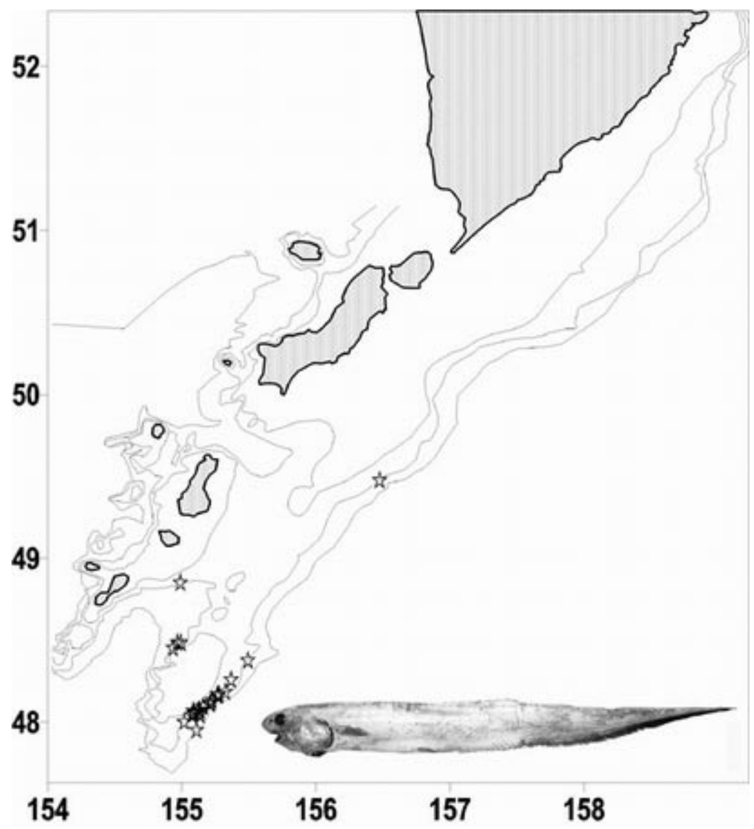
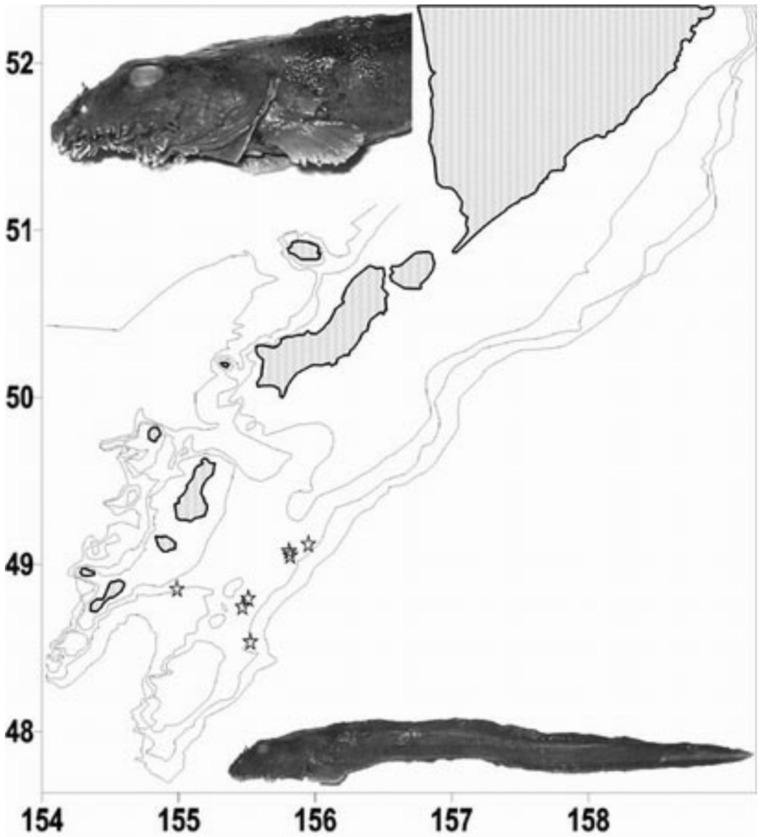


FIGURE 5
Capture sites of *H. lindbergi* in the Pacific waters off the northern Kuril Islands and southeastern Kamchatka, 1993–2002 (legends as for Figure 2)



et al. 1984, Anon. 1993, 1999, Anderson 1994, Borets 2000, Fedorov 2000, Sheiko and Fedorov 2000, Mecklenburg *et al.* 2002).

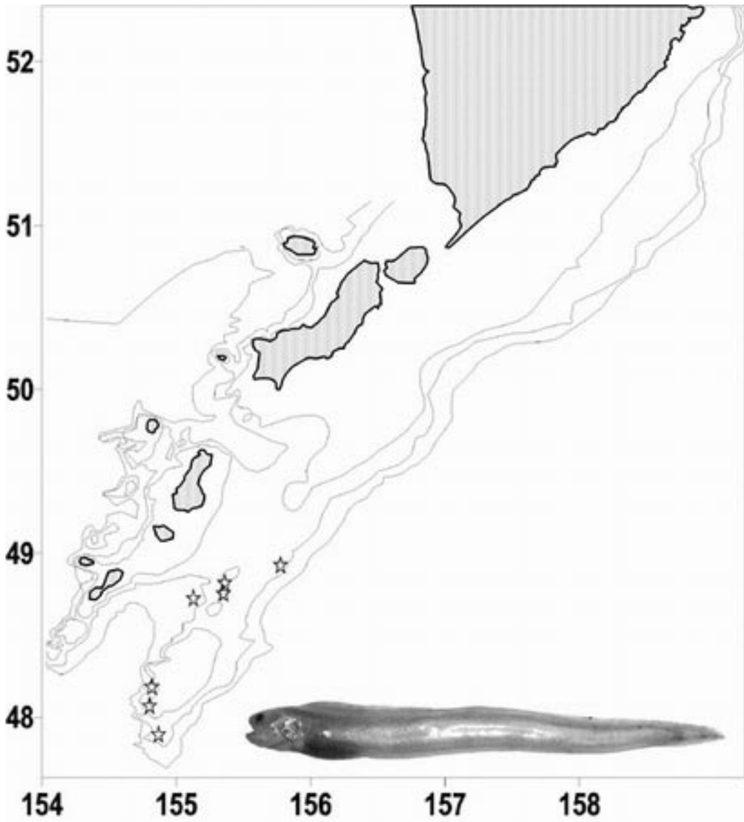
During the study period of 1993–2002 this species was caught only in the southern most region over a limited range (47° 52'–48° 56' N) mostly on the western slope of the underwater elevation in the left link of the outer ridge of the Kuril chain (Figure 6). The fish were found singularly on rocky ground with tree-like corals (Table 1), i.e. it has a low abundance and a habitat type that is hardly accessible to trawling. Anderson (1994), Sheiko and Fedorov (2000) and Mecklenburg *et al.* (2002) note that tough eelpout is a mesobenthic species found at 200–800 m. It is frequently observed at 250–350 m. In 1993–2002 this representative of the Zoarcidae family on the Pacific side of the North Kuril Islands was found at 225–733 m in bottom temperatures of 2.6°–4.1°C. Four of the seven individuals were caught in 225–307 m at 2.6°–3.2°C. In the North Bering Sea this species was caught at 320–380 m (Anon. 2000) while at the Aleutian Islands it was caught at depths of 351–488 m and 515–529 m (Anon. 1993).

3.2 The size and weight composition

Coster dory is a relatively large species (known length, 42 cm) – Mecklenburg *et al.* 2002. On the Pacific side of the North Kuril Islands and South East Kamchatka in 1993–2002, coster dory in trawl catches were 14–42 cm long (35.1cm on the average) and weighed 100–1 300 g (average 900 g) (Figure 7). The bulk of coster dory catches mostly comprised large fish of 34–38 cm (about 65 percent) and 600–1 200 g (over 81 percent). A notable feature is that the length of the dory from other ocean areas is similar. In the southern Indian Ocean catches were represented by fish of lengths 15.3–33.6 cm but mostly in the range 26–34 cm and 320–1 000 g (Melnikov 1981). In Australian waters coster dory lengths were in the 15.2–36.5 cm range. For females, 50 percent maturity was reached at a length of 28 cm (Lyle and Smith 1997). The maximum age of this species is estimated to be from 14–15 years (Melnikov 1981) to 130–170 years (Stewart *et al.* 1995) for fish 34–35 cm long. Thus, coster dory caught off the Kuril Islands and Kamchatka had the maximum known length and was represented mostly by mature fish of older generations.

Spiny eel is characterized by an eel-like body and a length that exceeds 135 cm (Mecklenburg *et al.* 2002). The size of this species in the Pacific waters of the North Kuril Islands in 1993–2002 ranged from 36 cm to 85 cm (average 53.2 cm) and weighed from 140 to 1 000 g (average 395 g) (Figure 7). Fish of 45 to 55 cm length predominated in the catches (about 50 percent), with body weights of 100–500 g (over 77 percent). A spiny eel with a length of 135 cm was caught in the North Atlantic while maximum known sizes of this species in the Kuril Islands waters do not exceed 58–60 cm (Golovan *et al.* 1989, 1990).

FIGURE 6
Capture sites of tough eelpout in the Pacific waters off the northern Kuril Islands and southeastern Kamchatka, 1993–2002 (legends as on Figure 2)



Unlike spiny eel, *H. lindbergi* is a relatively small fish with an elongated body and a maximum length of 37 cm (Fedorov 1982). The length of *H. lindbergi* off the North Kurils in 1993–2002 were 24 to 35 cm and weights were 30–100 g. However, fish sized 31–35 cm weighing 80–100 g prevailed (six of the eight individuals taken).

The tough eelpout is a small representative of the family Zoarcidae. It has an elongated, laterally compressed body (Fedorov 1975). Maximum known length of this species is 32.3 cm (Mecklenburg *et al.* 2002). The length of tough eelpout caught in 1993–2002 on the Pacific side of the North Kurils varied between 22 and 38 cm while body weights were in the range 30–200 g. However, the size of most fish was between 31–38 cm, with weights being between 70–200 g (five out of seven individuals).

The length–weight relationship in the three fish species (except for the *H. lindbergi* whose length range in the individuals taken was rather limited) were as follows:

coster dory: $W= 1.859 \times 10^{-5} L^{2.9973}$ (R^2=0.886)

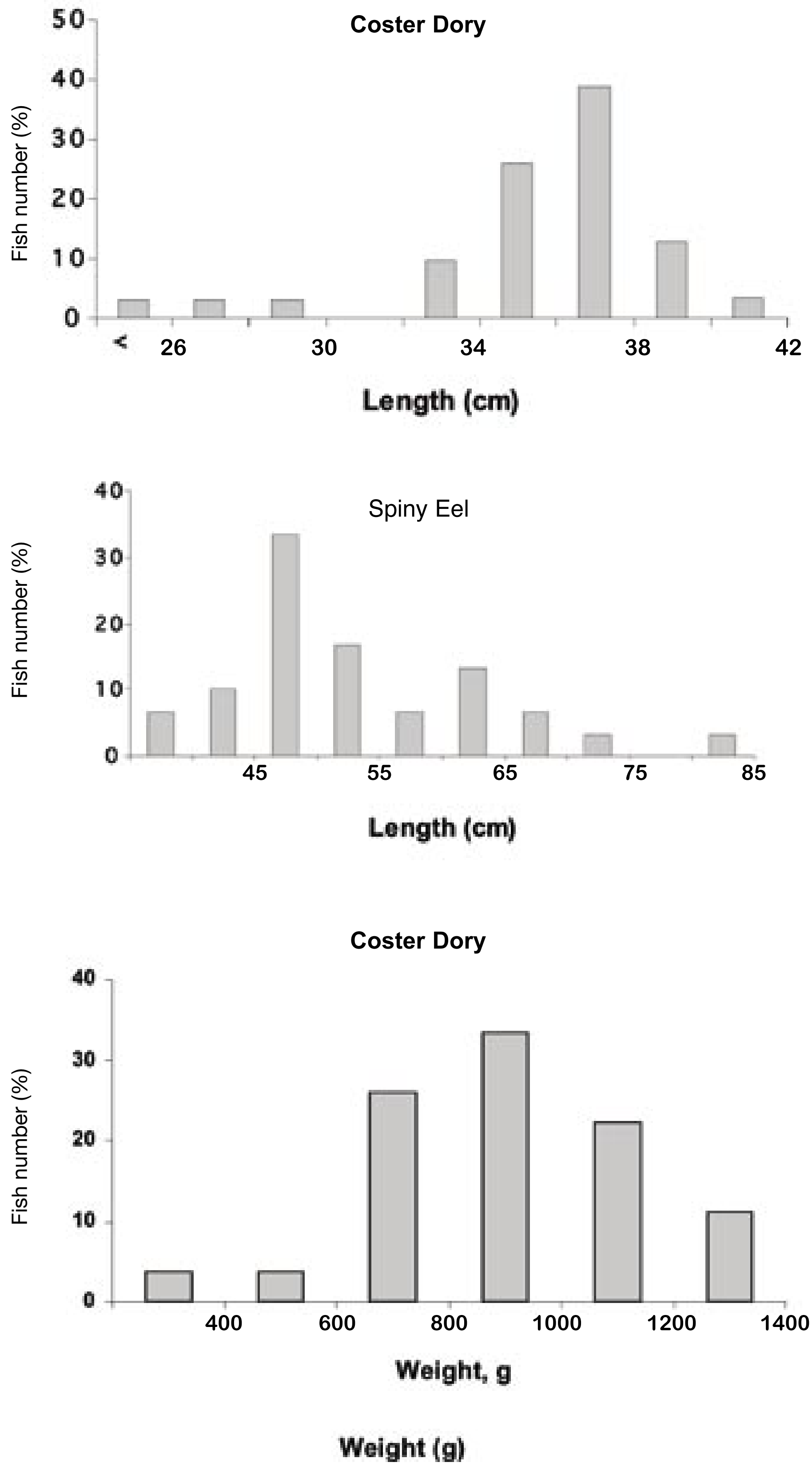
spiny eel: $W = 7.169 \times 10^{-6} L^{2.7244}$ (R^2=0.840)

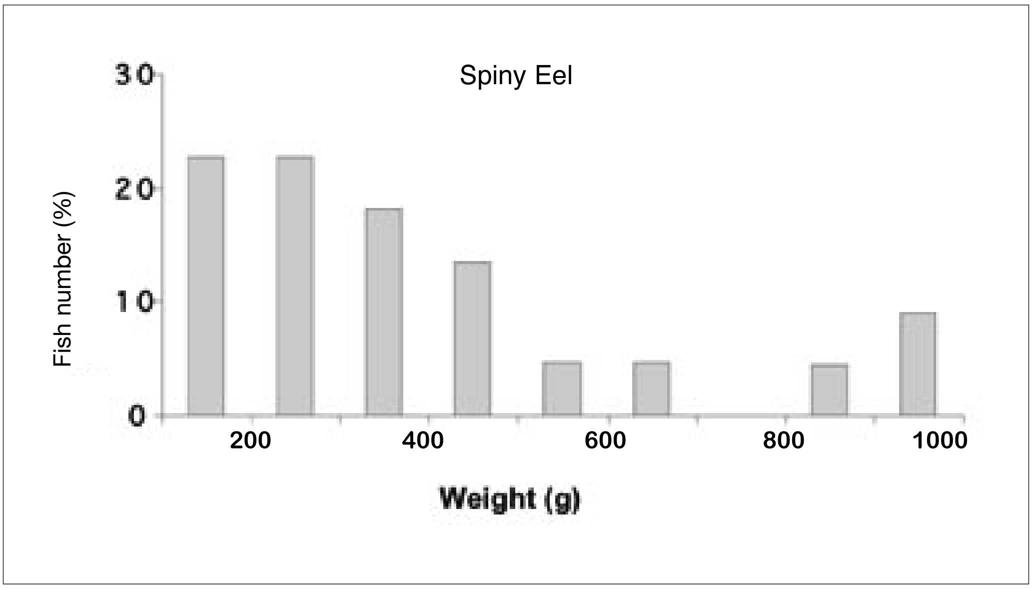
tough eelpout: $W = 1.196 \times 10^{-6} L^{3.2610}$, ($R^2$=0.835)

where W = body weight (g)
L = body length (cm).

The regression series calculated by the above formulae agreed well with the empirical data and may be used to determine the mean weights as a function of the lengths for the respective species.

FIGURE 7
Length and weight compositions of coster dory and spiny eel in the Pacific waters off the northern Kuril Islands and southeastern Kamchatka, 1993–2002





4. CONCLUSION

These data allow us to conclude that the abundance of all four species taken in the Pacific near the North Kuril Islands and the South East Kamchatka is insignificant. In 1993–2003 the coster dory occurred virtually throughout the whole area from 47° 50' N to 52° 00' N at depths of 310 m–750 m and bottom temperatures of 2.3°–3.6° C. Over 55 percent of individuals taken in the observed period came from 400–600 m. The spiny eel occurred in catches during those years only in the south of the area surveyed, mostly on the slope of the elevated region of the northern link in the outer ridge of the Kuril chain within 210 m–790 m where bottom temperatures ranged within 2.4°–3.,9°C. However, by far most of its individuals (about 90 percent) taken during the survey period came from depths greater than 500 m, with temperatures over 3° C. In contrast, the tough eelpout and *H. lindbergi* were found only in limited numbers on the continental slope of the North Kurils in the Pacific: the former between 48° 24'– 49° 12' N. (270–548 m) with bottom temperatures of 2.7°–3.6°C; and the latter between 47° 52'– 48° 56' N mainly on the western slope of the underwater plateau, at depths of 225 m to 733 m and bottom temperatures of 2.6°–4.1° C. The trawl catches in 1993–2002 contained primarily large individuals of coster dory, tough eelpout and *H. lindbergi*, with respective lengths and weights of 34–38 cm (600–1 200 g), 31–35 cm (80–100 g), and 31–38 cm (70–200 g). In contrast, the catches of spiny eel consisted for the most part of mid-sized fish: 45–55 cm (100–500 g).

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Seasonality in fish community and population structure on the continental slope of the Western Mediterranean

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The concept of temporal stability in the deep-sea is valid for much of the world oceans and over mesoscale terms. However, this presumed stability is only apparent as periodic variability occurs in certain areas more frequently than originally supposed. Seasonal changes in the spatial structure of several deep-sea faunal groups have been described in the western Mediterranean, even when this area is characterized by a high degree of environmental stability below a depth of 200 m. This contribution analysed seasonality in Mediterranean deep-sea fish assemblages by comparing species composition, ecological parameters, biomass spectra and length frequency distributions of the main species. The data were collected in the Algerian (AB) and Balearic (BB) Basins, in the southern and northern part of the Balearic Islands, respectively. These two areas are characterized by different oceanographic conditions and are connected by a series of sills between depths of 100 to 800 m and which play an important role in the general circulation and the transport of water masses between them. The Balearic basin is characterised by the presence of numerous submarine canyons, which can also influence the environmental conditions in this area. In the AB 38 trawls were taken along a continuous transect at 400 and 1 714 m depth (26 in autumn and 12 in spring'). In the BB 36 bottom trawls were carried out between 350 and 1 300 m depth at three different sampling locations. Three samples were taken at each station on four surveys carried out in spring, autumn, winter and summer.

The two surveys made in the AB, where the number of hauls by season and depth strata was different, and the bathymetric range prospected large, was analyzed by means of a partial-detrended Canonical Correspondence Analysis (CCA) to test between-cruise differences on species composition, both for standardised number of individuals and biomass. A partial CCA was performed in the case of the four surveys made in the BB examining the same number of hauls by season and depth strata over a restricted bathymetric range. Assuming that species turnover in a bathymetric range is determined mainly by the depth, we focus on the analysis on the season-depth interaction and evaluated if the species composition and the abundance-biomass profiles follow the same seasonal pattern in all three depth strata.

Depth is the most important feature affecting the turnover in the species composition and the community structure in both the Balearic and Algerian Basins. The habitat topography, in this case the presence of a submarine canyon, is another factor which determines the segregation between the samples of the upper slope. In addition, the ecological parameters, the normalised biomass spectra and the size of some dominant species are also characterised by seasonal variations. Thus, seasonality is another factor that determines the substitution of the relative importance of some dominant species, but mainly for species with a minor contribution. The species composition and the abundance-biomass profiles follow different seasonal patterns in all three depth strata but with a minor variability at greater depths. Seasonality characterises distinct normalised biomass spectra (nBS) and plays a different role in the upper and lower assemblages. A pronounced seasonal change in nBS takes place on the fish assemblages shallower than 800 m depth, while the temporal change is comparatively smaller at greater depths. Seasonal changes in deep-sea fauna seem to be linked to the influence of submarine canyons in transporting sediments rich in organic matter and changes in the density and the biological cycle of the Benthic Boundary Layer macrofauna, which constitute an important part of the available food exploited by megafauna.

NORFANZ biodiversity survey uncovers mysteries of the deep

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A survey of the biodiversity of fishes and benthic invertebrates was carried out on the Lord Howe Rise and Norfolk Ridge in May-June 2003. The principal objectives of the "NORFANZ" programme was to survey, sample and document the marine biodiversity from seamounts and slopes on the Norfolk Ridge and Lord Howe Rise, to support biosystematics research projects, to assess the faunal uniqueness and conservation value, and to relate observed distribution patterns with measured biological and physical parameters.

An international team of scientists was involved in the four-week survey which was done using the NIWA research vessel, the **R.V. Tangaroa**. Fourteen seamount and slope sites were sampled, ten on the Norfolk Ridge, and four on the Lord Howe Rise. A total of 168 stations were completed, consisting of 144 trawl-sled-dredge shots, 15 casts to measure oceanographic conditions and nine camera drops to photograph fauna on the seafloor. Trawl depths ranged from less than 100 m to over 2 000 m. A variety of gears were used, including bottom trawls, a midwater trawl, beam trawl, epibenthic sleds and rock and pipe dredges.

Over 500 fish species and 1 300 macro-invertebrate species were provisionally identified onboard. This is regarded as a minimum estimate of the biodiversity, as the sampling intensity on individual seamounts was not sufficient to measure the complete faunal composition. About 20 percent of the fish species are likely to be either new records for the region, or newly identified species. It may take researchers around the world several years to fully examine the material, especially the invertebrates, and describe the unknown species.

There were a number of special features of the survey that contributed to its success. There was a high level of collaboration and cooperation between the New Zealand and Australian funding agencies and all the scientific institutes and museums. The team of international scientists covered a wide range of skills and experience and this enabled much to be achieved during the survey. The variety of gear types deployed during the survey were able to sample different components of the fauna and will contribute to a better understanding of the structure of the benthic community. The multibeam system used by the **R.V. Tangaroa** enabled bathymetry and bottom type to be rapidly assessed and was a valuable aid to planning the trawling. Photographs were taken of every species caught and were used as a reference guide throughout the survey to ensure accuracy and consistency of species identifications. Overall, strong and productive synergies developed between scientists from various disciplines and this, coupled with the experience of the officers and crew, produced an excellent survey result.

On the diversity, population ecology and biogeography of myctophidae

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1. INTRODUCTION

An overview of the PhD project of the first author within the framework of an international collaboration on lanternfish (Myctophidae) ecology is given. Mesopelagic fishes play an important trophic role in the open ocean as well as close to steep slopes. Myctophidae in particular display a high diversity that can be used as an indicator of biogeographic distinctness of a specific area. The life history and adaptive strategies at the level of individual populations of myctophid species are poorly documented. In order to integrate these various aspects, a comparative study has been initiated.

2. MATERIAL

The investigations are based on material of the global "DANA" deep-sea expedition that is deposited at the Zoological Museum, Copenhagen (ZMUC), and on collections from recent pelagic research cruises in deep-water canyons south of Georges' Bank (NW Atlantic), the Canary Islands (Eastern Central Atlantic) and the Gulf of Mexico.

3. DATA ANALYSES AND PERSPECTIVE

Data on species composition and spatial distribution of mesopelagic fishes collected off the Canary Islands shows that myctophids are distributed patchily at a rather small spatial scale (Wienerroither 2003). These distribution patterns are consistent with areas characterized by high productivity and specific hydrological phenomena like upwellings and eddies. MOCNESS–catches close to deep-water canyons on the southern edge of Georges' Bank (Wienerroither, Suiblein and Youngbluth 2003) enable an even more detailed analysis of the small-scale distribution of myctophid species. Populations of geographically separated areas will be compared using meristic and morphometric characters to reveal possible adaptations to ecologically different environments.

Commercially-targeted fishes as well as marine mammals and birds use myctophid species as important sources of food. Adequate and sustainable ecosystem management requires holistic consideration of the food web, with detailed knowledge about the lifecycle and population structure of its components. This necessity is reinforced but also complicated by the insight that geographically separated populations of the same mesopelagic fish species have differing life history data.

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Spatial pattern of demersal fish in the upper continental slope off Northeast Atlantic in Moroccan waters

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1. INTRODUCTION

The upper continental slope off the Northeast Atlantic in Moroccan waters (21°–28° N) have been surveyed between 100 and 800 m. A total of 90 bottom trawl hauls allowed us to obtain and identify 156 species from 72 families of demersal and benthic macrofaunal fish. Relative ichthyofaunal biomass per bathymetric strata estimates confirms a decrease in biomass with increase in depth but only from the strata corresponding in depth 400–500 m onwards. Above this strata, from 100 to 400 m, the upper continental slope corresponds to the transition zone between the continental shelf and the continental slope ecosystems, in which occurred most of the 38 macrofaunal fish species that are both slope and shelf-dwellers. The limit around 400 m is characterized by the inversion of ichthyofaunal biomass, biodiversity indexes and species richness tends.

The objective of this study was first to complete the knowledge of the spatial pattern of demersal and benthic fish in this area. Second, it tries to show, in terms of relative biomass, species composition and biodiversity, the characteristics of this particular area of transition, which marks the beginning of the deep-sea ecosystem.

2. METHODS

Data for the present study were collected during the **R.V. Fridtjof Nansen** bottom-trawl survey (Cruise Reports, **Dr Fridtjof Nansen** 2000), which was carried out in October 2000 as part of a regional collaboration involving Norway, Morocco, Mauritania, Senegal and The Gambia. It undertook an exploration of the upper continental slope between 150 and 800 m. The results of this study concern only the Moroccan part, from 20°50' N to 28° N.

Ninety stations were trawled following a bathymetric-stratified sampling strategy (Figure 1). Each station was sampled for about half an hour by trawling, but all results have been standardized to a tow duration of one hour.

The depth strata were defined as follows:

S1 : 100–200 m
S2 : 200–300 m
S3 : 300–400 m
S4 : 400–500 m
S5 : 500–600 m
S6 : 600–700 m
S7 : 700–800 m

Formulas used in estimating indices were as follows.

N = Species richness

Hill(1973) indexes

$$N_1 = exp(-\sum_{i=1}^{s} p_i \, ln \, p_i)$$

where s is species richness and p_i relative abundance of the i^{th} species.

$$N_2 = \frac{1}{\sum_{i=1}^{s} (p_i)^2}$$

where p_i is the relative abundance of the i^{th} species.

Shannon Index

$$H = -\sum_{i=1}^{s} p_i \ln p_i$$

where p_i is the relative abundance of the i^{th} species.

Evenness Index

$$J = \frac{\ln N_1}{\ln N_0}$$

Specie(s) Indicator Value for strata, j

$$IV_{j,s} = FI_{j,s} * SP_{j,s} * 100$$

where

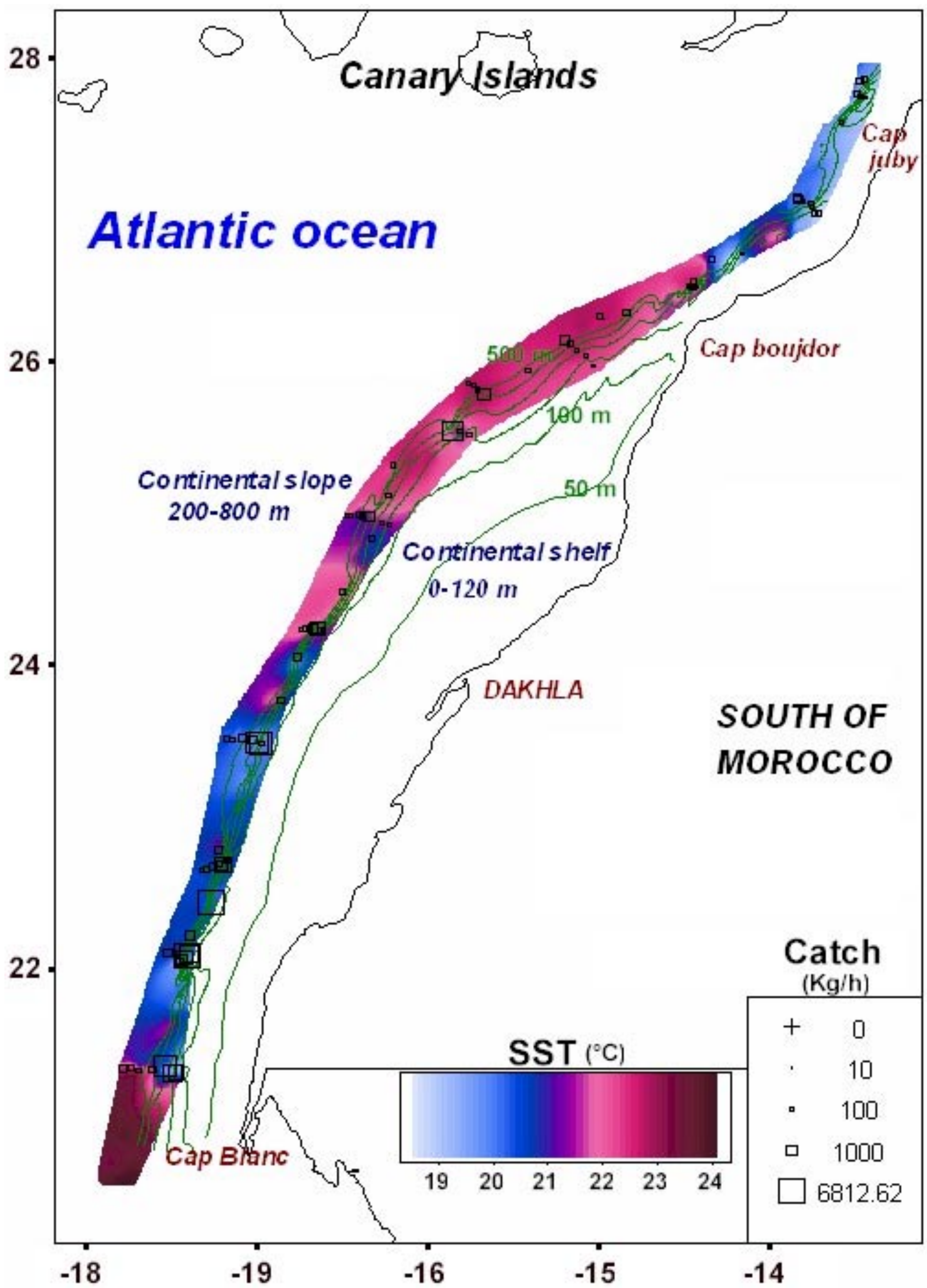
$$SP_{j,s} = \text{Specificity}$$

and,

$$FI_{j,s} = \text{Fidelity}$$

(Dufrêne and Legendre 1997).

FIGURE 1
Global map: Survey area (100–800 m; 20°50′–28°), SST and total biomass catch of demersal fishes



3. RESULTS

One hundred and fifty-six species of macro fauna fish were identified from 72 families. The more important families are represented according to their relative catch proportions (Figure 2). The stations' specific richness varied from 6 to 26 species (Figure 3).

Among the most important species in terms of biomass catch, were Helicolinus dactylopterus (Sebastidae), Hoplostethus mediterraneus (Trachichthyidae), Capros aper (Caproidae) and Merluccius merluccius (Merlucciidae). We also found numerous species of Macrouridae including *Hymenocephalus italicus, Trachyrincus scabrus*

FIGURE 2
Relative biomass of macrofauna fish families in the upper continental slope

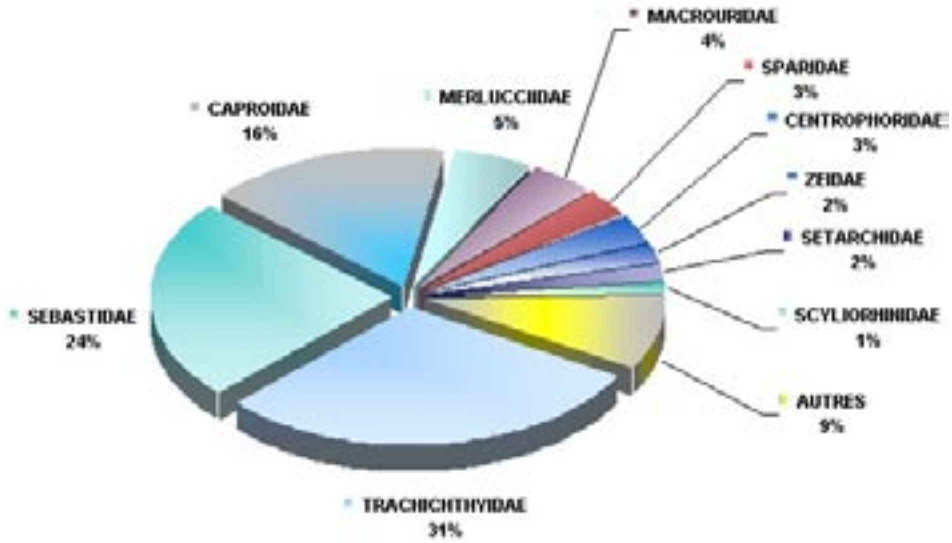
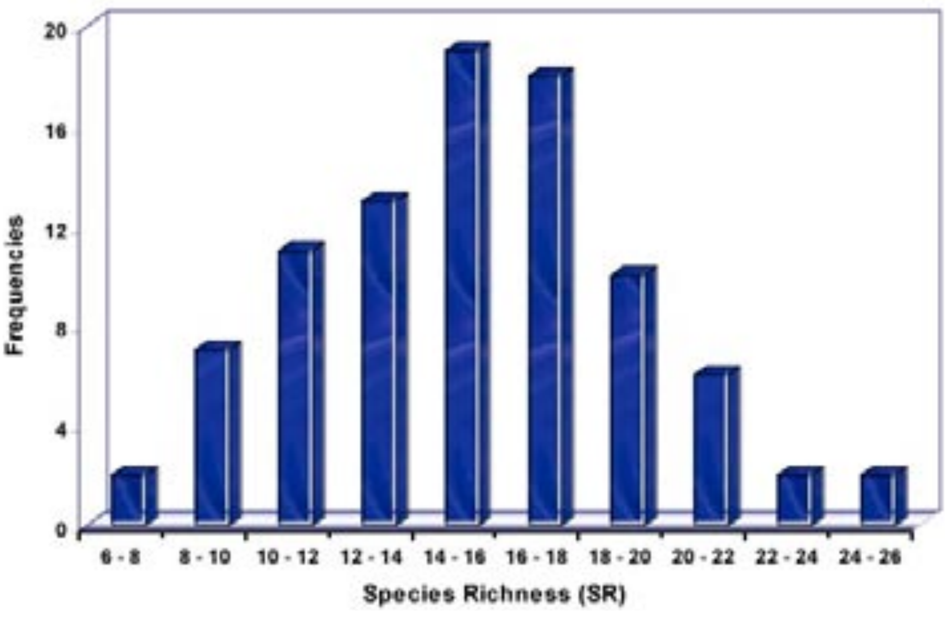


FIGURE 3
Distribution of species richness



and *Nezumia aequalis*. The three most diversified families found were the Rajidae represented by 11 species, the Dalatiidae represented by 11 species and the Macrouridae represented by nine species.

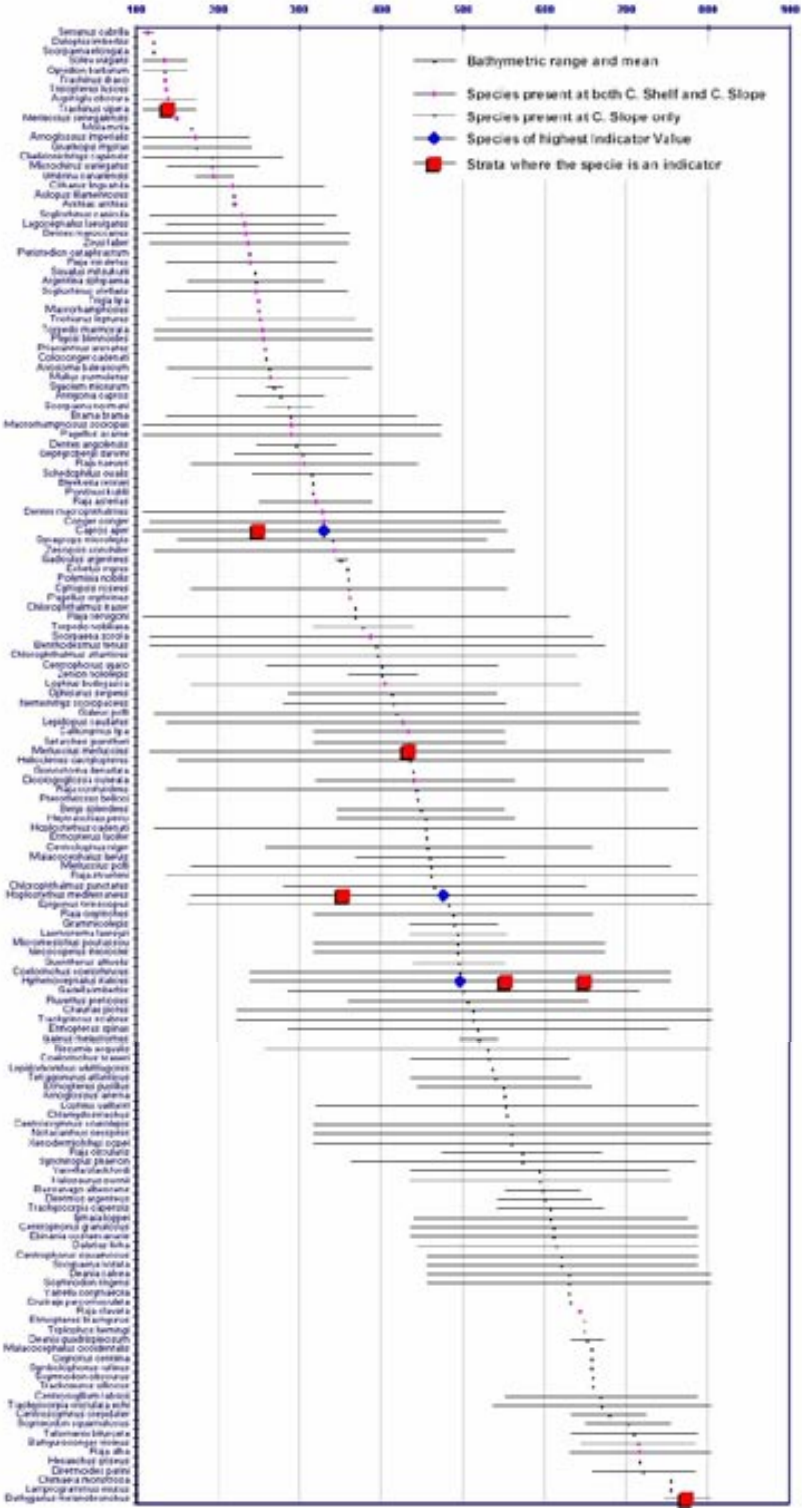
The major result was the gradual evolution, from shallower to deeper water, of the species composition (established according to the relative importance index) per strata. This evolution was marked by a simultaneous and gradual decline of those species that are present either on the shelf and the slope, and a gradual increase of the species that are the deeper-strata dwellers (Table 1 and Figures 4 and 5). Figure 5 shows the indicator values of the most representative species of each stratum.

TABLE 1
Relative biomass of macrofaunal fish species per bathymetric strata (%)

Species	S1	S2	S3	S4	S5	S6	S7
Bathygadus melanobranchus	-	-	-	-	-	-	0.43
Capros aper	52.68	63.03	4.23	-	-	-	-
Chaunax pictus	-	-	-	-	-	0.97	-
Chlorophtalmus atlanticus	1.89	-	-	-	-	-	-
Chlorophtalmus punctatus	-	-	-	-	-	1.18	-
Coelorinchus coelorinchus	-	-	0.04	0.22	-	-	-
Cyttopsis roseus	-	-	0.01	-	-	-	-
Deania calcea	-	-	-	-	-	-	4.54
Dentex macrophtalmus	14.71	0.36	0.01	-	-	-	-
Dentex maroccanus	0.89	-	-	-	-	-	-
Epigonus telescopus	-	-	-	0.41	1.88	1.48	1.12
Galleus polli	-	-	0.01	-	-	-	-
Helicolenus dactylopterus	25.27	26.17	19.04	76.41	40.97	1.07	-
Hoplosthetus cadenati	-	-	-	0.48	2.95	5.56	5.16
Hoplosthetus mediterraneus	-	10.36	76.60	10.62	24.58	33.19	0.24
Hymenocephalus italicus	-	-	-	0.27	10.80	23.11	0.11
Lepidopus caudatus	1.79	0.01	-	-	-	-	-
Macrorhamphosus scolopax	1.38	0.03	-	-	-	-	-
Merluccius merluccius	-	0.02	0.04	8.24	3.00	-	-
Merluccius polli	-	-	-	0.24	-	-	-
Nezumia aequalis	-	-	-	0.35	5.13	17.34	39.71
Scorpaena elongata	0.10	-	-	-	-	-	-
Setarches guentheri	-	-	-	2.13	1.27	-	-
Synagrops microlepis	1.05	-	-	-	-	-	-
Trachyrincus scabrus	-	-	-	-	8.23	13.05	41.76
Trachyscorpia cristulata echi	-	-	-	-	-	0.85	6.26
Xenodermichthys copei	-	-	-	-	-	-	0.24
Zenopsis conchifer	-	-	0.01	-	-	-	-
Zeus faber	0.09	-	-	-	-	-	-
Others	0.16	0.01	-	0.62	0.79	2.19	0.44

FIGURE 4

Bathymetric ranges and indicator value results for the 156 macro faunal fish

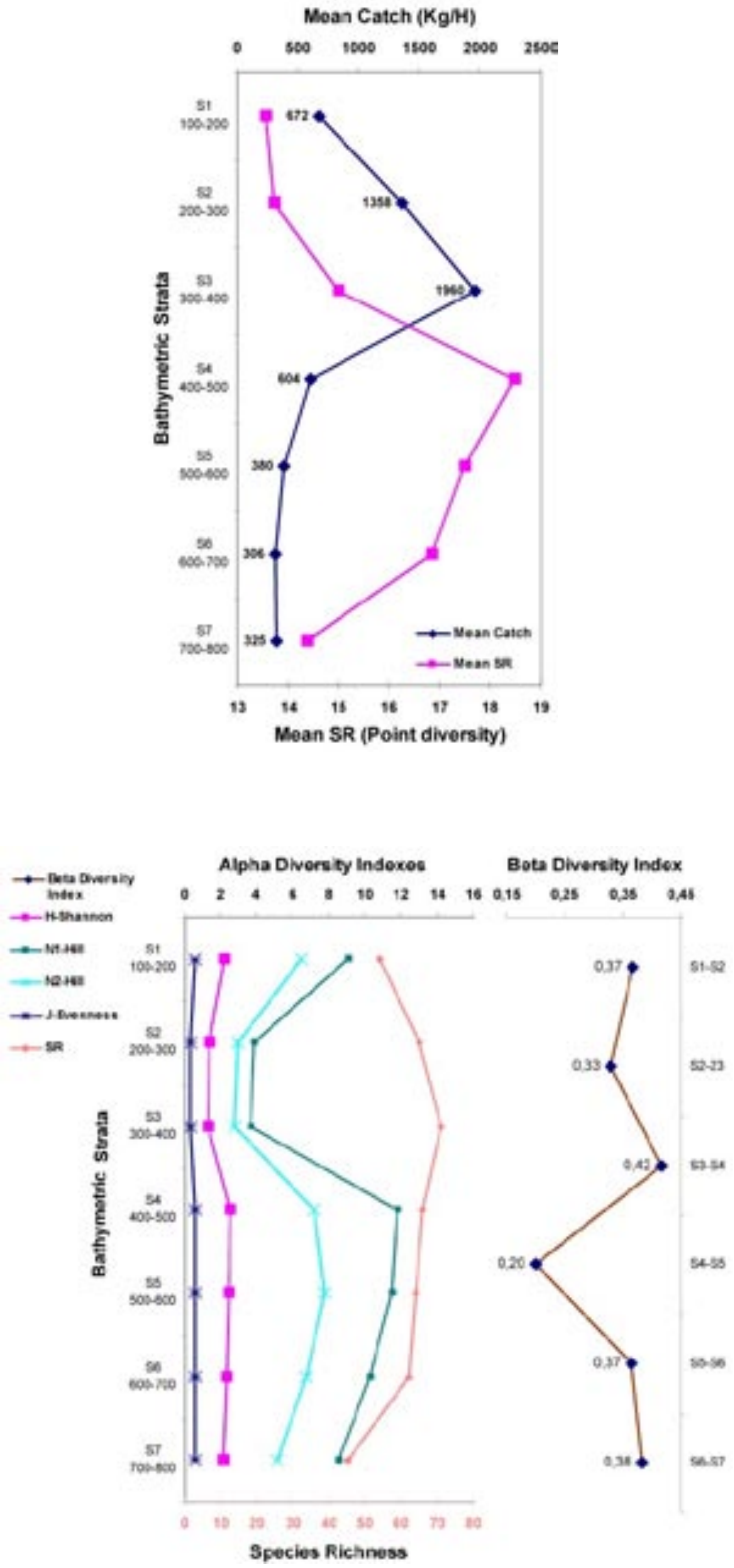


The biodiversity indexes (Gray 2000) computed at different scales [point scale, bathymetric strata scale (α–diversity) (Whittaker 1960) and inter-bathymetric strata scale (β–diversity)] showed a faunal break line around a depth of 400 m (Figure 6). An inversion of both point diversity and α–diversity index trends occurred after S4 strata (400 to 500 m). The maximum of the β–diversity occurred between the S3 and S4 strata and the minimum was observed between the S4 and S5 strata. There is also an inversion of the total demersal fish biomass (mean catch) trend with increasing depth.

FIGURE 5
Indicator value results of the most representative species for each stratum

Strata	Family	Species	IVs
S1 100-200	TRANCHINIDAE	*Trachinus vipera*	55
	ZEIDAE	*Zeus faber*	51
	SPARIDAE	*Dentex maroccanus*	50
S2 200-300	CAPROIDAE		
	SCYLIORHINIDAE	*Capros aper*	52
	SPARIDAE	*Scyliorhinus stellaris*	28
		Dentex macrophthalmus	26
S3 300-400	TRACHICHTHYIDAE	*Hoplostethus mediterraneus*	48
	ZEIDAE	*Cyttopsis roseus*	36
	MACROURIDAE	*Coelorinchus coelorhincus*	27
S4 400-500	MERLUCCIIDAE	*Merluccius merluccius*	48
	ZEIDAE	*Zenopsis conchifer*	28
	MERLUCCIIDAE	*Merluvvius polli*	26
S5 500-600	MACROURIDAE	*Hymenocephalus italicus*	36
S6 600-700	MACROURIDAE	*Hymenocephalus italicus*	28
	SEBASTIDAE	*Trachyscorpia capensis*	26
S7 700-800	MACROURIDAE	*Bathygadus melanobranchus*	45
	SEBASTIDAE	*Trachyscorpia cristulata Echi*	29
	RAJIDAE	*Raja alba*	27

FIGURE 6
Biodiversity trends per strata



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Seamount fishes – species composition on seamounts and adjacent slope

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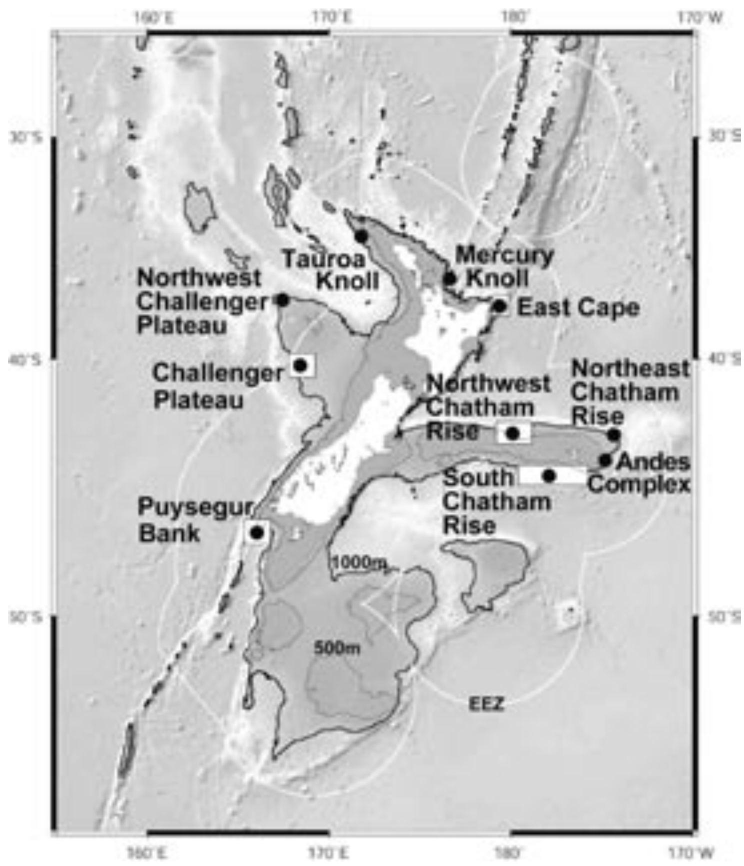
Seamount features are prominent in the New Zealand marine environment and provide an important habitat for deepwater fish such as orange roughy, smooth oreo, black oreo, and black cardinalfish.

Research trawl and acoustic surveys have been regularly carried out in several areas around New Zealand and, while primarily monitoring the change in relative abundance of the major deepwater commercial species over time, information on the composition of fish assemblages on seamounts and the adjacent slope area has also been reported. These surveys provide an opportunity to compare and examine such variables as species dominance, diversity, fish density and faunal rarity. In addition, data from these surveys have enabled an examination in trends in abundance between the seamounts and between the seamounts and neighbouring flat area (Figure 1).

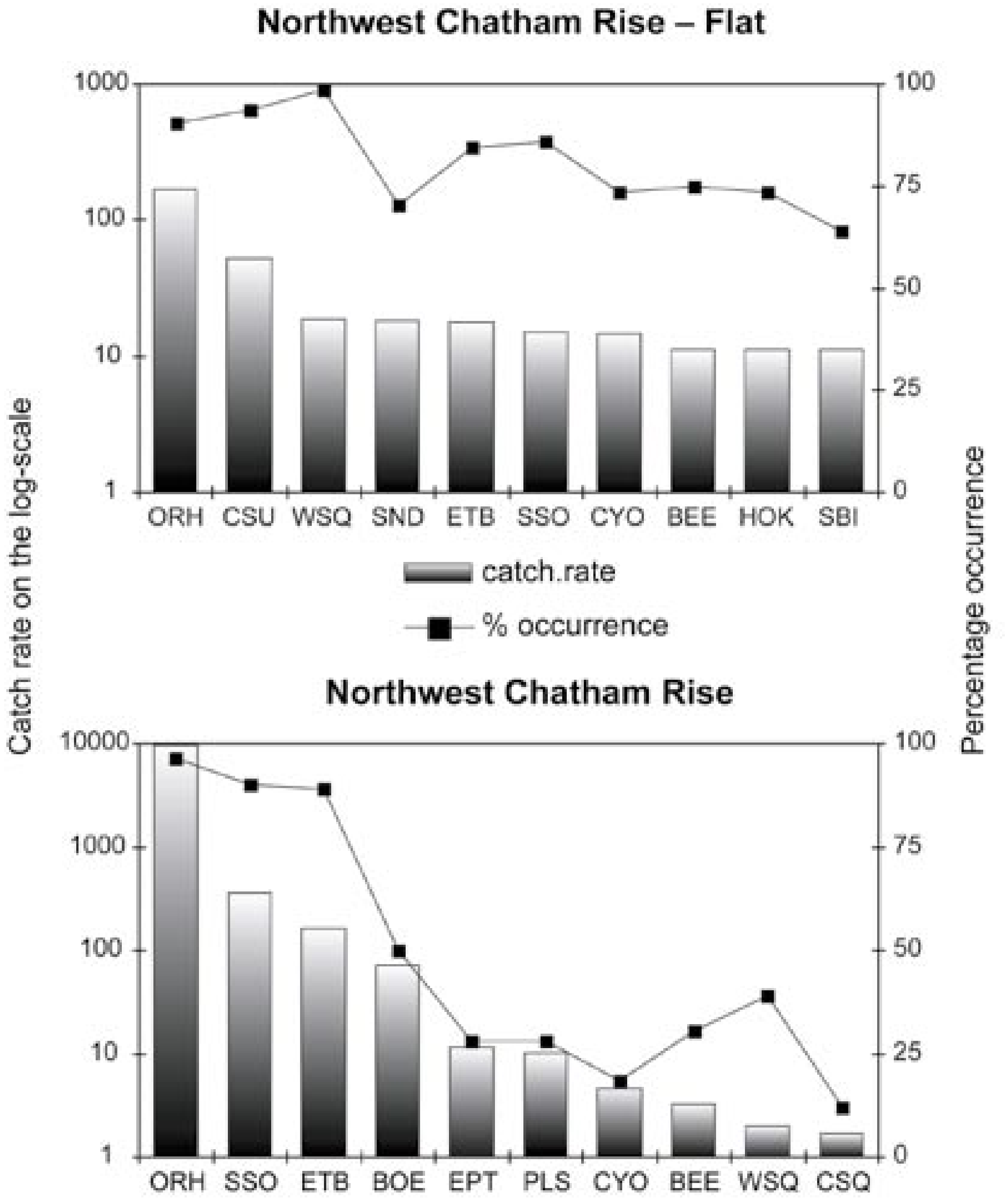
In this paper we report on species dominance on the Northwest Chatham Rise ("Graveyard seamounts") and show how the species composition on theses seamounts differs from that of the neighbouring slope area. The top 20 species caught were ranked by weight. Log catch rates and percentage occurrence for

FIGURE 1
New Zealand regions included in the study. Seamount complexes are indicated by black dots and adjoining slope areas by pale rectangles



the top 10 species for the seamount complex and neighbouring slope are presented in Figure 2. The catch rates and percentage occurrence of orange roughy was high followed by a steep decline to the occurrence levels of other species. In the flat slope area, while orange roughy was still the dominant species, a less dramatic decline of catch rate and occurrence is displayed (top graph, Figure 2).

FIGURE 2
Catch rate on the log scale (left-axis) and percentage occurrence (right axis) for the ten species with the highest catch rate in the Northwest Chatham Rise area



We also examined species variation within a seamount complex. A descriptive analysis of species composition for six seamounts in the Southeast Chatham Rise "Andes Complex area was described. Of the 36 species recorded, five (13%) were caught on every seamount, a further 18 (50%) occurred on three to five seamounts, and six (16%) 'rarer' species occurred on only one seamount.

The mean species richness at each seamount complex in the New Zealand region was estimated and a trend with latitude was evident, with southern areas having higher mean species richness (Figure 3).

FIGURE 3

Relationship between latitude and mean species richness on seamount complexes

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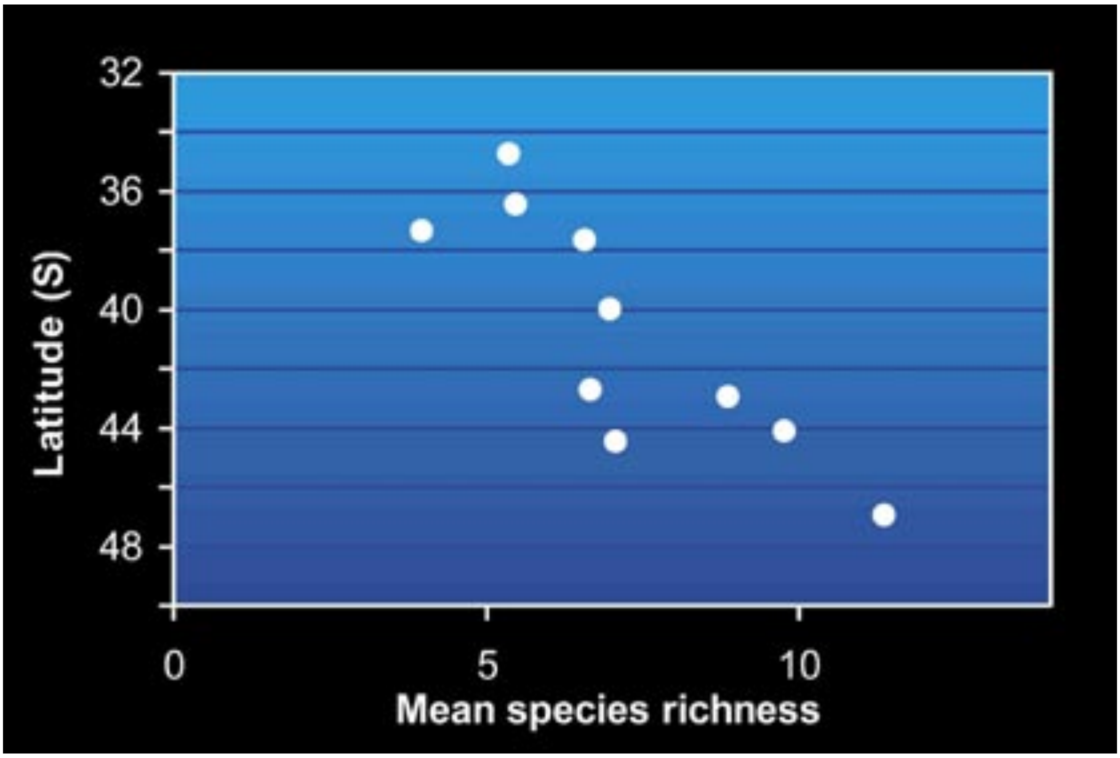

Peruvian deep ocean potential resources: fishes and shrimps

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1. INTRODUCTION

In Peru a priority is to identify new species as potential resources to satisfy the national and international demand for fish, to create employment opportunities for the Peruvian community, to stimulate fishing investment and try to provide a fishing alternative when there is a decrease, for whatever reasons (overexploitation or by natural events), in abundance of fisheries resources. While earlier studies have been done (e.g. Del Soar and Alamo 1970, Del Soar and Mistakides 1971a, b, Del Soar and Flores 1972, Kameya *et al.* 1997)) it was clear that further work was needed and hence a number of cruises were undertaken to identify new species as potential resources to satisfy national and international demand for fish.

2. MATERIALS AND METHODS

Information was obtained during the cruises to identify potential fishery resources. These cruises were carried out using several different vessels. The fish caught were identified as to their species and their size and weight distributions were measured to determine if any of them might be potential fishery resources. A Granton-type net trawl, bottom long-lines and traps were used for sampling. The studied area was between 3° 30' – 18° 7' in a depth range of 201–1 500 m.

The cruises to survey potential resources in the waters of Peru were carried out on board of the Research vessels **Antum Brum** (1966), **Kaiyo Maru** (1968), **Challwa Japic N° 1** (1971), **SNP-1** (1970–1972), **Chatyr-Dag** in 1971, **Wiracocha** in 1971 (Vilchez, Del Soar and Viacava 1971), **Kinca** (1985), **Fridtjof Nansen** in 1990 (Veles *et al.* 1992), **BIC Humboltd** (1996), **R.V. Nova Peru** (1997), **R.V. Moresko** (1997) and **R.V. Shinkai Maru** in 1998, 1999 and 2000 (Chipollini *et al. 1999*, Zeballos *et al.* 2001).

3. RESULTS

During the cruises mentioned above about 150 species were identified. The most important potential resources found were: deep red shrimps (7 species) including (*Haliporoides diomedeae*), Chilean knife shrimps (*Solenocera agassizii*), colibrí shrimp (*Nematocarcinus agassizzi*), spider shrimp (*Heterocarpus vicarius*), northern nylon shrimp (*Heterocarpus hostilis*), Panama nylon shrimp, deep-sea crab species (*Paralithodes camtschaticus*) and king crab (10 species): *Lithodes panamensis*, *Lithodes wiracocha*, *Paralomis inca, Paralomis longipes, Neolithodes* spp. This last species was encountered as bycatch in the *Dissotichus eleginoides* fishery. More than 20 species of fishes were encountered including *Roulenia* spp., *Alopocephalus tenebrosus*, Macrouridae (ratfishes), orange roughy (*Hoplostethus pacificus*), black brotula (*Cherublemma emmelas*), snake eels (Ophichthidae spp.) and whiteface hagfish (*Myxine circifrons*). All of these species are in strong demand on international markets. Further details are provied by Zeballos *et al.* (1999).

4. CONCLUSIONS

The conservation of the deep oceans' diversity requires effort to maintain its productivity and ensure sustainable development, especially considering that deep colonizers are slow growing species.

Three phases are necessary to develop a fishery for these resources: (a) exploration, (b) application and (c), fishery developing. At the same time, it is necessary to carry out further operations to obtain the scientific knowledge for the conservation of species and to develop and sustain the local fishing economy to increase economic and social benefits (Del Solar 1987).

It is important to consider at the beginning of the search the risk of over exploration in any new fishery and to understand the effects of this fishery on the ecosystems, i.e. their ecological integrity, diversity and productivity.

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The deep ocean biodiversity of the Peruvian sea: fishes and invertebrates – Peruvian activities

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1. INTRODUCTION

Peru is considered to have mega-ecological biodiversity; however, the biodiversity of its marine ecosystem has received little attention up to now compared with its terrestrial environments. In spite of the Peruvian coast line being more than 3 000 km in length, the amount of knowledge and conservation of the marine ecosystem are scarce compared with those of the terrestrial environments. It is necessary to focus on the marine biological diversity processes and their enormous potential, not only as a sources of proteins but also as source of a great variety of active principles for industrial applications and medicine.

More recent studies have given scientists plenty of scope to argue that the ocean bottom supports as diverse habitats as any community on Earth. Therefore, since 1970 IMARPE has been researching the biodiversity of these marvelous bottom ecosystems.

2. PROGRAMME OBJECTIVES

To research the distribution, concentration and abundance of the Peruvian deep marine biodiversity, focusing mainly on fishes and invertebrates, to plan their management and conservation as well as contribute with information to the Convention of Biological Diversity.

3. MATERIAL AND METHODS

Information was obtained from three cruises carried out on board at the **BIC Shinkai Maru** during 1998, 1999 and 2000 (Chipollini *et al.* 1999, Zeballos *et al.* 2000). The surveyed areas were between 3° 30' to 11° 00' S. The trawls were undertaken in the depth range of 201 m to depths exceeding 1 500 m.

According to procedures established in previous cruises, the acoustic tracks were determined by means of a random stratified sampling design. The detection of fish schools was used to recognize suitable zones for bottom trawling. The main oceanography characteristics in these zones were recorded. The following papers were used in this regard: Fitch and Lavenber (1968), Chirchigno and Velez (1998), Chirchigno and Cornejo (2001) and Méndez (1981).

4. RESULTS

In the analyses of the results, 247 species of fishes and 284 species of invertebrates were identified (Chirichigno and Vélez 1998). During the three cruises, fishes were found to be the dominant group (94–96.6 percent) including *Merluccius gayi peruanus*, *Roulenia* sp., *Cherublemma emmelas*. Those of *Alepocephalus tenebrosus*, *Hoplostethus pacíficus*, and *Dicrolene filamentosa* were the dominant species. Regarding invertebrates, the deep-sea red shrimp *Haliporoides diomedeae* was the dominant species in 1998, 1999 and 2000 (Zeballos *et al.* 1998).

The fishes *Merluccius gayi peruanus* and *Cheurublemma emmelas* were the species most frequently found in Stratum I (200–500 m). Other species found were *Physiculus talarae*, *Ophichthus tetratema*, *Gnathohis cintus*, *Pontinus furcirhinus,* and *Peristedion* spp. but these were not observed in the other zones.

The degree of species of diversity was associated with the depth. It was highest as the depth increased with the highest diversity registered in stratum II (500–1 000 m 5.4–5.5 bits), the diversity value then decreased in stratum III (1 000–1 500 m). Oceanographic parameter mean values observed between 500–1 000 m deep were: temperature 4.5–8.5° C, salinity 34.5–34.65 ups and oxygen, 0.5– 1.5 ml/l.

The following species were frequently found in stratum II (500–1 000 m): *Hoplostethus pacíficus*, *Coryphaenoides delsolari*, *Coelorinchus canus, Rajas* spp., *Xenomystax rictus*, *Apristurus nasutus*, *Hydrolagus macrophthalmus*, *Trachyrinchus helolepis*, *Rhinochimaera pacifica* and *Alepocephalus tenebrosus*.

In stratum III (1 000–1 500 m), *Alepocephalus tenebrosus* was the dominant species, *Roulenia* sp. and *Dicrolene filamentosa* were observed but were much less frequent than the main species.

5. CONCLUSIONS

- During the three cruises on board the **Shinkai Maru** (1998, 1999 and 2000), the dominant species were found to be *Merluccius gayi peruanus* and *Roulenia* sp.
- The frequently observed species in stratum I (200–500 m) were merluza peruana (*Merluccius gayi peruanus*) and congrio negro (*Cherublemma emmelas*).
- In stratum II (500–1 000 m) black brotula (*Cherublemma emmelas*) and orange roughy (*Hoplostethus pacíficus*) were the dominant species.
- In stratum III (1 000–1 500 m) slickhead (*Alepocephalus tenebrosus*), softskin smooth head (*Roulenia* sp.) and deepwater thread brotula (*Dicrolene filamentosa*) were the dominant species.
- The highest value of diversity was registered in stratum II (5.4–5.5 bits) because of decreased abundance as well as the dominance of some species.

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The biology of deep-sea fishes: A review for the Mediterranean

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The knowledge of the Mediterranean deep sea has increased progressively over the last few decades. Improvements in technology have allowed the bathymetric ranges that have been investigated to be expanded and thus enlarge the understanding of its deep-sea ecosystems and the biology of the most important species. A total of 84 fish species have been collected from bottom trawl deep-sea surveys carried out in the western Mediterranean. Some aspects of the biology of twenty demersal fish species (1 Scyliorhinidae, 2 Squalidae, 1 Alepocephalidae, 1 Clorophthalmidae, 2 Notacanthidae, 7 Macrouridae, 2 Gadidae, 2 Moridae, 1 Trachichthydae and 1 Scorpaenidae), which represent more than 90 percent of abundance in terms of biomass, have been analysed, following a standardized format. This included whenever possible (a) distribution, (b) depth range, (c) length range, (d) sex composition, (e) longevity, (f) von Bertalanffy growth parameters, (g) morphometric relationships for Macrouridae species (HL-PAL relationships), (h) spawning season and type of spawn, (i) size of first maturity or smallest fish mature, (j) recruitment (season and depth) and, (k) diet. This biological information is complemented with research related to (a) depth-size trends, (b) population structure and differences in size between Mediterranean and Atlantic populations, (c) fecundity, (d) exploitation aspects and, (e) biological aspects to be studied in the future.

The data used came from two bottom trawl surveys undertaken during the spring and autumn off the Balearic Islands (Western Mediterranean) and from available biological studies on these species developed in the same, or adjacent, areas. The current knowledge of the biology of deep-water species in the Mediterranean is still fragmentary, especially in aspects related to the age composition, growth, reproductive characteristics and fecundity. However, we can conclude that species with different life histories are segregated by depth. Large fish, with high energy requirements are found mainly on the upper and middle slope while the more sedentary and, or, smaller species with low energy costs seem to be better adapted to the poorer environment of the lower slope.

In the context of *r-k* selection theory, some common patterns, such as slow growth, longevity, long life span and delayed maturity, show the deep-sea ichthyofauna to be *k*-strategists. These bio-ecological traits should be considered when establishing management policies for the regulation of any possible expansion of the Mediterranean deep-sea decapod crustacean trawl fisheries. Such considerations would be relevant in reducing the impact upon the fragile ecosystem of the Mediterranean deep sea by such fisheries.

In situ observations of the scavenging fauna of the South Georgia slope

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1. INTRODUCTION

The South Georgia region of the Scotia Sea is characterized by high biomass and productivity of both phytoplankton and zooplankton (Atkinson *et al.* 2001). This high surface productivity supports large populations of penguins, seals and fish, which are heavily reliant on Antarctic krill, which forms the basis of the pelagic food-web. This high productivity will also produce substantial deposition of material on the sea-floor on both the continental shelf, slope and the abyssal plain, which may stimulate a diverse scavenging community.

The fish fauna of the South Georgia shelf has been described in some detail (Gon and Heemstra 1990, Kock 1992), largely as a consequence of commercial interest in species such as mackerel icefish (*Champsocephalus gunnari*) and the marbled notothen (*Notothenia rossii*). But, the deeper fauna has been largely overlooked, and with the fishery for toothfish operating in deep-water it is important to establish the composition and abundance of the deep-sea fauna. However, investigating the demersal deep-sea fauna can be problematic, particularly as traditional commercial trawls do not extend much below 1 000 m and alternate gears such as Agassiz and single warp trawls are considerably smaller sampling devices.

An alternative method of studying deep-sea fauna is through the use of baited cameras, which have been used to investigate the abundance and behaviour of scavengers in the Atlantic (Collins, Priede and Bagley 1999, Jones *et al.* 1998, Priede and Bagley 2000) and Pacific Oceans (Priede, Bagley and Smith 1994) and the Mediterranean Sea (Jones *et al.* 2003). This method is highly selective exclusively attracting scavengers, but with knowledge of their behaviour, it does permit density estimates, either by using the first arrival time (Priede and Merrett 1996, 1998) or by estimating the area of the odour plume from which scavengers are attracted (Collins *et al.* 2002, Sainte-Marie and Hargrave 1987).

In 1997 the Government of South Georgia and the South Sandwich Islands (GSGSSI) funded a pilot study to use a baited camera system to investigate toothfish populations at South Georgia and subsequent studies have been undertaken in 2000 and 2003. The data from the 1997 and 2000 surveys have been used to describe the scavenging fauna at South Georgia (Yau *et al.* 2002), assess abundance of stone crabs (Collins *et al.*

2002), identify commensal relationships between fish and crabs (Yau, Collins and Everson 2000) and investigate the utility of using arrival time at bait to assess density of toothfish (Yau *et al.* 2001). Here we present the new data from 2003 and take the opportunity to review the data so far, focusing in particular on the distribution and behaviour of toothfish.

2. METHODS

During three cruises at South Georgia (September 1997, **F.V. Argos Galicia;** January 2000, **F.V. Argos Galicia;** January 2003, **F.P.V. Dorada**) baited camera systems were deployed on the South Georgia slope from depths of 200–2 500 m (Table 1, Figure 1). The baited camera systems were modifications of the Aberdeen University Deep Ocean Submersible (AUDOS) system (Bagley and Priede 1997, Priede and Bagley 2000) (Figure 2), which were designed to photograph and track scavenging fish and invertebrates on the sea floor.

TABLE 1
Details of deployments with numbers of toothfish encounters and maximum numbers of crabs

Exp.	Camera System	Date	Area	Latitude	Longitude	Depth (m)	Temp. C	Toothfish Encounters	Max. Paralomis	Crabs Neolithodes
1	35 mm	7-Sep-97	SR	53°19.1′ S	41°56.7′ W	1039	1.5	1	3	0
2	35 mm	8-Sep-97	SR	53°31.2′ S	40°20.5′ W	1149	1.5	2	18	0
3	35 mm	10-Sep-97	SR	53°46.0′ S	41°59.1′ W	1000	1.4	3	4	1
4	35 mm	11-Sep-97	SR	53°17.7′ S	42°12.0′ W	747	1.8	9	43	1
5	35 mm	13-Sep-97	SG	53°35.2′ S	37°59.2′ W	1000	1.6	1	27/4	0
6	35 mm	17-Sep-97	SG	53°45.1′ S	35°59.8′ W	1100		4	44	0
7	35 mm	18-Sep-97	SG	54°14.9′ S	35°15.8′ W	775		0	33/3	0
8	35 mm	19-Sep-97	SG	54°30.9′ S	35°06.1′ W	1487		1	28	1
9	35 mm	21-Sep-97	SG	55°25.4′ S	34°55.3′ W	625		6	24	4
10	35 mm	22-Sep-97	SG	55°09.1′ S	36°21.2′ W	1143		4	37	1
11	35 mm	23-Sep-97	SG	55°02.6′ S	36°59.6′ W	1275	1.3	5	20	3
12	35 mm	24-Sep-97	SG	54°52.7′ S	37°58.7′ W	1178		1	26	1
13	35 mm	27-Sep-97	SG	53°44.4′ S	39°22.6′ W	872		3	21/2	0
14	DV	17-Jan-00	SR	53°16.9′ S	42°22.1′ W	719	2.2	7	40	0
15	DV	17-Jan-00	SR	53°26.2′ S	41°35.6′ W	1085	1.8	8	22	0
16	DV	21-Jan-00	SG	53°35.5′ S	36°20.9′ W	1035	1.6	24	74	1
17	DV	22-Jan-00	SG	54°05.5′ S	35°20.9′ W	1114	1.6	38	17	0
18	DV	22-Jan-00	SG	54°05.0′ S	35°20.1′ W	1294	1.6	44	27	1
19	DV	23-Jan-00	SG	54°37.3′ S	34°47.6′ W	780	1.9	14	39	1
20	DV	23-Jan-00	SG	54°36.8′ S	34°42.8′ W	1005		10	22	1
21	DV	24-Jan-00	SG	54°38.1′ S	34°37.6′ W	1250	1.4	32	12	2
22	DV	24-Jan-00	SG	54°38.1′ S	34°32.6′ W	1518		21	15	1
23	DV	26-Jan-00	SG	54°50.7′ S	38°31.5′ W	1120	1.6	7	24	0
24	DV	26-Jan-00	SG	54°50.9′ S	38°31.5′ W	1335	1.6	16	3	0
25	DV	27-Jan-00	SG	54°23.7′ S	39°28.7′ W	946	1.7	3	108	0
26	DV	27-Jan-00	SG	54°23.9′ S	39°23.6′ W	1202	1.7	18	30	1
27	DV	29-Jan-00	SR	53°36.1′ S	40°44.9′ W	1283	1.7	18	21	0
28	DV	29-Jan-00	SR	53°36.2′ S	40°45.7′ W	1140		18	20	1
29	DV	11-Jan-03	SG	53°48.2′ S	36°7.0′ W	1056	2.0	5	6	0
30	DV	13-Jan-03	SG	53°23.2′ S	36°53.0′ W	1611	1.45	7	27	0
31	DV	13-Jan-03	SG	53°16.9′ S	36°54.4′ W	2335	0.9	0	0	0
32	DV	15-Jan-03	SG	53°48.0′ S	39°28.4′ W	1018	2.05	7	25	1

33	DV	18-Jan-03	SR	53°39.9′ S	40°37.7′ W	471	2.4	5	9	0
34	DV	20-Jan-03	SR	53°32.9′ S	41°7.8′ W	1005	2.25	5	28	1
35	DV	25-Jan-03	SG	54°54.2′ S	38°9.6′ W	1160	1.9	2	35	2
36	DV	26-Jan-03	SG	54°53.6′ S	38°24.7′ W	1984	1.2	0	3	0
37	DV	27-Jan-03	SG	55°28.9′ S	36°13.3′ W	1896	1.3	0	1	0
38	DV	27-Jan-03	SG	55°18.4′ S	36°17.1′ W	769	2.25	3	19	0
39	DV	29-Jan-03	SG	54°39.8′ S	35°35.2′ W	1356	1.55	9	10	0
40	DV	30-Jan-03	SG	54°49.4′ S	34°26.0′ W	790	2.15	3	26	1
41	DV	31-Jan-03	SG	53°51.1′ S	35°40.4′ W	890	2.05	4	35	0

The basic system consists of an aluminium frame on which a camera system is mounted, a current meter (Sensortec), acoustic releases (Mors AR and RT) and a battery. Buoyancy was provided by glass spheres (Benthos Inc., each giving 24 kg positive buoyancy) attached to a 100 m mooring line. In 1997 a conventional, high capacity still camera (Ocean Instruments) was used, while in 2000 and 2003 a video camera (JVC Colour Video Camera, TK-C1380 in housing with controller) was used.

FIGURE 1
Map showing the locations of baited camera deployments at South Georgia in 1997 (red), 2000 (green) and 2003 (blue)

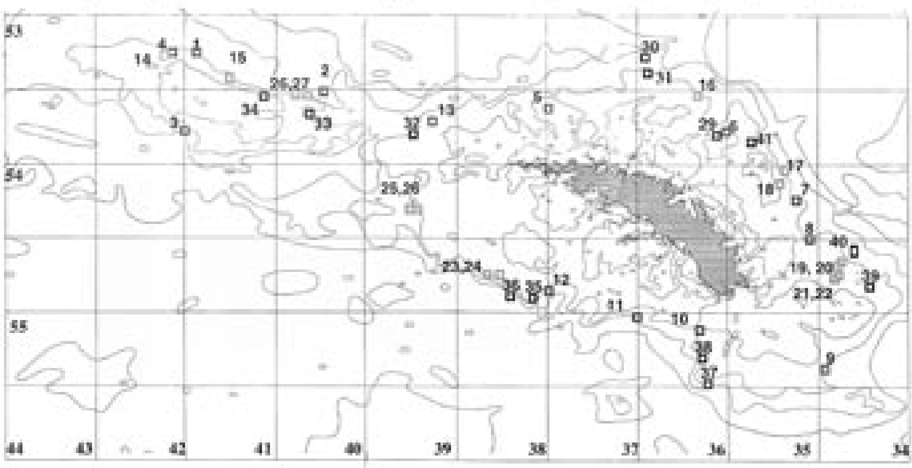
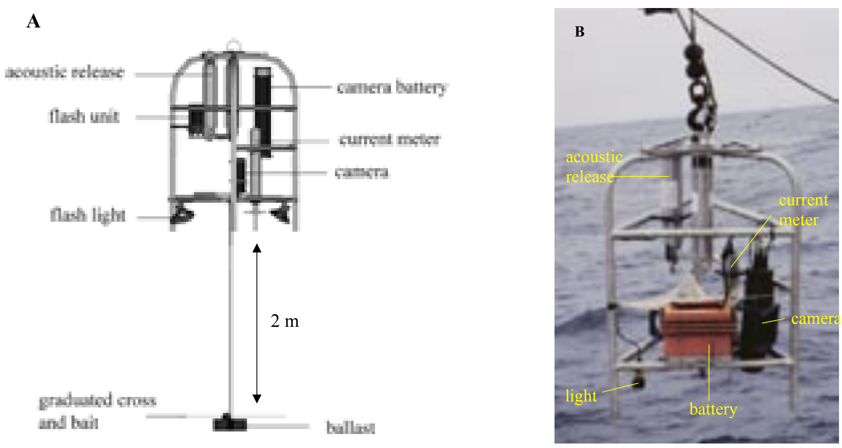


FIGURE 2
Diagrammatic view of the baited camera system used in 1997 (A) and photograph of the system used in 2000 and 2003 (B)



The camera systems descended by free-fall. It had 100 kg of ballast, which held the rig in position on the seafloor. The ballast, with a graduated cross and baits attached, remained on the seafloor and was connected to the AUDOS vehicle by a 2 m length of wire. The cross therefore rested 30–50 cm above the seafloor on top of the ballast; positive buoyancy of the mooring line held the AUDOS 2 m above the cross. Each deployment was baited with four squid (*Illex argentinus*) hung from the cross with sardines inserted in the mantle cavity and attached to the ballast (total 800 g).

Each experiment lasted between 6 and 10 hours. The conventional time-lapse camera system (1997) took photographs every minute. The camera was loaded with Ektachrome 200 ASA film with a capacity of approximately 750 full frames. Small strips of film were developed on board to test that the camera was working, but the bulk of the film was developed after the cruise.

The video camera systems (2000, 2003), recorded a total of one hour of video and were typically programmed to record 45 consecutive seconds in each 2½ minutes for the first two hours; 45 seconds in each five minutes for the next two hours and 45 seconds every 15 minutes during hours five and six. The camera recorded onto digital videotape and after recovery a copy was made on the SVHS. The camera viewed an area of sea-floor of approximately 4.9 m^2. The current meter was programmed to record depth, temperature, current direction and current speed at one-minute intervals throughout the deployment.

On completion of the experiment the camera systems were released from the ballast by an acoustic signal from a Mors deck unit (TT301) using a transponder lowered into the water. The vehicles surfaced at a rate of approximately 0.8 ms^{-1} under their own buoyancy. A marker buoy was attached at the surface to the end of the mooring, which incorporated a VHF radio beacon (Novatech) together with a large pink flag. This aided in its location and recovery.

3. RESULTS

3.1 Scavenging fauna

The scavenging fauna was dominated by lithodid crabs (*Paralomis formosa* and *P. spinosissima*), toothfish, grenadiers and morids (Table 2, Figure 3). Lithodid crabs were present at all but the deepest deployment (2 235 m). Toothfish were not seen at the three deepest deployments and were also absent from Deployment 7 (1997, 775 m). Grenadiers (*Macrourus* sp.) were frequently attracted to the bait, but the species could not be identified with any certainty from the videos or still photographs. Three species (*M. holotrachys*, *M. carinatus* and *M. whitsoni*) were taken in trawls (up to 900 m) on the South Georgia slope during the 2003 survey. Two species of morid were also seen at the bait: *Antimora rostrata*, which is easily recognizable from the black colour and a second species that was either *Lepidion ensiferus* or *Halargyreus johnsoni*. Two species of skate were seen, *Bathyraja meridionalis* and *Raja georgianus*. See Yau *et al.* (2002) for full details of the scavenging fauna from the 1997 and 2000 surveys.

3.2 Toothfish abundance and distribution

The 1997 and 2000 cruises were standard South Georgia groundfish surveys. Camera deployments were made each evening and recovered in the morning but the depth choice was constrained by the requirements of the trawl survey. In 2003 the survey was designed to investigate deep-sea fauna in a series of down-slope transects, with the camera deployments extending to depths in excess of 2 000 m. The number of toothfish photographed at the bait was low during the 1997 survey, but greater numbers were attracted to the baits in 2000. However, numbers were again low in 2003. The low number of encounters with toothfish in the 1997 survey was attributed to the effects of the powerful flash associated with the stills camera. During the 2003 survey, three deployments were made at depths greater than 1 800 m and toothfish were not seen in these deployments (Table 1). These deep deployments corresponded to the lowest temperatures (< 1 °C). Even excluding these, there were less toothfish encounters in 2003. The maximum encounter rate for toothfish was at depths of 1 200–1 400 m (Figure 4A), corresponding to temperatures of around 1.5 °C (Figure 4B).

TABLE 2
Scavenging species identified from baited camera studies on the South Georgia slope

	Species	Depth Range	Encounters/ Max		
			1997	2000	2003
Fish	*Dissostichus eleginoides*	471–1 611	40	278	47
	Macrourus sp.	764–2 328	25	55	55
	Antimora rostrata	466–2 328	10[1]	72[1]	22
	Lepidion ensiferus/ Halargyreus johnsoni	769–1 896	0[1]	0[1]	29
	Raja georgianna	719–1 519	0	11	1
	Raja sp A[2]	1018–1 896	0	1[2]	6
Invertebrates	*Paralomis formosa-/ Paralomis spinossissima*	471–1 896	44	108	35
	Neolithodes diomedea	764–1 519	4	2	2
	Thymops birsteini	471–1 896	3	7	3

For fish species numbers refer to the number of encounters and for invertebrates to the maximum number at any time.
[1]All morids from 1997 and 2000 recorded as *Antimora rostrata*, but probably included *Lepidion ensiferus* and, or, *Halargyreus johnsoni.*
[2]Recorded as *Bathyraja meridionalis* in Yau *et al*. (2002).

FIGURE 3
Scavengers from the South Georgia slope
A. Video still (Jan 2000) of aggregation of crabs (*P. formosa*) – B. Photograph of *Parolomis formosa* and *P. spinosissima* – C. Toothfish (*Dissostichus eleginoides*) – D. Video still of skate, *Raja* spA.

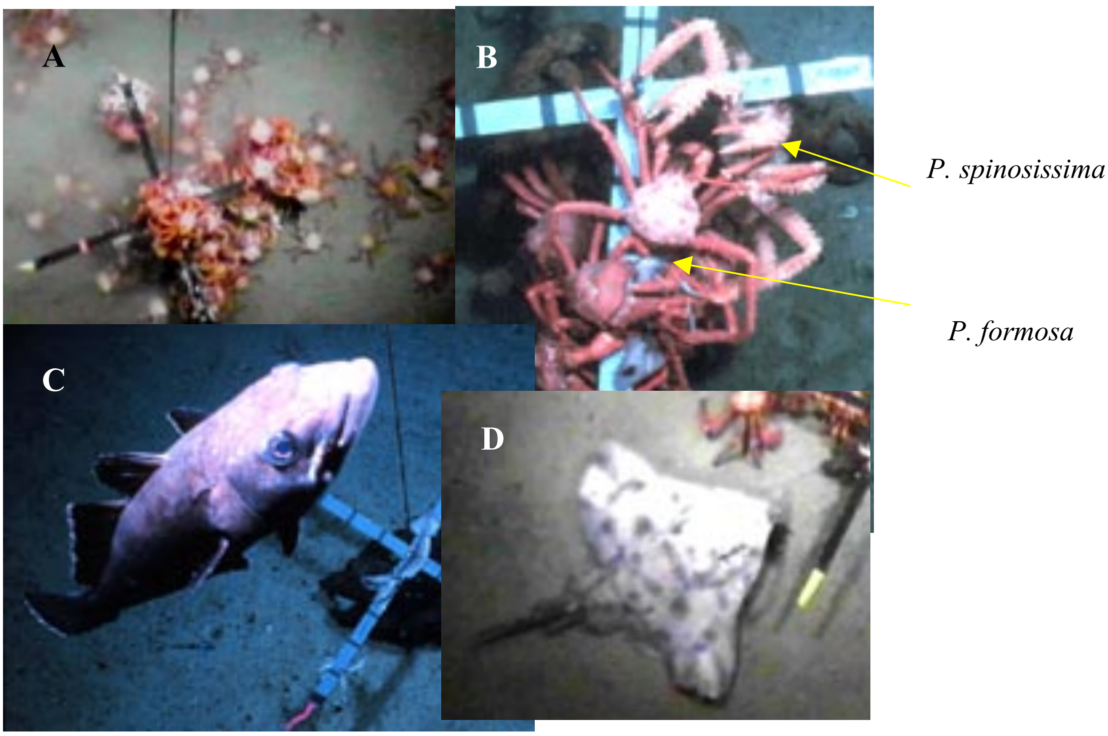
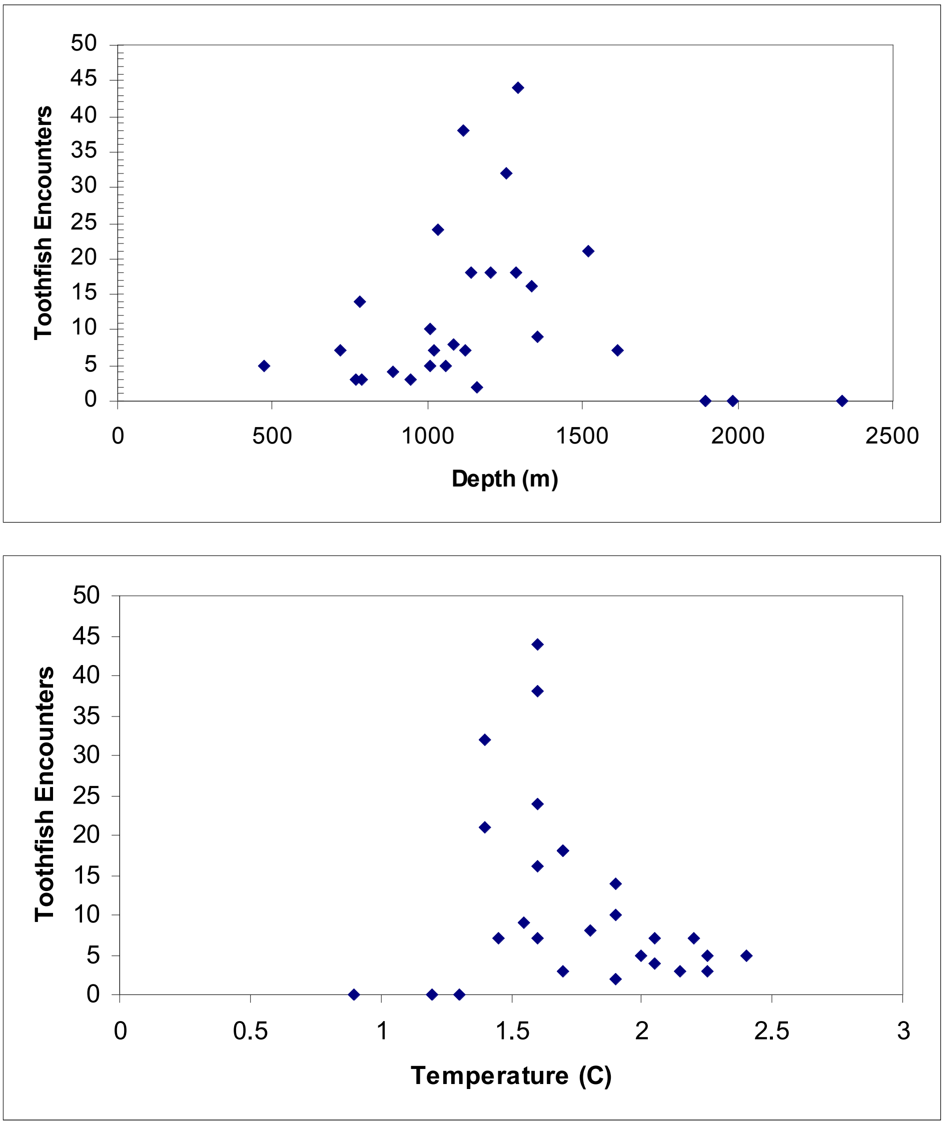


FIGURE 4

Relationship between toothfish encounters and deployment depth (upper panel) and temperature (lower panel) from the baited video camera deployments in 2000 and 2003



3.3 Toothfish behaviour

Swimming: Toothfish generally approached the bait from down-current, swimming close to the sea-floor with gentle sculling motions of the pectoral fins (i.e. labriform swimming). Occasionally toothfish were startled by knocking each other, touching crab spines or the cross and swam away rapidly. On one occasion a toothfish was startled outside the field of view, and swam rapidly through the field of view, skirting around the ballast. The fish was approximately 80 cm long and swam with a velocity of 3.1 body lengths sec^{-1}.

Bait attendance: Toothfish numbers did not accumulate at the bait, fish usually arrived individually, investigated the area around the bait and if they could not easily obtain the squid bait would depart. Fish occasionally rested on the sea-floor close to the bait, but usually only for a minute or two.

Colour change: In the video camera deployments the lights were programmed to turn on before the camera started. There were many incidents when a toothfish was in the field of view when the video turned on and the fish were frequently very pale.

The toothfish were subsequently seen to change colour, changing from light, back to dark, in less than 30 secs. On other occasions a cloud of sediment was visible when the camera came on, indicating that a fish (probably toothfish) had been startled by the lights, and swam away rapidly.

Taking the bait: Toothfish were videoed taking the bait on numerous occasions, usually the fish would grab the squid, pull it from the cross and swallow it whole. On one occasion a toothfish rotated three times in order to remove the bait from the cross. Toothfish also tried to eat the current ribbons that were attached to the ends of the cross and were probably covered in bait.

Interactions with crabs: When large numbers of crabs (*Paralomis* sp.) were present at the bait toothfish did not stay around long. There was no evidence that toothfish prey on crabs. Toothfish frequently came into contact with the spines of the crabs and rapidly swam away.

3.4 Crab abundance

The principal crab species attracted to the bait was *Paralomis formosa*, although *Paralomis spinnossissima* was also seen during shallower deployments. The much larger *Neolithodes diomedea* was seen occasionally. However, when large numbers of crabs were present at the bait, it was difficult to distinguish between the *Paralomis* species. Data from the higher resolution 35 mm camera system in 1997 suggested that *P. spinossissima* was limited to depths of less than 600 m.

Crab numbers increased rapidly at the bait, and crabs remained in the area while bait was accessible. The crabs formed large clumps around the squid bait and were occasionally seen fighting for parts of the bit.

From the current meter data, the size of the odour plume (assumed to be an elipse) can be estimated at a given time, and with knowledge of crab walking speed, and numbers at the bait, an estimate of density can be obtained. Density estimates were made from the 2000 survey (see Collins *et al*. 2002) but the analysis has not yet been undertaken on the 2003 data.

4. DISCUSSION

The South Georgia slope supports a diverse community of scavengers that respond rapidly to the arrival of bait on the sea-floor. The main scavenging species are crabs of the genus *Paralomis* and Patagonian toothfish (*Dissostichus eleginoides*). Smaller scavengers such as amphipods could not be quantified. The data suggest that the abundance of scavengers is lower at depths greater than 1 800 m, which may be a consequence of reduced food availability at this depth or the physiological intolerance of the scavengers to greater depths and lower temperatures.

The data suggest that *D. eleginoides* are absent from depths greater than 1 800 m and, or, temperatures of less than 1.3 °C. Unlike *Dissostichus mawsoni*, *D. eleginoides* does not have anti-freeze glycopeptides in its blood (Eastman 1990) and it is therefore likely that low temperatures limit its distribution.

The 35 mm camera system used in the 1997 survey produced high resolution images from which the fauna could be better identified, but it was thought that the powerful flash may have discouraged toothfish from attending the bait. On the other hand, the video camera system, with lower light levels, gave poorer resolution for species identification but, for the common species provided valuable behavioural data. Even with the comparatively low-light levels on the video camera, there was still evidence that toothfish reacted to the lights, either by rapidly leaving the illuminated area (evidence by clouds of sediment when the camera started) or by rapid colour change. The ability to change colour appears unusual for a deep-sea fish species, where light is usually low or absent, but the toothfish clearly attempt to camouflage themselves against the background, indicating that the fish have the ability to detect and respond to light of varying intensity. Juvenile, and occasionally adult, toothfish inhabit shallow water, where the ability to detect and respond to light will be advantageous, so it appears likely that adults have retained this ability.

The labriform swimming of the toothfish appears designed to conserve energy, typically sculling close to the sea-floor with gentle beats of pectoral fins. However, when startled they are capable of more rapid, sub-carangiform swimming and the speed of one fish of 3.1 BL sec^{-1} is quicker than cod are reported to swim at similar temperatures(Videler and Wardle 1991). In general, the toothfish did not remain long at the bait, which may be a consequence of the lights, but may also be indicative of plentiful food. Priede *et al.* (1991) and Priede and Merrett (1998) have demonstrated that the staying time of grenadiers at bait is related to the overlying productivity and thus, probably, to food availability on the sea-floor.

Providing that the bait was accessible, crab numbers accumulated at the bait over time, which permited estimates of local density to be made from the arrival times (Collins *et al.* 2002). However, such an approach is not possible for toothfish, which stayed only briefly at the bait. Local crab density was estimated to be as high as 25 000 km^{-2} with a mean density of 8 318 km^{-2} (depth range: 719–1 518 m).

The relationship between *Paralomis formosa* and the liparid *Careproctus* sp. was first described (Yau *et al.* 2000) from the 1997 survey with the high resolution camera, but subsequent work with the video system has shown that the fish are able to move between crab hosts and aggregations at bait may provide opportunities for fish to switch host and, perhaps, feed on scavenging amphipods.

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Towards an international census of marine life research program on seamounts

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1. INTRODUCTION

The Census of Marine Life (CoML) is a worldwide science initiative promoting research to assess and explain the diversity, distribution, and abundance of species throughout the world's oceans (<*www.coml.org*>; Decker and O'Dor 2003). As one of several activities, the CoML fosters international field programmes to facilitate research into under-explored marine ecosystems. Recognizing the growing scientific interest in seamounts, the Census of Marine Life hosted an international workshop on seamounts on 22–24 August 2003 at the Hatfield Marine Science Center in Newport, Oregon, USA. The goals of the workshop were to (a) evaluate the existing state of knowledge of seamounts, (b) determine the priorities for future seamount research, (c) outline the next steps required to address these research priorities and (d), evaluate the potential role of the CoML in fostering research progress through an international field programme.

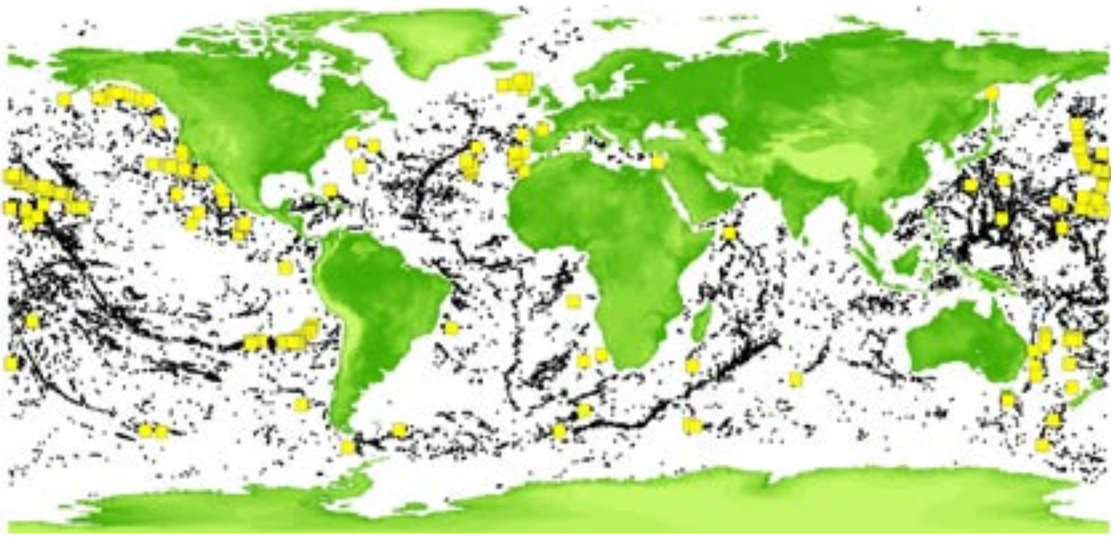
2. WORKSHOP OUTCOMES

The workshop concluded that seamounts represent important ecosystems for studies that have not, to date, received scientific attention consistent with their biological and ecological value (Stocks, Boehlert and Dower 2004). A comprehensive understanding of ocean biodiversity and biogeography will require directed study of seamounts to learn of their unique features. Specifically, it was noted that seamounts

- are ubiquitous seafloor features: >30 000 exist and they are found in all ocean basins (Figure 1; Smith and Jordan 1988)
- are biologically distinct from other oceanic ecosystems
- support unique biological communities, sometimes with very high levels of endemism (Richer de Forges, Koslow and Poor 2000)
- can serve as model systems for studying processes that regulate marine communities in the oceans in general
- are geographically isolated, and therefore potentially fragile ecosystems and
- are becoming increasingly affected by human activities.

Important policy and management decisions regarding seamounts will be made in the next five to seven years (e.g. UN General Assembly considerations of marine protected areas) and good science will be essential for guiding management and conservation efforts. Further, the workshop participants determined that a CoML field programme on seamounts could have a valuable role in stimulating and coordinating seamount research. Workshop presentations on past and planned seamount work highlighted that seamounts are an area of active research. However, important science questions, detailed below, will not be addressed by simply continuing with a "business as usual" approach. In particular, there is a compelling need for an international effort to promote and coordinate future field efforts and synthesize existing knowledge in order to extend our results beyond individual seamount ecosystems.

FIGURE 1
Seamount locations
Squares indicate seamounts that have been sampled biologically (from SeamountsOnline; *seamounts.sdsc.edu*). Small black dots indicate predicted locations of ~14 000 seamounts (from Kitchingman and Lai 2004).



3. SCIENCE PRIORITIES

To provide a scientific framework for the envisioned CoML program on seamounts, the following priority science question was articulated: "*What roles do seamounts play in the biogeography, biodiversity, productivity, and evolution of marine organisms, and what is their effect on the global, oceanic ecosystem?*". This primary theme was further sub-divided into three specific research themes.

Theme 1

Given the large number of seamounts globally, can we categorize seamount community structures and, or, develop proxy variables in order to (a) use our knowledge from a limited number of well-known seamounts to make predictions about unknown ones, (b) efficiently guide future research programmes and (c), understand the key processes regulating the structure and maintenance of seamount communities?

One topic considered was whether some minimal set of physical factors might be formulated in order to provide a biologically meaningful description and categorization scheme for seamounts. Although by no means exhaustive, the following list of factors were identified as being important to consider in any such scheme:

- physical and geological setting of the seamount (age, substrate type, etc.)
- geography (latitude, ocean basin, distance from nearest continental margin, etc.)
- seamount size, depth, shape and physiography and
- productivity of the overlying water column and its associated hydrographic characteristics (e.g. localized upwelling, presence of recirculating eddies such as Taylor columns and relationships to mesoscale oceanographic features).

Theme 2

How do seamount communities, both within and between seamounts, differ in ecological structure and function? This theme explicitly recognized that there can be substantial patchiness within a given seamount as well as between seamounts, and that variability at both scales is important for understanding seamount ecosystems. Particular questions of interest include: How do the physical characteristics of a given seamount influence the composition of communities that occupy its various habitats? What are the roles of biological interactions (e.g. trophic structure and food web function) both within seamount communities and with surrounding ocean communities? How vulnerable are seamount ecosystems to disturbance, and how might the structure of these ecosystems change in response to natural (e.g. seasonal variability, inter-annual cycles, climate change) and anthropogenic (e.g. overfishing) influences? What roles do larval dispersal and recruitment dynamics play in the long-term persistence of seamount populations? How do the surrounding deep-sea communities interact with seamounts? On what scales do seamounts influence the biological and physical structure of adjacent oceanic habitats (i.e. what is the spatial and ecological "footprint" of a seamount or seamount chain in the surrounding ocean)?

Theme 3

On a broader scale, what roles do seamounts play in global oceanic ecosystems with respect to (a) biogeography, (b) biodiversity, (c) evolution and (d), productivity? This theme will involve the synthesis of seamount studies from around the world. Specifically, workshop participants proposed investigating issues such as whether seamounts act as centres of speciation or as refugia for relict populations, to what extent do seamounts serve as stepping-stones for trans-oceanic dispersal and whether they represent regional hotspots of biological production, which may be important e.g. for migratory species.

4. PROPOSED ACTIVITIES

To address the priorities stated above, workshop participants identified several key planning and research activities. The primary focus will be on developing an international scientific programme that concurrently catalyzes and coordinates field sampling while continuing databasing and data analysis efforts.

Activity 1: Promoting future field sampling

Given that fewer than 150 of the tens of thousands of seamounts have been explored in any detail (Figure 1), new field research is obviously critical to improving our understanding of seamount biogeography. Therefore, supporting and coordinating existing field efforts and developing new collaborative projects have been identified as high priorities for a future CoML seamount program. While funding is always a limiting factor for expedition work, the growing concerns, both within many countries and internationally, over human impacts on seamounts may open new sources of funding. In addition to leveraging funds for new initiatives, future seamount research should also be linked to existing sampling programmes and, where appropriate, national agendas (e.g. several nations, including Australia, New Zealand and Canada, already have programmes underway to protect certain seamounts within their Exclusive Economic Zones).

Workshop participants recommended that a planning stage for this activity address:

- *Standardized sampling.* A minimum set of standardized samples and data should be defined that is required or recommended for all participating field programmes.
- *Scientific impacts.* Seamounts are already known as potentially fragile habitats. The project may need to develop practices or recommendations to ensure that negative impacts from research activities (e.g. sample collection) are minimized and documented.
- *Sampling priorities***.** Based in part on the results from Activity 3 (below), it should be possible to rank a list of seamounts in terms of the importance for research attention. This could be based either on (a) a lack of existing seamount data from a particular part of the world ocean or a category of seamount or (b), the recognition that a particular seamount (or seamounts) is at imminent risk from fishing or other destructive activities.
- *Defining the programme scope*. While geologists have a strict definition of seamounts (a feature over 1 000 m high and of restricted spatial extent) there is growing evidence that this definition is not biologically meaningful. Even relatively small hills and offshore banks can have many of the ecological features of "true" seamounts (e.g. Probert, McNight and Grove 1997, Koslow *et al.* 2001, Rowden, O'Shea and Clark 2002). If seamounts are defined too narrowly within this programme, there is little incentive for groups working in allied hill and bank systems to participate in the programme and provide valuable comparative data.
- *Taxonomy.* Workshop participants highlighted that the lack of taxonomic expertise and the need for quality control and standardization of taxonomy will be challenges for a seamount field programme. It was noted that this is an issue that cuts across all CoML field programmes.

Activity 2: Networking and coordination

The scope of the science recommended above will require substantial coordination within the international scientific community. Geographically, it is desirable (indeed essential) that many countries participate, given how widely distributed seamounts are and how many lie in international waters. Scientifically, expertise from a wide range of fields (e.g. genetics, population biology, fisheries biology, physical oceanography, geology, taxonomy, ecosystem ecology, etc) will be needed. Further, a variety of existing programmes (e.g. MAR-ECO <*mareco.imr.no/index.html*>; OASIS <*www.rrz.uni-hamburg.de/OASIS/*>; NOAA Ocean Explorations <*oceanexplorer.noaa.gov*>) are undertaking seamount research. These programmes typically have objectives that are consistent with the science objectives identified by this workshop, and can provide established networks of experts. Facilitating collaboration among these projects, while not competing with them, will be critical.

During the planning phase of a CoML seamount project, international planning workshops will bring together the varied scientific expertise required and help to engage scientists who were not represented at the initial CoML seamount workshop. By these means we will involve a broader group of scientists and expertise to improve the design of the scientific programme. Presentations at established scientific meetings will be used to raise awareness of the project.

Activity 3: Databasing and retrospective analyses

A substantial body of work exists on seamount biogeography and ecology (Figure 1). To date, however, these data remain fragmented and, in many cases, are all but inaccessible to the scientific community. Several information systems relevant to seamount biology were demonstrated at the workshop: SeamountsOnline <*seamounts.sdsc.edu*>, the Seamount Catalog of EarthRef <*earthref.org*> and the MBARI Video Annotation and

Reference System <*www.mbari.org/vars/*>. The workshop participants recommended that the planning phase for a global CoML seamount project must continue the development of an online seamounts database and help create an analysis and synthesis effort on existing data. This is not to say that future field studies should not be undertaken until such a synthesis is complete, but rather that full advantage must be taken of existing data to assist in the planning and refining of future field efforts.

After the planning phase is complete, efforts to further develop databases should continue for the repository and archiving of new data collected during the field programme and as the programmes' contribution to the Ocean Biogeographic Information System (Zhang and Grassle 2003, *www.iobis.org*).

Activity 4: Outreach

As photogenic and exciting habitats, seamounts have a rich potential for public outreach and for pre-collegiate education efforts. Because of the emerging interest in conservation issues of seamounts – such as national and international efforts to site marine protected areas on seamounts and manage seamount fisheries – communicating science results to managers and decision makers was highlighted as a special emphasis for a future CoML seamounts programme. While it is beyond the scope of the CoML to make policy recommendations, scientific outcomes from seamount research are likely to be critical to decision making. Because the traditional lines of communication between science and management (i.e. publication in the primary research literature) are often not effective, new mechanisms should be considered.

5. THE NEXT STEPS

The next actions towards realizing a Census of Marine Life International Field Program on seamounts will be further outreach efforts to scientists not represented at the workshop, further refinement of the science plan and the development of a programme secretariat for coordination. Anyone interested in participating in this effort or learning more can contact the authors or visit seamounts.sdsc.edu and follow the links to the CoML Seamount Program.

6. ACKNOWLEDGEMENTS

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Environmental assessment of fisheries – working towards an ecologically sustainable future

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The depletion of fish stocks and the ecological sustainability of global fisheries are issues of international concern. The Australian Government has responded to these concerns by incorporating ecological sustainability requirements into Commonwealth environment and fisheries legislation.

The Australian Oceans Policy, released in 1998, announced the Australian Government's intention to require environmental assessment of Commonwealth managed fisheries and to remove the general exemption for fisheries from the export permit requirements of environmental legislation. The purpose is to independently audit the environmental performance of Australian fisheries to ensure that they are managed in an ecologically sustainable way.

This means that decision makers must ensure that the impacts of fishing on target, bycatch and by-product protected species and the wider marine environment are sustainably managed. Achievement of a balanced triple bottom line depends on an integrated, comprehensive assessment of impacts and not an exclusive focus on target stocks. The long-term economic viability of fisheries, and their continuing role in supporting communities, depends on governments, industry and communities working together to ensure that fishing practices are ecologically sustainable.

The assessment process is facilitating a change in management practices across Australia's commercial fisheries. There has been a positive shift away from largely target-species focused management to a more ecosystem-based approach.

The paper provided an overview of Australia's Commonwealth environmental assessment requirements and a brief analysis of progress with the assessments. It also provided examples of results from a range of Australian-managed fisheries, including a number of deep-sea fisheries.

Gulf Stream and formation of intraspecific structure in fishes of northeast Atlantic

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The essence of ontogeny is the transformation of hereditary information into a system of living connections of the phenotype with its environment. The natural selection is based on the evaluation of phenotypes, and is the mechanism of the information feedback conversion in the biogeocenosis.

I.I. Schmalhauzen (1968)

1. INTRODUCTION

The geographic distribution and intraspecific diversity of marine fish is, to a considerable extent, determined by the variable environmental conditions created by the complicated system of oceanic currents. The Gulf Stream is no exception in this respect.

Migrations are among most important features of specie, whose life cycles are connected with currents. Migrations lead to an expansion in the range of the species and development of migration cycles in fish. The principal peculiarity of migrations is the integrity of passive dispersion of the young and active migration of subadult and mature individuals (Marti 1980). In the same publication Marti also stresses that "migrations do not favor speciation, and a species frequently preserves its uniformity in this case". At the same time, "the wider the reproductive range and the more variable its environment, the more probably homing is directed not to the 'home itself' but to 'domestic conditions'; pelagic migrants spawning in deep water may be such an example. Therefore migrations always lead to isolated existence of separate biological groups in fish. In this connection investigation of migrations poses the problem of investigation of population structure of the species, which may be solved only by proper understanding of migration cycles of small taxonomic units and their reproductive ranges (i.e. different intraspecific groups such as ecological forms, races, populations, etc.).

A population may be understood as an reproductively isolated group, representing an elementary unit for the process of evolution and possessing two major qualities (a) genetic uniformity (specificity) and (b), genetic self-dependence (isolation). These are most important when analyzing intraspecific structure. But, it is precisely these parameters that are most controversial in the determination of population status for intraspecific groups (Novikov and Karpov 1989).

2. GENETIC STRUCTURE OF POPULATIONS

Genetic uniformity (specificity) of the population depends on mechanisms that maintain mixing of population (panmixia). In natural fish populations panmixia is sustained simultaneously both among spawning individuals and in sequences of generations.

There are several factors favoring a high level of panmixia in fish:

- high abundance of brood stock, providing a large effective population size" (N_e)
- high migration activity of mature individuals i.e. high values of R – the radius of spatial displacement
- high fecundity, i.e. at the levels of the individual and population
- the presence of numerous age classes in the brood stock
- formation of the "cloud of gametes" at spawning grounds
- intermittent spawning, accompanied by changes of a spawning partner and
- existence of the pelagic developmental stages during early ontogeny, contributing to effective spatial distribution and mixing of individuals during the passive migration (drifting) and others.

On the other hand, such parameters as numerous spawning grounds, the presence of circulating locking currents, creation of retention areas, local ecological niches, homing, favoring reproductive isolation, etc., intensify species differentiation (Novikov and Karpov 1989).

The intraspecific structure is more pronounced when the following features are observed:

- strict containment of spawning places
- migratory activity of individuals is small
- the pelagic developmental stage is absent and
- there are no constant currents, providing passive dispersion of young and mature individuals.

Changes in any of these features will result in changes of the existing population boundaries with subsequent alteration of intraspecific relations among different groups of individuals. Appearance of gene flow among them will be accompanied by the formation of a cline or mosaic variability of characters. The presence of prolonged pelagic developmental stages coupled with directed drifting may result in a total absence of differentiation and give rise to genetic uniformity.

A similar pattern is observed in the intraspecific structure of the main commercial fish species in the North Atlantic. Here, the presence of principal "oceanic" populations with numerous smaller local groups is connected with certain regions and currents. The fact that such groups are evolutionary related is beyond question, and comparison of their distribution with the system of main ocean currents offers a clearer view on their origin and the degree of their genetic similarity.

One may easily imagine that both modification (functional) and genetic (structural) adaptations, determining later differences in their gene pools should develop within the area of any local group living in its specific environment. In this connection some authors believe that every species could be divided into a multitude of populations, adapted to their specific conditions (Altukhov 1990).

But this situation is far from being the case in all natural situation. The following variations are possible:

- the population may adapt to a new environment without genetic divergence
- the adaptation may be accompanied by divergence and formation of several independent populations and
- the adaptation may be accompanied by cline variability, by the development of ecologic forms or by temporary local isolates.

The combined influence of factors such as those limiting panmixia should be considered when analyzing the intraspecific structure of a species, because the presence of only one factor favoring panmixia condition, may be sufficient to neutralize all limiting factors. Unlike other groups of animals, fishes as a whole have significant factors contributing to the gene flow between different groups in space and time, i.e. across the generations.

3. THE SITUATION IN THE NE ATLANTIC

In the North-East Atlantic different selective factors are in effect. The adaptations are developed in coping with conditions of a new local ecological niche, which are connected primarily with changes in intensity and direction of metabolic processes, such as alterations in growth rate, age of maturation, reproductive parameters, life extent, etc. (Table 1). They are induced by differences of environmental conditions in high seas and in coastal waters, including fiords and contribute to forming biological variability and development of different ecological forms. At the same time, the spatial isolation of habitats, including breeding areas, is responsible for establishing reproductive and genetic isolation, and, consequently, for complications in the intraspecific structure.

TABLE 1
Frequency of alleles and affinity to oxygen of cod HB-1 in the cod populations

Population	Mean many-year demersal temperatures °C		Frequency of allele Hbl-1
	February	August	
Cod of the Baltic Sea	+4	+6	0.03
Cod of the Danish Straights	+4	+17	0.7
Cod of the Northern Sea	+7	+15	0.5
Coastal cod of the Norway Sea	+5	+10	0.4–0.3
Arcto-Norwegian cod	+2	+5	0.2–0.1
Coastal cod of the Barents Sea	+2	+7	0.3–0.2
White Sea cod	-1.5	+10	0.2
Cod of the West Atlantic	+1	+5	0.1–0.01

To better understand the complex processes of development of intraspecific structure, which take place in the North-East Atlantic, we will analyze relationships between the most distant local groups of fish inhabiting the eastern region (White Sea) and central (oceanic) areas of the North Atlantic.

The distribution and life cycles of many species of fish in the North-East Atlantic agree well with distribution of major currents of the Gulf Stream that reach the Novaya Zemlya Archipelago and the White Sea. It is obvious that the formation of the ichthyofauna of this region took place under the direct influence of the Atlantic fauna. But, by no means were all species able to adjust to the new specific ecological niches.

Such species as cod, Atlantic wolfish (one of three species inhabiting the Barents Sea), several species of flatfishes, Atlantic salmon, herrings, sculpin, and some others, colonized separate bays of the White Sea and established local population groups. But the degree of isolation of these groups, from oceanic populations to those living in the Barents Sea, differs among the various species. One may suggest a high degree of reproductive and genetic isolation of the White Sea groups of Atlantic wolfish and sculpin, which are characterized by low migratory ability of mature individuals, relatively low abundance in the North-East Atlantic and some other features.

Several other species, such as haddock and ocean perch (*Sebastes marinus*) did not encounter appropriate conditions for reproduction, and did not form separate stocks. The White Sea represents a part of the foraging area for adult individuals of these fishes. It also may be “a zone of sterile exportation” for the Atlantic populations of these species. To the contrary, the Atlantic cod in the White Sea forms a local population, which previously has been attributed to a separate subspecies. But studies conducted during the last decade point to the fact that no marked genetic difference exists between groups of oceanic cod from the North-East Atlantic and the White Sea population.

One of the mechanisms, supporting the genetic uniformity of populations is the combining of different fish groups within the bounds of a common reproductive zone during spawning. The pattern of distribution of alleles within the area is equalized due to such factors as a spacious spawning area, presence of differently aged individuals in the brood stock, which reflects multiple spawning during several successive years, fractional spawning with a large number of batches of eggs released, high fecundity of females and the ability to spawn with different partners including young adult males from fiords, passive drifting of eggs and larvae, and high migratory activity of adults. All these factors favor realization of panmixia.

FIGURE 1
Fish migrations in Gulf stream branches into the White Sea

FIGURE 2
Spawning time and temperature conditions of low-vertebrae herring

4. DISCUSSION

Relationships between the Atlantic and White Sea groups may be described as follows. When population abundance is high, the main body of the group during foraging and nesting migrations occupies all possible areas appropriate for feeding and spawning, but first of all in the fiords. A decrease of population abundance or changes in hydrologic conditions leads to restricted in-shore cod migration, and "temporary isolates" or local groups which may originate in some fiords. Their genetic composition may alter rather quickly depending on the intensity of selective pressure.

But when the contact with the main body of population recommences, genetic adaptations of temporary isolates are absorbed (eliminated) by the original population. A peculiar fluctuating mechanism is developed changing the level of genetic polymorphism [diversity] in the united population. It has been known that "the gene flow and its consequences exert an inhibitory effect on the process of evolution" (Mayr 1968) primarily during its early stages, i.e. in the course of intraspecific differentiation (Novikov and Karpov 1989).

In different parts of the area various degrees of genetic isolation of local groups is determined by the specific character of dominating currents – are there strong constant dispersing currents such as the main branches of the Gulf Stream, or circular locking currents in fiords or over some banks? The diversity of ecomorphological features of these groups is determined by the specific character of the abiotic and biotic factors.

Atlantic herrings of the genus *Clupea* display similar intraspecific structure. Their movement into the Baltic and White Seas is accompanied by significant differentiation according to places and season of spawning (in spring, summer or autumn), and considerable variations in average vertebral number and in some genetic indices may be evident. This suggests a different degree of divergence in the two forms with small and large vertebral number, which allows some scholars to consider them as separate species.

A high degree of ecomorphological plasticity (a wide norm of reaction to different temperature and salinity) enables herring to settle different ecological niches. Specific hydrological conditions, including currents in some bays of the White Sea, are beneficial for ecological variability according to the time of spawning, reproductive conditions, rate of maturation, etc. (Figure 2). But genetic divergence is insignificant owing to conditions favorable to mixing of individuals from different bays during the drifting of larvae from one bay to another and in regions of over-wintering by adult individuals. It is supported by the presence of a clearly defined cline in allele frequencies in different bays, which correlates well with the direction of the resulting current in the White Sea.

Thus, the intra-specific structure is the result of the realization of adaptive specific potentials ("norm of reaction" of a gene pool) under particular ecological conditions including physical barriers.

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Biological and genetic characteristics of redfish *Sebastes mentella* of the Irminger sea and adjacent waters

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1. INTRODUCTION

Sebastes mentella is the most important species taken by the fishery of three species of redfish dwelling in the North-East Atlantic. Bottom fishery for deep-sea redfish (*S. mentella*) (shelf redfish) is carried out on the shelf and slope of Iceland, Faroe Islands and East Greenland (ICES Subareas V, VI, XIV). The pelagic fishery for redfish is prosecuted in the Irminger Sea and adjacent areas of the Labrador Sea (ICES Divisions Va, XII, XIVb, NAFO Divisions 1F and 2HJ). In the early 1990s Magnusson (Magnusson 1991, Magnusson and Magnusson 1995) hypothesized the existence in the pelagial of the Irminger Sea of two types of redfish – "oceanic *S. mentella*" and "pelagic deep-sea *S. mentella*". In his opinion, redfish of the first type are distributed at depths less than 500 m, whereas those of the second type live deeper than 500 m. In the last two decades, Russian scientists carried out investigations on the populational structure of redfish of the pelagic Irminger Sea (Pavlov and Shibanov 1984, Pavlov 1992, Shibanov, Melnikov and Pedchenko 1996, Melnikov 1998, Bakay and Melnikov 2001, 2002, Melnikov, Pedchenko and Shibanov 2001, Melnikov and Bakay 2002, Novikov *et al.* 2002). The identity of the origin and uniformity of the pelagic deep-sea *S. mentella* stock in the Irminger Sea and adjacent area of the Labrador Sea over the entire range of the vertical distribution of concentrations was revealed.

In recent years, the intensive fishery for pelagic redfish was carried out at depths greater than 500 m north of the Reykjanes Ridge close to areas of the bottom fishery for redfish. Thus, the relation between redfish from the slope of Iceland and those of the adjacent area of the pelagial of the Irminger Sea is important for developing conservation measures and rational exploitation of this stock.

2. MATERIAL AND METHODS

Results of investigations of redfish caught in two areas are presented. The first area is part of the southwestern slope of Iceland (the Reykjanes Ridge, 63° 00′–63° 10′N and 25° 10′–25° 30′W). Samples were selected from catches taken by a bottom trawl at depths between 430 and 760 m. The second area is adjacent to the Reykjanes Ridge and its western slope over the area bounded by 60° 30′–63° 00′N and 27° 00′–33° 00′W. Samples were obtained from catches taken by a pelagic trawl at depths between 500 and 900 m.

Ichthyological material on redfish was collected using the methods of the PINRO. The data were obtained from one scientific-research and four scientific-fishing cruises in June-August 2001. The length-age composition, growth, maturation rate and range of feeding of redfish from the two surveyed areas were analyzed.

Differences in rates of maturation of redfish from different areas were tested using a X^2 test. Genetic investigations were carried out by starch-gel electrophoresis. A unified enzyme systems population and genetic investigations of redfish in Russia and abroad used NADH-dependent malate dehydrogenase malic enzyme) (MEP-2), NAD-dependent malate dehydrogenase (MDH), glucose 6-phosphate isomerase (PGI), isocitrate dehydrogenase (IDH), lactate dehydrogenase (LDG), phosphoglucomutase (PGM-muscle), superoxide dismutase (SOD) and fluorescent esterase (ESTD). This work followed the methods of e.g. Dushchenko (1986) and Johansen *et al.* (1996, 1997). For comparison of our results all names of loci and alleles follow (Johansen *et al.* (1997, pp. 9–11). Distributions were tested for a Hardy-Weinberg distribution. Specimens were not attributed to “oceanic” or ”deep-water” types by morphological analysis.

TABLE 1
Volume of the analyzed ichthyological material

Volume of measurements	Number
Individuals measured	23 358
Maturation analyses	13 895
Feeding analyses	9 054
Individuals aged	1 184
Enzymatic systems analyzed	640

3. RESULTS

3.1 Length-age composition

Length of redfish males and females in the pelagial of the Irminger Sea in 2001 measured from samples at depths of more than 500 m varied from 27 to 49 cm with males between 39–44 cm and females between 42–45 cm. Males represented 53.1 percent of fish measured. Length of redfish on the slope of Iceland fluctuated within the same range as in the pelagial, however, smaller fish predominated in catches: males were 36–41 cm long; females were 35–43 cm long. The sex ratio was approximately equal. The portion of redfish less than 35 cm on the slope was 2.5–3 times higher than for fish in the pelagic sea (Figure 1). Redfish age in the pelagial of the Irminger Sea and on the slope of Iceland varied from 8 to 24 years. Individuals in the pelagial ranged in the age from 17 to 20 years and on the slope, from 14 to 19 years. The age range of redfish in both areas was 16–24 years, however, the portion of fish of age 16 on the slope was larger than in the pelagial (Figure 2).

The result of analysis of length-age composition of redfish showed an absence of young fish in both areas in the investigated range of depths. Thus, redfish stocks in the pelagial of the Irminger Sea and on the slope of Iceland must recruit from other areas.

3.2 Rate of maturation

In the pelagial the mature males were found from 28 cm length, and females from 29 cm. The 50 percent level of fish maturity in males was at length 32 cm and age 10; and for females 33 cm and age 10. Full maturation (100 percent) of males happened at length 38 cm and age 16; and in females, at 41 cm and age 17 (Figures 3A, 4A).On the slope, mature males were first registered at length 34 cm and females at 38 cm. The length of 50 percent maturity in males was reached at length 37 cm and age 15; for females at 41 cm and age 17. All males became mature at length 43 cm and age 20;

and females at 47 cm and age 22 (Figures 3B, 4B). Highly significant differences were revealed between rates of maturation of redfish in the pelagial of the Irminger Sea and on the slope of Iceland during the statistical analysis.

A comparative analysis of maturity corroborated the lower rate of maturation of redfish on the slope compared with that of the pelagial of the Irminger Sea (Zakharov 1969, Melnikov 1998). Maturation of fish dwelling on the slope takes place at a greater length and later age. In the pelagial the portion of mature redfish constituted 59 percent for males under 33 cm and 82 percent for females under 37 cm. No mature fish of these length groups were registered on the slope. At the same time in the pelagial, immature males longer than 38 cm and females longer than 41 cm were completely absent. On the slope, immature fish of these lengths constituted 15 percent of males and 27 percent of females. Results of analysis of maturation rate by age corroborated the results of the ratio between mature and immature individuals by length groups (Figure 4). Consequently, the analysis of maturation rate of redfish did not reveal an interrelation, and exchange, between fish stocks in the pelagial of the Irminger Sea and on the slope of Iceland.

FIGURE 1
Length composition of redfish in pelagial of the Irminger Sea (A) and on the southwestern slope of Iceland (B)

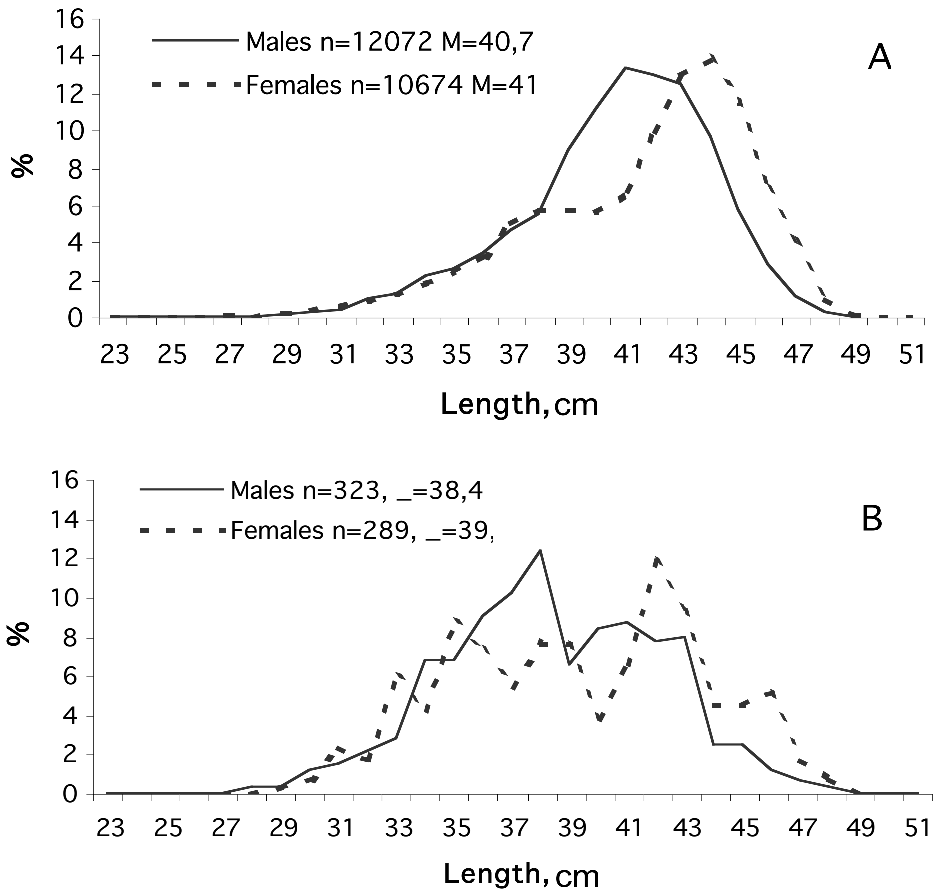


FIGURE 2
Age composition of redfish in pelagial of the Irminger Sea (A) and on the southwestern slope of Iceland (B)

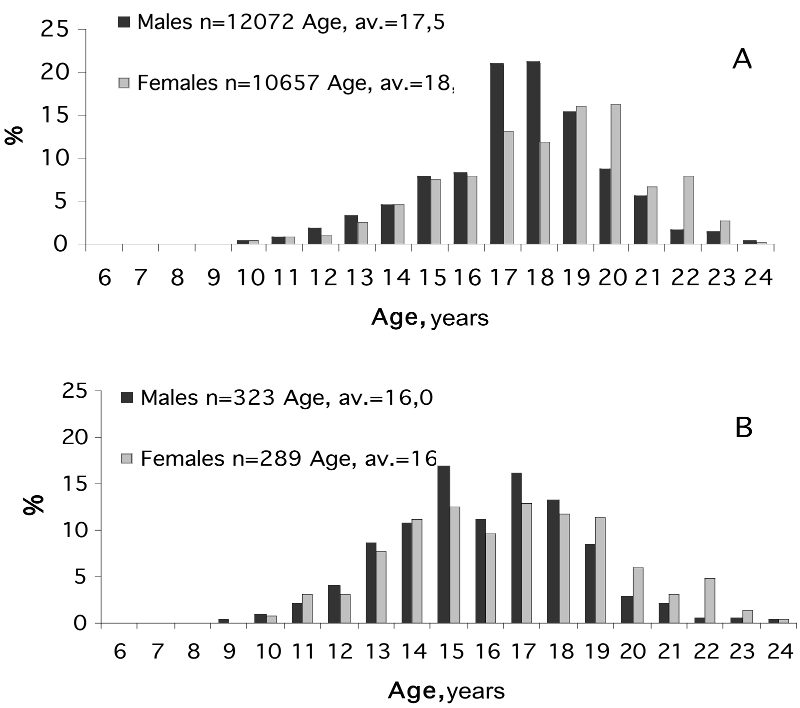


FIGURE 3
Maturation of males and females of redfish of different length groups in pelagial of the Irminger Sea (A) and on the southwestern slope of Iceland (B)

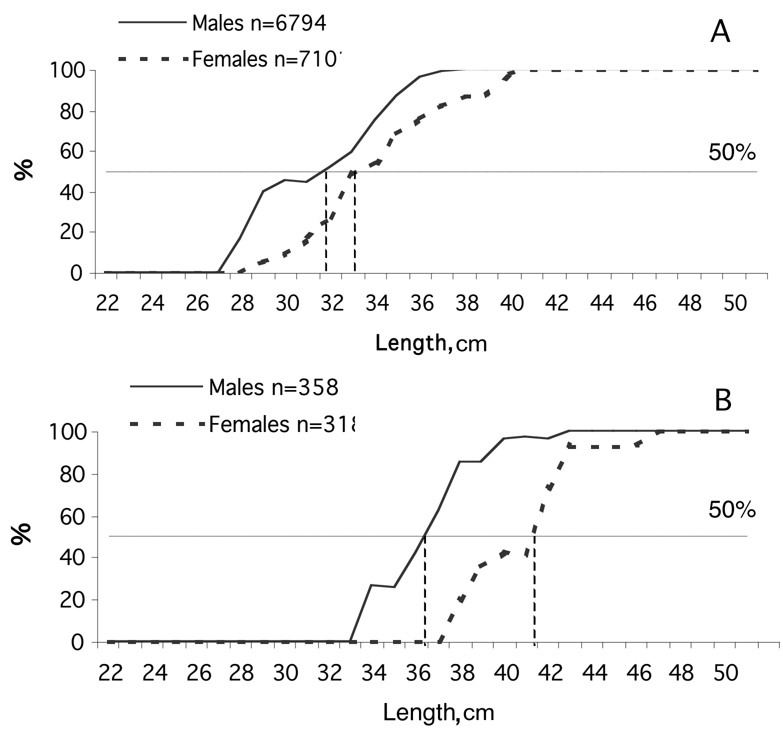
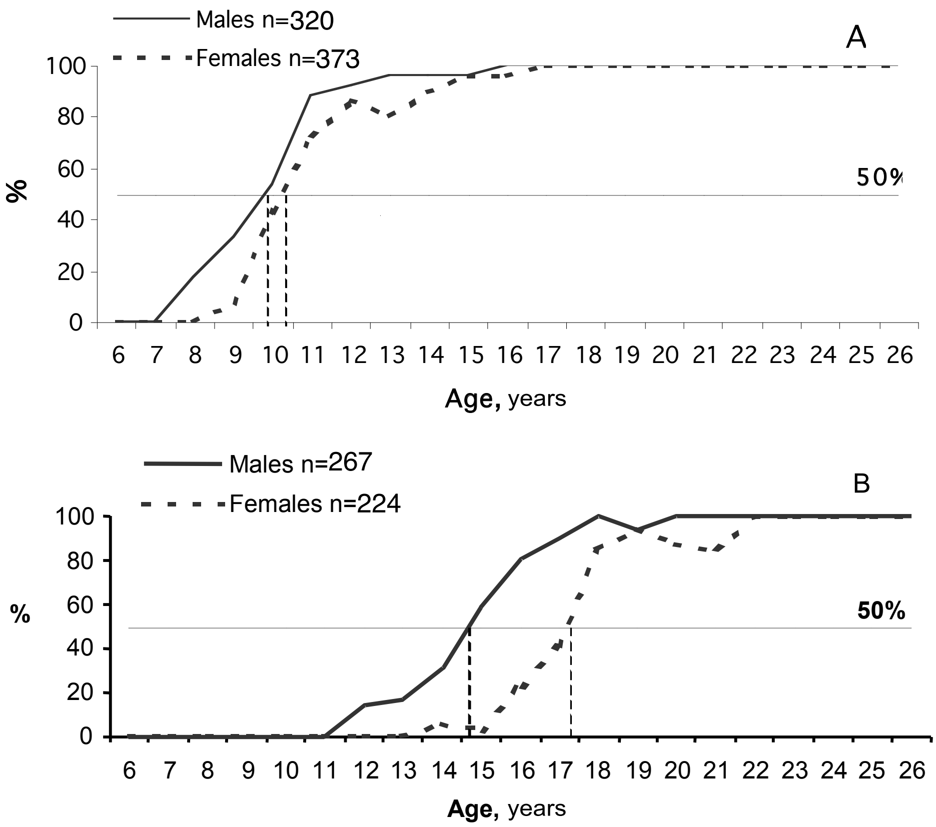


FIGURE 4
Maturation of males and females of redfish of different age groups in pelagial of the Irminger Sea (A) and on the southwestern slope of Iceland (B)



3.3 Growth in length and weight

The comparative analysis of fish of the same age and mean length revealed similar linear growth of redfish males and females in the pelagial of the Irminger Sea and on the slope of Iceland (Table 3). However, the mean weights of males and females on the slope were 1.8–19.4 percent higher than for fish dwelling in the pelagial. The largest deviation in weight (7.0–19.4 percent) was found in redfish at age 15. An analysis of maturation rate showed (Figure 4) that all redfish at this age were mature in the pelagial, whereas on the slope the proportion of immature fish exceeded 50 percent. The immature fish of many species have higher rates of weight growth than mature ones as big part of assimilated food is used for somatic growth rather than for reproductive products (Shatunovsky *et al.* 1975, Shatunovsky 1980). Therefore, the higher rate of weight growth of redfish on the slope compared to the pelagial can be explained by the greater fraction of immature fish at age 15 or less.

3.4 Feeding

The main food of redfish in the pelagial of the Irminger Sea was mesopelagic fish (*Myctophidae, Paralepidae*), shrimp and cephalopods (*Gonatus fabricii*). On the slope off Iceland fish and young squids were eaten 2–3 times less than in the pelagic sea. The portion of *Euphausiacea* in the food range reached 50 percent (Table 2). Mean stomach fullness of fish in the pelagial was 0.2 and on the slope, 0.8.

TABLE 2
Diet (%) of *Sebastes mentella* in the pelagial of the Irminger Sea and on the southwestern slope of Iceland in 2001

Food Item	Pelagial of the Irminger Sea (%)	S.-W. slope of Iceland (%)
Calanus	0.2	3.5
Euphausiids	5.1	50.0
Shrimp	22.0	23.3
Squid	18.3	9.3
Fish	38.0	8.1
Other species	16.4	5.8

In summer, there were peculiarities in the distribution of food plankton in the two areas. In the pelagial of the Irminger Sea, variation in the distribution of food organisms by depth was clearly observed. Planktonic crustaceans were concentrated predominantly in the upper 500 m layer. In the lower 500 m layer of the pelagial, the main fishery concentrations of redfish coincided with the predominantly mesopelagic fish and macroplankton food base (Pavlov 1992). In the area of the Icelandic continental slope the dominant food organisms were euphausids and shrimp (Zakharov 1969). One of the reasons for the differences in the distribution of plankton prey is the characteristics of the hydrological regime in the Irminger Sea and on the slope of Iceland.

3.5 Distribution of redfish in the pelagic Irminger Sea and on the south-western slope of Iceland as indicated by protein type

The distribution of frequencies of alleles of locus MEP-2* in the samples studied reflects the mosaic of distribution of samples with different frequencies at different depths and in different areas (Tables 4, 5 and 6). Frequency of allele “100” of locus MEP-2* in redfish from samples taken at depths of 292 m and 490 m is 0.570 and 0.750 respectively. In samples from 500 to 800 m depths it varied from 0.357 to 1.000. We propose that such amplitudes prove the integrity of the redfish stock from the pelagic Irminger Sea throughout its entire vertical distribution (Bakay and Melnikov 2002).

TABLE 3
Mean length (cm) of the *Sebastes mentella* by age groups in the pelagial of the Irminger Sea and on the southwestern slope of Iceland in 2001

Age (years)	Pelagial of the Irminger Sea		S.-W. slope of Iceland	
	Males	Females	Males	Females
6	-	22.0	-	-
7	24.8	25.5	-	-
8	27.2	27.5	-	-
9	28.0	28.8	28.0	-
10	29.0	29.4	31.0	30.0
11	30.5	30.5	31.2	31.2
12	33.0	32.3	33.3	32.7
13	34.0	34.0	34.2	34.2
14	35.0	35.3	35.7	35.5
15	36.8	37.1	36.9	36.9
16	39.2	38.3	38.4	38.5
17	40.2	39.8	40.0	40.4
18	41.8	42.0	41.8	42.2
19	43.0	43.0	43.2	43.0
20	44.4	44.4	44.2	45.0
21	45.7	45.7	45.3	46.0
22	46.6	46.6	46.5	46.6
23	47.2	47.8	-	48.0
24	48.0	48.5	-	-
25	49.0	49.4	-	-
26	-	50.5	-	-

The frequency distribution of the allele MEP-2*100 was analysed for samples from two areas (a) pelagic trawls in the Irminger Sea (Tables 5 and 6) and (b) bottom trawls on the southwestern slope of Iceland. The results (Table 6) showed a similar distribution of frequencies, e.g. the frequency of allele MEP-2*100 varied over a wide range in samples from each area (Tables 5 and 6). A similar distribution of frequencies of allele MEP-2*100 was described by Johansen, Danielsdottir, Meland and Nevdal (1997). Frequencies changed from 0.60 to 0.83 and from 0.42 to 0.61 for the different redfish types.

An attempt was made to reveal differences observed in the distribution of a rare allele 20 at the locus MDH*. The distribution in some areas of alleles of the locus MDH* was characterized by peculiarity connected with a low level of polymorphism (Tables 7 and 8). It was shown that the presence of the rare allele MDH*20 could change in samples over different years and differed in some measure in the fish from the pelagic zone of the Irminger Sea and on the southwestern slope of Iceland (percentage of individuals-carriers of the rare allele in the united samples). Allele MDH*20 was found in 5 percent of the individuals from the pelagial of the Irminger Sea in the year of 2000 and in 2001. Only 2.8 percent of such fish were detected. In samples taken by bottom trawl on the southwestern slope of Iceland the portion of individuals of redfish with allele MDH*20 was 1.7 percent.

The close ratio between individuals with the rare allele 20, locus MDH*, probably indicates a genetic unity of redfish stock in the two investigated areas, but one can also assume some differentiation of redfish from the southwestern slope of Iceland caused by the specific hydrological conditions of the area. In connection with the higher percentage of individuals with rare allele in the pelagial of the Irminger Sea, one can expect the migration of genetic material from the pelagial of the Irminger Sea to the southwestern slope of Iceland. The other loci investigated were monomorphic (PGM, IDH, LDH, ESTD, SOD). These demonstrated a low measure of polymorphism (PGI) in the studied areas.

TABLE 4
Mean weight of the *Sebastes mentella* by age groups in the pelagial of the Irminger Sea and on the southwestern slope of Iceland in 2001 (grams)

Age (years)	Pelagial of the Irminger Sea		S.-W. slope of Iceland	
	Males	Females	Males	Females
6	-	136.0	-	-
7	180.0	211.5	-	-
8	235.2	249.0	-	-
9	257.7	307.5	300.0	-
10	298.5	360.6	319.0	386.0
11	360.0	385.0	429.9	433.9
12	433.3	422.3	497.6	499.8
13	476.6	473.4	542.7	556.1
14	520.0	539.0	593.2	627.4
15	616.0	673.6	704.3	670.4
16	785.7	762.7	799.0	750.0
17	819.9	828.6	862.2	863.1
18	928.7	944.7	961.4	987.4
19	1030.7	1031.7	1046.5	1043.9
20	1075.7	1101.8	1076.7	1203.1
21	1150.9	1132.5	1120.8	1159.2
22	1203.1	1233.2	1262.5	1308.3
23	1292.9	1285.9	-	1230.0
24	1304.7	1348.2	-	-
25	1585.0	1494.8	-	-
26	-	1585.0	-	-

TABLE 5

Frequencies of alleles of MEP-2* locus in samples of *Sebastes mentella* in the pelagial of the Irminger Sea in 2000

Sample No.	Latitude (N)	Longitude (W)	Trawling depth range (m) Min	max	Volume of sample	Alleles of the MEP-2* locus 60	100
1	61.30	28.10	740	835	10	0.200	0.800
2	61.20	28.10	705	770	10	0.350	0.650
3	61.30	28.20	640	740	10	0.300	0.700
4	61.20	28.10	760	780	10	0.100	0.900
5	61.20	28.10	740	760	10	0.300	0.700
6	61.30	28.10	760	770	10	0.200	0.800
7	61.20	28.10	760	760	10	0.300	0.700
8	61.40	29.10	780	800	10	0.000	1.000
9	61.20	28.10	650	720	10	0.150	0.850
10	61.30	28.20	720	750	10	0.150	0.850
11	61.14	28.10	580	600	10	0.300	0.700
12	61.10	28.10	540	700	10	0.100	0.900

TABLE 6

Frequencies of alleles of MEP-2* locus in samples of *Sebastes mentella* in 2001

Trawl no.	Latitude (N)	Longitude (W)	Trawling depth range (m) Min	max	mean	Volume of sample	Alleles of the MER-2* locus 60	100
Pelagial of the Irminger Sea **(R.V. AtlantNIRO)**								
62	60.65	31.53	640	691	666	17	0.412	0.588
63	60.60	31.53	277	307	292	63	0.421	0.579
64	61.87	28.92	660	740	700	18	0.500	0.500
65	62.05	27.28	788	853	821	35	0.200	0.800
66	62.55	27.20	710	790	750	18	0.333	0.667
68	63.12	25.73	695	915	805	25	0.120	0.880
Southwestern slope of Iceland **(R.V. AtlantNIRO)**								
69	63.00	25.15	639	639	639	50	0.380	0.620
70	63.03	25.42	755	755	755	28	0.250	0.750
71	63.17	25.57	824	824	824	11	0.409	0.591
72	63.15	25.17	430	430	430	37	0.622	0.378
73	63.12	25.18	509	509	509	50	0.450	0.550
74	63.10	25.20	597	597	597	50	0.490	0.510
76	62.97	24.12	597	597	597	29	0.241	0.759
77	62.85	24.02	688	688	688	50	0.300	0.700
78	63.07	23.80	525	525	525	50	0.320	0.680
Pelagial of the Irminger Sea **(R.V. A.Fridriksson)**								
275	62.25	28.10			560	50	0.360	0.640
287	61.30	21.02			680	7	0.643	0.357
290	61.30	26.54			490	4	0.250	0.750
291	61.30	28.37			670	13	0.346	0.654
293	60.31	30.25			650	23	0.326	0.674

TABLE 7
Frequencies of alleles of MDH* locus in samples of *Sebastes mentella* in the pelagial of the Irminger Sea in 2000

Sample no.	Latitude (N)	Longitude (W)	Trawling depth range (m)		Volume of sample	Alleles of the MDH* locus	
			min	max		20	100
1	61.30	28.10	740	835	10		1.000
2	61.20	28.10	705	770	10	0.050	0.950
3	61.30	28.20	640	740	10		1.000
4	61.20	28.10	760	780	10		1.000
5	61.20	28.10	740	760	10	0.050	0.950
6	61.30	28.10	760	770	10		1.000
7	61.20	28.10	760	760	10	0.050	0.950
8	61.40	29.10	780	800	10		1.000
9	61.20	28.10	650	720	10	0.050	0.950
10	61.30	8.20	720	750	10	0.100	0.900
11	61.14	28.10	580	600	10		1.000
12	61.10	28.10	540	700	10		1.000

TABLE 8
Frequencies of alleles of MDH* locus in samples of *Sebastes mentella* in 2001

Sample no.	Latitude (N)	Longitude (W)	Trawling Depth range (m)		Volume of sample	Alleles of the MDH* locus	
			min	Max		20	100
		Pelagial of the Irminger Sea **(R.V. AtlantNIRO)**					
62	60.65	31.53	640	691	17	0.059	0.941
63	60.60	31.53	277	307	63		1.000
64	61.87	28.92	660	740	18	0.056	0.944
65	62.05	27.28	788	853	35	0.057	0.943
66	62.55	27.20	710	790	18		1.000
68	63.12	25.73	695	915	25		1.000
Southwestern slope of Iceland **(R.V. AtlantNIRO)**							
69	63.00	25.15	639	639	50	0.040	0.960
70	63.03	25.42	755	755	28		1.000
71	63.17	25.57	824	824	11		1.000
72	63.15	25.17	430	430	37		1.000
73	63.12	25.18	509	509	50		1.000
74	63.10	25.20	597	597	50	0.040	0.960
76	62.97	24.12	597	597	29		1.000
77	62.85	24.02	688	688	50	0.020	0.980
78	63.07	23.80	525	525	50	0.020	0.980
Pelagial of the Irminger Sea **(R.V. A. Fridriksson)**							
275	62.25	28.10	560		50	0.020	0.980
287	61.30	21.02	680		7		1.000
290	61.30	26.54	490		4		1.000
291	61.30	28.37	670		13	0.076	0.924
293	60.31	30.25	650		23		1.000

4. CONCLUSIONS

These investigations established the following.

- Analysis of length-age composition of redfish has shown that mean length and mean age of fish on the southwestern slope of Iceland were 2.3 cm and 1.5 years less than those in the pelagial of the Irminger Sea. No fish less than 27 cm were collected in either survey area.
- Statistically significant differences were established in the maturation rate of redfish in the pelagial of the Irminger Sea and on the slope of Iceland. Analysis

of maturity data indicated a lower rate of maturation of redfish on the slope than in fish from pelagic areas. Fish dwelling on the slope become mature (50 percent and 100 percent) at larger lengths and older ages. Analysis of the maturation rate of redfish by length and age groups did not reveal an interrelation and exchange between fish stocks in the pelagic sea and on the slope.

- A comparative analysis of mean lengths of same-age fish has shown the similarity of growth rates of redfish males and females in the pelagic Irminger Sea and on the slope of Iceland. Higher rates of weight growth of redfish on the slope compared to fish in the pelagial is explained by larger portion of immature fish at age 15.
- Analysis showed a difference in the food base of redfish in the two areas. The food of redfish in the pelagial of the Irminger Sea consisted of mesopelagic fish, shrimp and cephalopods. The portion of fish and young squid eaten by these was 2–3 times less than for those in the pelagial. The portion of euphausids in the food of redfish reached 50 percent.
- The distribution of frequencies of alleles of locus MEP-2* reflects the genetic unity of redfish population from the investigated areas. A lower percentage of individuals with the rare allele MDH*20 was found in samples from the southwestern slope of Iceland. Further study is required to explain this.
- Thus, the investigation of biological and genetic parameters in a population of redfish found differences between samples from the two areas that could be caused by the different hydrological conditions of the regions.

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Inter- and intraspecific variation of eyespot formation in the secondary deep-sea fish genus *Neobythites* (Ophidiidae, Ophidiiformes)

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1. INTRODUCTION

Among the 50 hitherto known species of *Neobythites*, a genus of sedentary deep-sea fishes that occurs in subtropical and tropical waters at moderate depths (cf. Nielsen 1999, 2002), 23 show well-developed eyespots or ocelli, i.e. dark spots surrounded by a contrasting white ring, on the dorsal fin. To obtain further insights into the ecological function and evolutionary origin of these conspicuous structures we compared co-occurring species and populations from different areas with respect to several characters including number, size and position of ocelli.

2. RESULTS

Ocellus-bearing *Neobythites* species occur at shallower mid-depths than those without. Optimal signal transmission may be restricted to the lower shelf and upper slope. Species with single ocelli reach mostly into shallower waters than species with two or more ocelli. *N. stefanovi* occurs to a particularly great depth in the Red Sea, most probably due to the high temperature isothermy (Uiblein 1996).

In populations of *N. stefanovi* (northern Indian Ocean) and *N. ocellatus* (northern Carribbean) that partly overlap in distribution with the morphologically similar species *N. steatiticus* and *N. gilli*, respectively, a significant deviation in ocellus position was found when compared to allopatric populations. This character displacement supports the hypothesis that ocelli may have an important signaling function related to intraspecific communication. Earlier evidence on intraspecific variation in ocellus size in *N. stefanovi* and published data on other ocellus-bearing fishes, however, do suggest a primary anti-predator function (Uiblein, Nielson and Klausewitz 1994, Uiblein 1996).

3. DISCUSSION

In fishes that live under extended dawn conditions of the deep shelf and upper slope signal transmission by ocelli may be particularly efficient and hence these structures may have evolved to support several ecological functions. Two hypotheses shall be further examined. First, ocelli may serve at least two different ecological functions as an anipredator device and a means for species recognition. Second, ocelli are still subject to an ongoing evolutionary process and have evolved repeatedly to serve various functions (i.e. they are homoplastic characters). At present a morphological phylogeny of *Neobythites* is planned.

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The yellow squat lobster (*Cervimunida johni*) fishery off Northern Chile, 1994–2001

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1. INTRODUCTION

The yellow squat lobster (*Cervimunida jonhi*) along with the red squat lobster (*Pleuroncodes monodon*) are two species of the family Galatheidae that occupy mainly the lower continental shelf and upper slope between 150 and 300 m depth off the Chilean coast. This particular habitat has a low oxygen content and is thought to provide a refuge against predators (Villarroel, Acuña and Andrade 2001). Both species play an important role in the trophic foodweb since they are the prey of many benthodemersal fishes and so transfer a great amount of energy towards upper levels (Arancibia and Meléndez 1987, Villarroel, Acuña and Andrade 2001).

The yellow squat lobster is an important fishing resource off central-northern Chile where it is caught by bottom trawls. According to Acuña, González and González (2003), data on yellow squat lobster was scarce until the beginning of the 1990s in this zone, when the first direct assessments using the swept-area method begun. These authors did an analysis of the biological data obtained between 1995-2000, which indicated a decrease in size and size at first sexual maturity in the yellow squat lobster, which they attributed as probably owing to fishing mortality and, or, environmental variability. This work incorporates new information about the demographic structure of the resource and catch and effort data from the central-northern Chilean fishery. The objective is to describe inter-annual differences in these parameters that may be related to biological variability.

2. METHODS

Data of commercial fishing hauls performed between 26° 04′ S and 32° 10′ S and between 120 and 420 m depth were analyzed. The study area was divided into Region III (26° 04′–29° 12′S) and Region IV (29° 12′–32° 10′S). Biological data were obtained between 1994 and 2001 and fishing data since 1996.

The median size (cephalothorax length (CL), mm), sex proportion and the size at first sexual maturity were analyzed from 1995 to 2001. The size at first sexual maturity was determined using the method described by Udupa (1986).

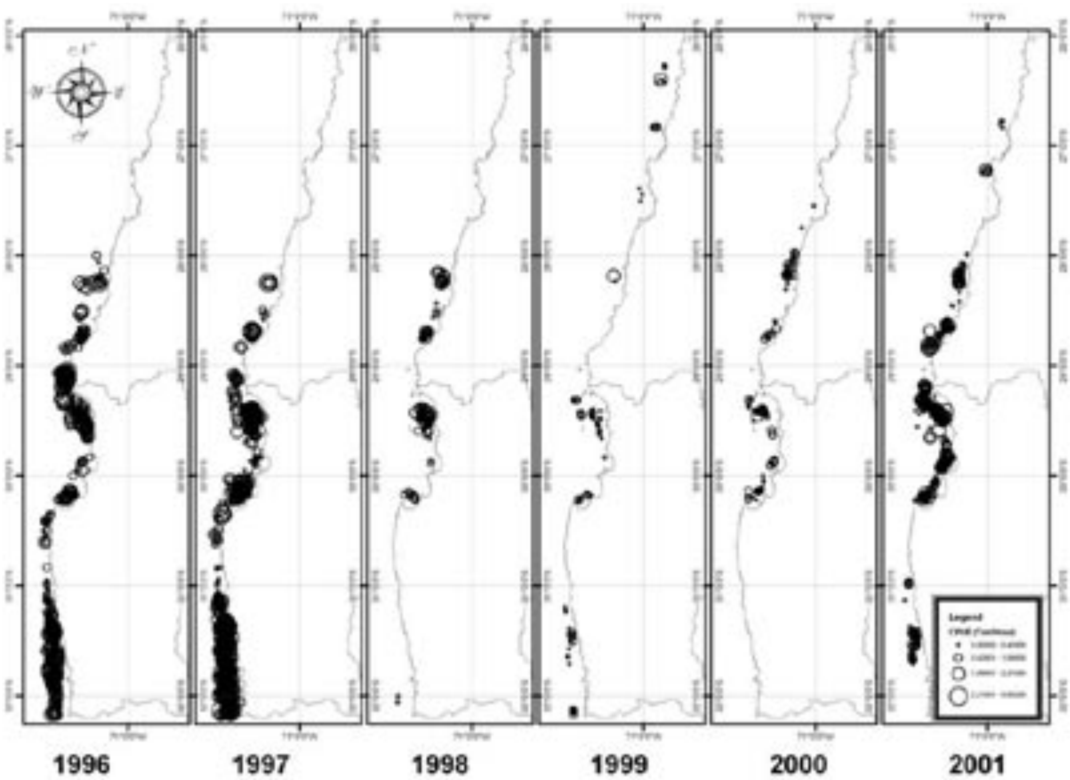
Fishing data time series were analyzed based on fishing effort, catch and catch per unit of effort (CPUE, kg/hour of trawling). Analysis of spatial-temporal distribution used data from the fishing hauls and latitude and longitude records. Thus, a series of year-to-year maps were prepared with CPUE values obtained between 1996 and 2001.

3. RESULTS

The spatial distribution of CPUE shows that most of the hauls and the highest relative biomass was located between 28 ºS and 32 ºS during 1996 and 1997. Two main concentration zones were observed south and north of 30 º 40 ′ S. A contraction in the distribution of fishing effort was observed between 28 ºS and 30 ºS during 1998, with the most important concentrations located between 29 ºS and 28 ºS. The spatial distribution showed an expansion again during 1999, but as several restricted areas, isolated from each other but spread through the study area that showed lower CPUE values. A new concentration of the fishing area towards the central area was observed during 2000, similar to 1998, although CPUE values were lower than in 1998. Higher CPUE values were found mainly between 28 ºS and 30 ºS in the central area and between 31 ºS and 32 ºS in a smaller area during 2001 (Figure 1).

FIGURE 1

Spatial-temporal distribution of the relative biomass of the yellow squat lobster of central-northern Chile

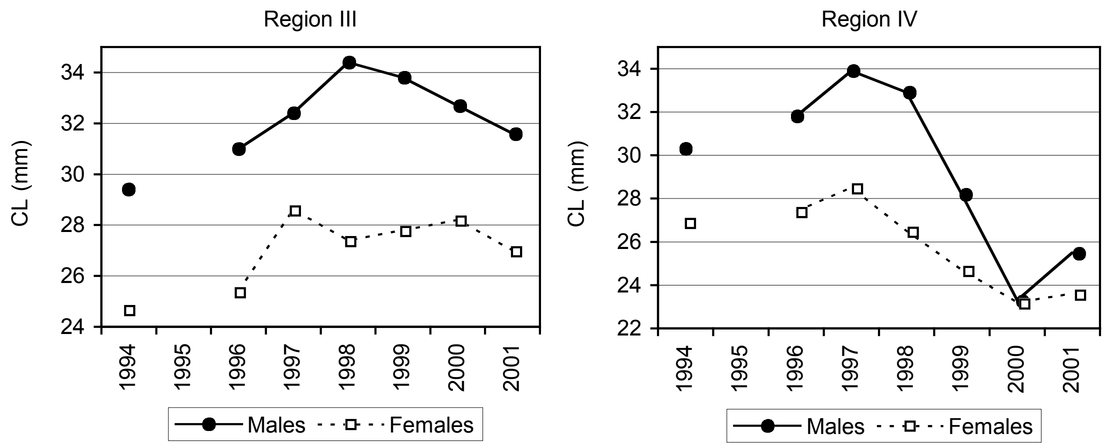


This species shows sexual dimorphism in size; males are larger than females. The median size of the males increased significantly in Region III between 1994 and 1998, when a significant decrease was observed. A similar trend was observed for females, but the median size decreased slightly from 28.6 mm CL to 27 mm CL from 1997 to 2001 (Figure 2). Median size in Region IV increased for both sexes between 1994 and 1997, when a sharp decrease was observed. However, both sexes showed a slight increase during 2001, suggesting a recovery of this biological characteristic.

The size at first sexual maturity showed an increase of 15 mm CL between 1994 and 1998. Then, it decreased from 35.4 to 23.9 mm CL between 1998 and 1999 and increased again between 1999 and 2001 (Figure 3).

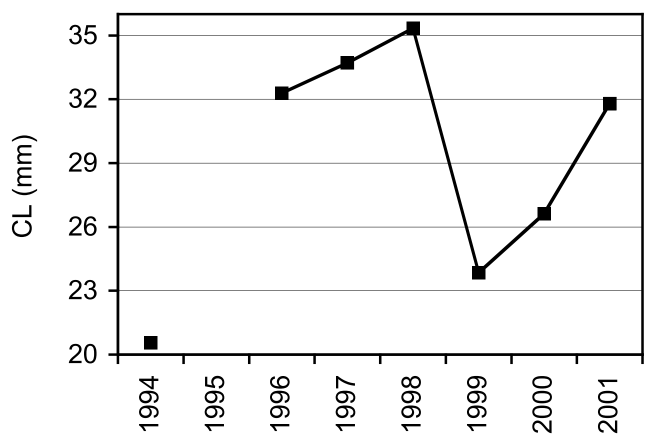
There was an increase in the fraction of males in Region III between 1996 and 1998 and a decrease between 1998 and 2000, being around 50 percent in 1994 and 2001. The proportion of males increased between 1996 and 1999 in Region IV and decreased between 1999 and 2001, reaching around 50 percent (Figure 4).

FIGURE 2
Annual time series by region showing the yellow squat lobster median size, for both sexes



The median effort by haul increased between 1996 and 1999 in Region III and between 1996 and 2000 in Region IV. The highest fishing effort (hours of trawling) was observed during 1999 and 2000 in Regions III and IV respectively. The median catch by haul decreased significantly between 1998 and 1999 in Region III, and remained at these low levels between 1999 and 2001. This decrease occurred between 1997 and 1998 in Region IV with the lowest values observed in 2000. The CPUE decreased between 1996 and 1999 in Region III, and between 1997 and 1999 in Region IV. In both regions, the relative biomass remained stable at low levels during the last years, but showed a slight increase during 2001 (Figure 5).

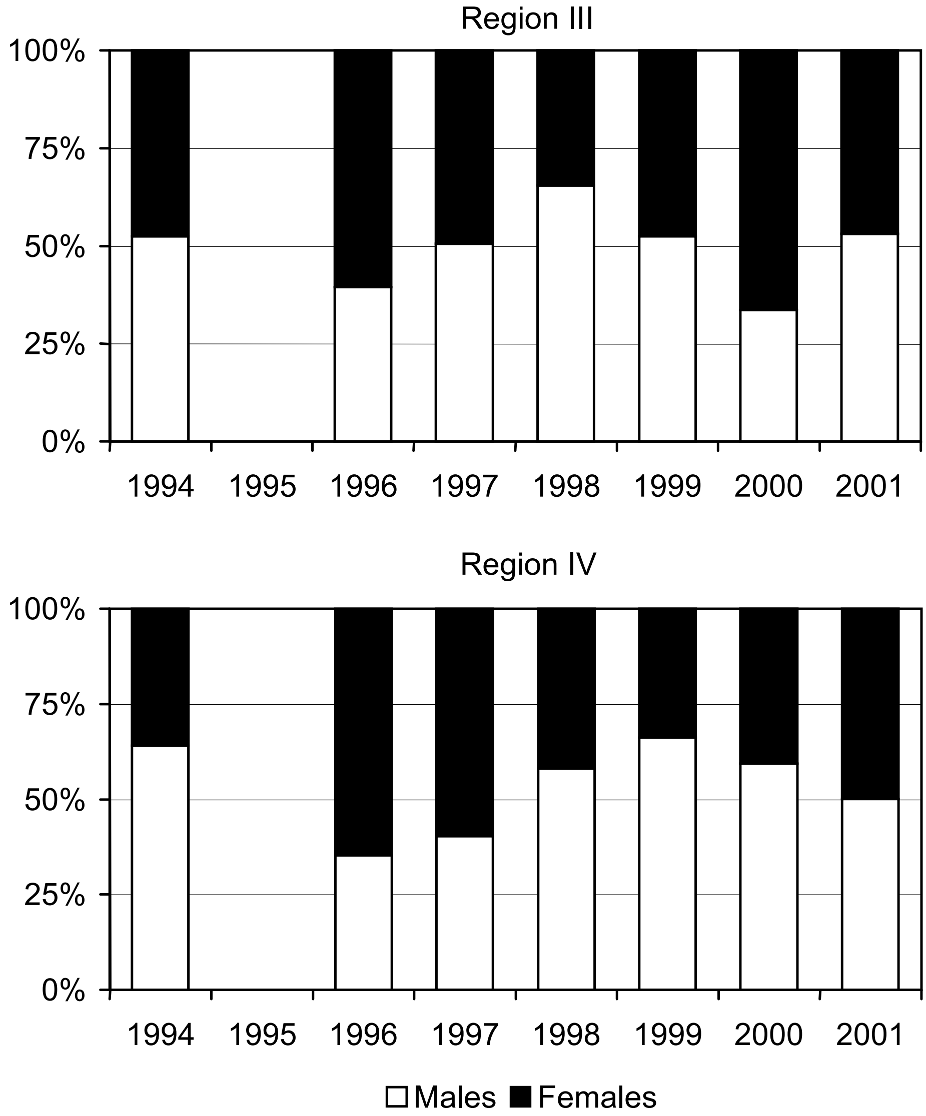
FIGURE 3
Annual time series showing the size at first sexual maturity of females yellow squat lobster



4. DISCUSSION

Fishing removes larger and older individuals, changing the size and age structure of exploited populations. Reducing the abundance of larger specimens leads to a decrease of the stock spawning potential (Goñi 1998). Our results, show that an increase of the

FIGURE 4
Annual time series by region showing the yellow squat lobster sex ratio

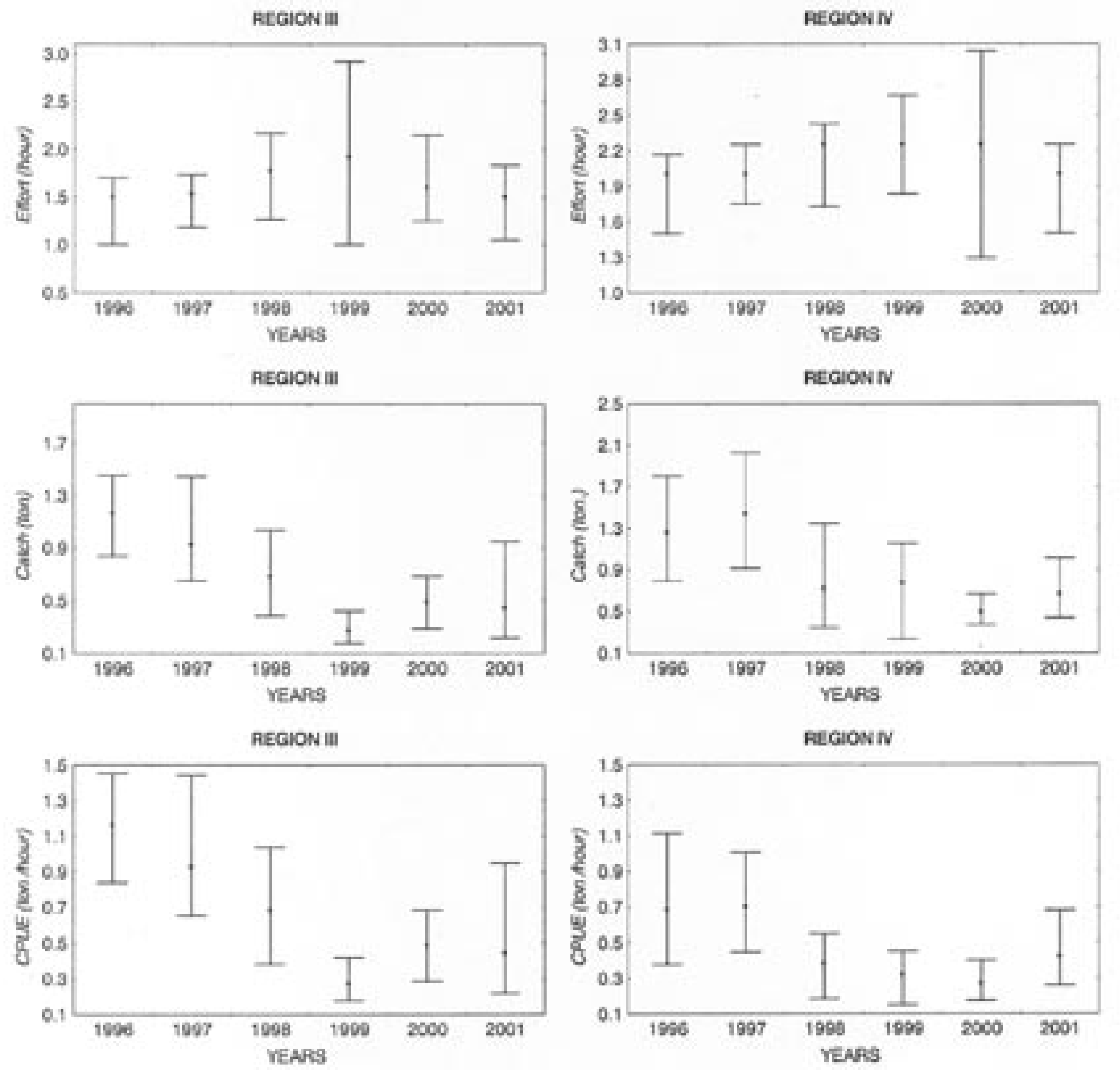


median size and size at first sexual maturity was observed along with a decrease of the biomass during the first fishing period (1994-1998), suggesting that the effect of this decrease in the demography of the species lagged a couple of years.

Inter-annual fluctuations in the availability of fishing resources are due to multiple factors. Hannah (1993) and Ye (2000) have demonstrated the influence of the environmental variability and the level of the spawning stock on crustacean recruitment. Population changes are also influenced by natural and fishing mortality as it has been found in other fisheries (Sinclair 2001, Myers, Barrowman, Hoenig and Qu 1996).

According to Wolff and Aroca (1995) and Acuña *et al.* (1995) during the beginning of the study period the population of the yellow squat lobster showed no signs of overexploitation. The population was relatively abundant and there was a large supply of recruits resulting in a decrease in median size (Villarroel *et al.* 2001, Acuña *et al.* 1995, Acuña, González and González 2003). However, low recruitment occurred during 1998 and the increase of fishing effort caused a decrease in biomass. This

FIGURE 5
Annual time series by region showing median effort, catch and CPUE of the yellow squat lobster fishery of central-northern Chile



decrease mainly affected the spawning stock and gravid females carrying eggs, whose proportion in the population was high in the catches. Campodónico (2002) pointed out this feature indicating that the decrease of the biomass was caused by a high level of fishing mortality and a decrease in the parental stock biomass.

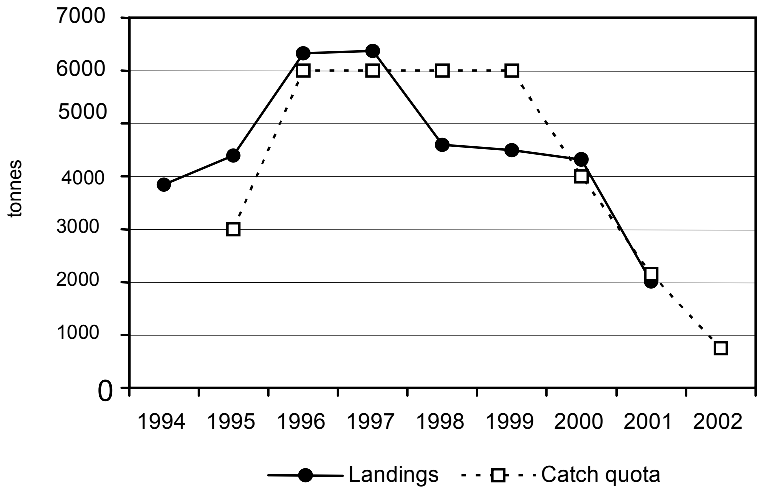
It is difficult to determine if fishing could be the only factor causing the decrease in resource biomass, but it might be the most important. In the yellow squat lobster fishery, increases in fishing effort owing to an increase in number of vessels occurred between 1988 and 1998 (Wolff and Aroca 1995, Acuña *et al.* 1998) and was concentrated in the southern area where greater biomasses and larger specimens were found (Acuña *et al.* 1998). The decrease in CPUE coincides with an increase of fishing time and the spatial distribution of the fishing grounds contracted to several small, isolated areas.

An improvement in the biological and demographic parameters was observed during 2001, indicating a slight recovery of the resource. This was also observed during 2002 (Guerrero *et al*. 2003) coinciding with a sharp decrease in landings and catch quotas during the last two years (Figure 6). Campodónico (2002) suggested that better recruitment was the important factor in the recovery of the stock.

FIGURE 6

Annual time series showing landings and catch quota for the yellow squat lobster fishery from regions III and IV

Note the annual quota system began in 1995.



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A note on the reproductive biology of the longnose velvet dogfish (*Centroscymnus crepidater*) from the Northeast Atlantic[1]

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The reproductive biology of the little known and generally discarded deep-water shark *Centroscymnus crepidater* was examined from a total sample of 97 females and 44 males. Specimens were collected by observers from trawls between 710 m and 1317 m aboard commercial fishing vessels over a three-month period from October to December 2002 in the north-east Atlantic. Individuals ranged from 350 mm to 868 mm total length and mature males and females dominated the sample. Females were generally larger than males, with male and female modal sizes identified at 625 cm and 800 cm total length respectively. Counts of ova greater than 1 mm in diameter ranged from 26 to 117. Ova diameter ranged from 1 mm to 58 mm with the most common diameter between 1mm and 3mm. Of the 17.5 percent of the females found carrying embryos, the uterine fecundity ranged from 1 to 9 embryos. A total of 48 embryos were recorded in various stages of development, ranging from 0.2 g to 98.0 g in mass and 32 mm to 261 mm in total length with a male:female ratio of 1:1.125. Liver mass ranged from 200 g to 735 g and contributed 24 percent and 25 percent to the total body mass in males and females, respectively. The hepatosomatic index (HSI) was relatively constant in males but showed a significant decrease in females following ovulation, consistent with the translocation of resources from the liver to developing ova. The diversion of resources to ova production was also evident in the gonadosomatic index (GSI) where a maximum, of 18.16 percent was recorded in a mature female. Consistent with other *Centroscymnus* species, *C. crepidater* does not appear to have a defined breeding season. Ovarian and uterine fecundity are low indicating that the reproductive capability of this species is low. Results have been interpretted relative to the limited data on reproduction available for this species.

[1]This note is a summary of the poster entitled "The reproductive biology of the longnose velvet dogfish, *Centroscymnus crepidater*, in the northeast Atlantic", presented at Deep-Sea 2003. The main body of this research is currently in press.

A note on the fecundity and reproductive capability of orange roughy (*Hoplostethus atlanticus* Collett 1889) on the Porcupine Bank, Northeast Atlantic[1]

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The first comprehensive analysis of the fecundity and reproductive capability of orange roughy (*Hoplostethus atlanticus*) from a specific area in the Northeast Atlantic is reported. Specimens were collected from commercial vessels targeting this species on the Porcupine Bank (ICES sub-area VII), in waters of between 1400 m and 1650 m depth. Between September and December 2002, a non-random, stratified, sampling protocol was implemented by fisheries biologists to collect mature female fish between 300 mm and 540 mm SL. Ovaries from 70 individuals, representing the majority of 10mm SL size classes sampled, formed the analytical sample. A novel and semi-automated method of oocyte counting was developed, allowing digital images of oocytes to be annotated, counted and stored.

Total fecundity ranged between 20 352 and 244 578 oocytes per female and mean total fecundity was estimated to be 97 368 oocytes per female (S.D. = 48 322). Mean relative fecundity was estimated to be 33 376 oocytes per kg (S.D. = 11 407). Total fecundity showed an increase with both length and weight; however, the relationship between fecundity and age appears to decline for extremely old fish (>120 years). Macroscopic analyses showed that 50 percent of females were not mature until they reached 28.7 years and 387 mm SL.

The relationships between fecundity and the variables: length, weight, and age are characterised by high variability. The variability is proposed to be related to heterogeneity in habitat productivity, as fish from different regions aggregate, and the genetic structure of the gravid population.

A comparison with stocks from the southern hemisphere indicates that orange roughy from the northeast Atlantic generally mature at a larger size and have a higher mean fecundity than those found in the southern hemisphere. This may reflect differences in growth rates influenced by environmental variables and fishing pressure. Lower productivity in the northeast Atlantic is suggested to be the cause of an increase in the length and age at maturity.

[*] This note is a summary of the poster entitled "The fecundity and reproductive capability of orange roughy off the Porcupine Bank, north-east Atlantic", presented at Deep-Sea 2003. The main body of this research is currently in preparation.

It is emphasized that the populations currently being fished are the product of spawning events that occurred prior to the start of the fishery and that the effects of fishing on the overall population fecundity will only be evident when the age of the fishery is approximately equivalent to the age of the fish at maturity.

Deepwater trawl and longline sampling levels

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Ireland, as a member state of the European Union, must implement observer schemes to improve the quality of the scientific data used for assessment of deep-water species (Council Regulation No 2347/2002). Optimal sampling levels for deep-water trawl and longline sampling are presented here in relation to precision limitations. The analysis is based on surveys carried out between 1993 and 2000 in the North East Atlantic using two of the main commercial gears: trawl (four surveys) and longline (three surveys). Due to the hierarchical structure of the data – hauls/sets nested within surveys – a multistage analysis was performed, according to the approach detailed in Allen *et al.* (2002), to determine the levels of precision achieved in the past.

The analysis is based on mixed-models, where the unexplained variability of catch per unit of effort (CPUE) is partitioned over the two sampling levels of trip and haul (random effects), and in the process, the major parameters likely to affect catches (for example: gear, year, depth, area, catch richness haul position, temperature and salinity) are also determined (fixed effects). CPUE was chosen as the dependent variable due to the multipurpose nature of the surveys studied. The results show that trawl catches are highly variable – 36 percent – coefficient of variation (CV) while longline catches shows the opposite, a 9 percent CV. Longline catches are also highly dependent on depth, particularly when depth strata are considered in 300 meters intervals (200, 400 and 500 m depth intervals were also tested). Another depth-related parameter, temperature, was also significant in explaining catch variability, but could not be considered in the final model due to low sampling levels.

None of the parameters studied appear to explain catch variability in trawl fisheries. Only random variability is present, in both sampling levels of trip and haul, thus future sampling schemes should reflect this fact. In both gears, area and year were not significant factors in the analysis. When recommended sampling levels are stratified by depth, sampling should be grouped in 300 m depth strata to improve precision.

Trawl sampling levels should be doubled to achieve at least a 25 percent CV annually, while longline levels can be reduced by half and still achieve a 14 percent CV. The recommended sampling levels are a product of the sampling plan objectives, i.e. catch qualification and quantification and also collection of biological information. If the resulting data are to be used specifically in discard studies, then geographical area and the corresponding increase in sampling should also be taken into account in future sampling schemes.

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The estimation of catch levels for new orange roughy fisheries on seamounts: a meta-analysis of seamount data

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1. INTRODUCTION

Seamounts are widely regarded as being fragile habitats that are susceptible to overfishing. This implies that careful management is required in the initial stages of any fishery development to reduce the risks from rapid expansion in fishing effort and possible overexploitation of the fish resources.

The task of designing and carrying out appropriate fish abundance surveys on seamounts can be a lengthy, expensive and complicated task. And, the stocks to be assessed may be small and localized, which raises the question of whether a research programme is warranted or cost-effective.

2. METHODOLOGY

Physical attributes and catch data of deepwater fisheries were compiled for 77 seamounts in the New Zealand region (Figure 1). Characteristics of location, depth, size, elevation above the seafloor, age, continental association, geological origin, distance offshore and from surrounding seamounts and degree of spawning were defined. These were then analysed as independent variables against the minimum orange roughy population size estimated from the historical amount of catch taken from the seamounts to investigate whether they could be useful predictors of likely safe catch from newly found seamounts.

Multiple regression procedures were used to model the effects of the physical variables on orange roughy stock size. There were two stages in the analysis. First, biomass was modelled on individual seamounts grouped in regions (as a categorical variable) and included predictors specific to individual seamounts. This analysis showed region, depth of the peak, and slope of the seamount to be significant. The relative region effects are shown in Figure 2. A second analysis was carried out where the region effects were modelled, using predictors related to entire regions. This showed latitude (Figure 3) and association (continental and oceanic) to be important. The predictive power of the models was tested by cross validation and compared with simpler models to assess their informative value.

3. RESULTS

For the individual seamount model, the approximating formula is

Predicted biomass = exp(intercept + region effect + depth of top effect + slope effect)

where the intercept is 6.89 and the region, depth of top, and slope effects are given by Clark, Bull and Tracy (2001). This formula can be used where a new seamount is found within an existing region. For example, the approximate prediction for Mt. Ghost (if it were a new feature on the southern Louisville Ridge) would be:

Biomass = exp(6.89 + 0.83 (Louisville South) + 0.76 (top depth is 620 m) + 0.08 (slope is 0.14))
= 5 200 t.

FIGURE 1
Regions and seamount features included in the study
The Chatham Rise regions are indicated by "CR".

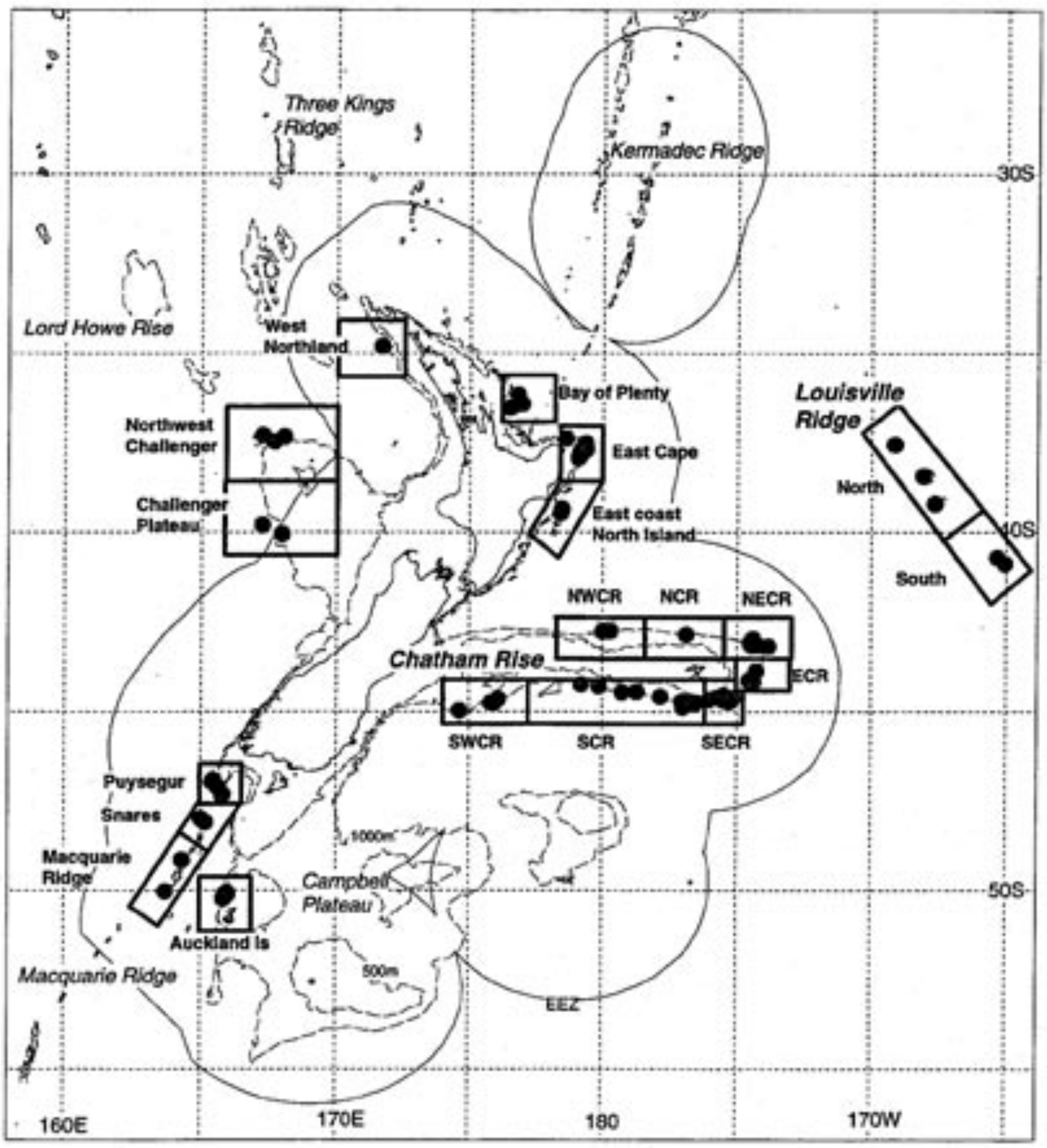


FIGURE 2

Effect of region on estimated seamount biomass

The length of each bar indicates the average relative abundance of orange roughy on seamounts in the region once the effects of the 'slope' and 'depth of top' predictors have been removed.

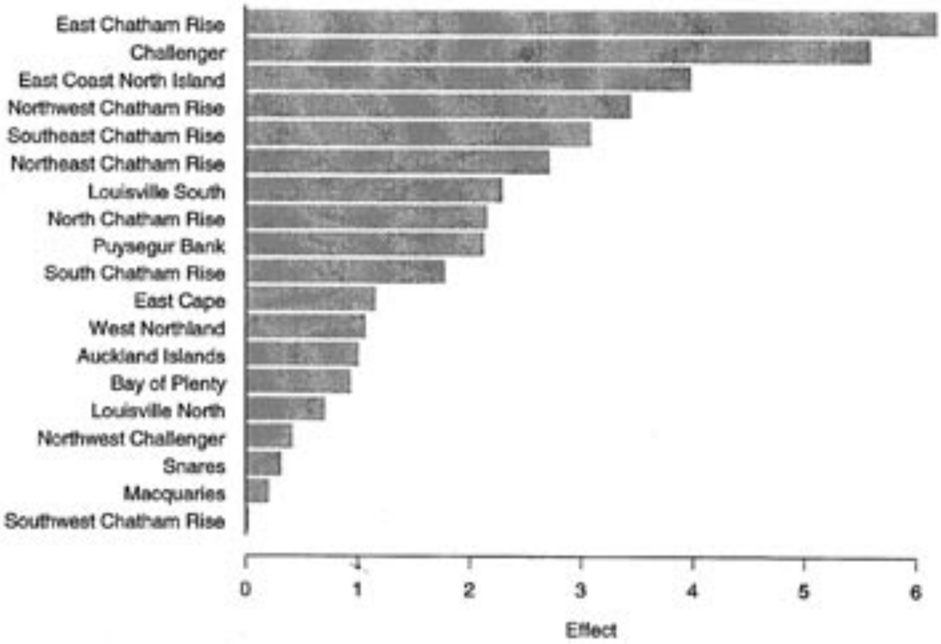
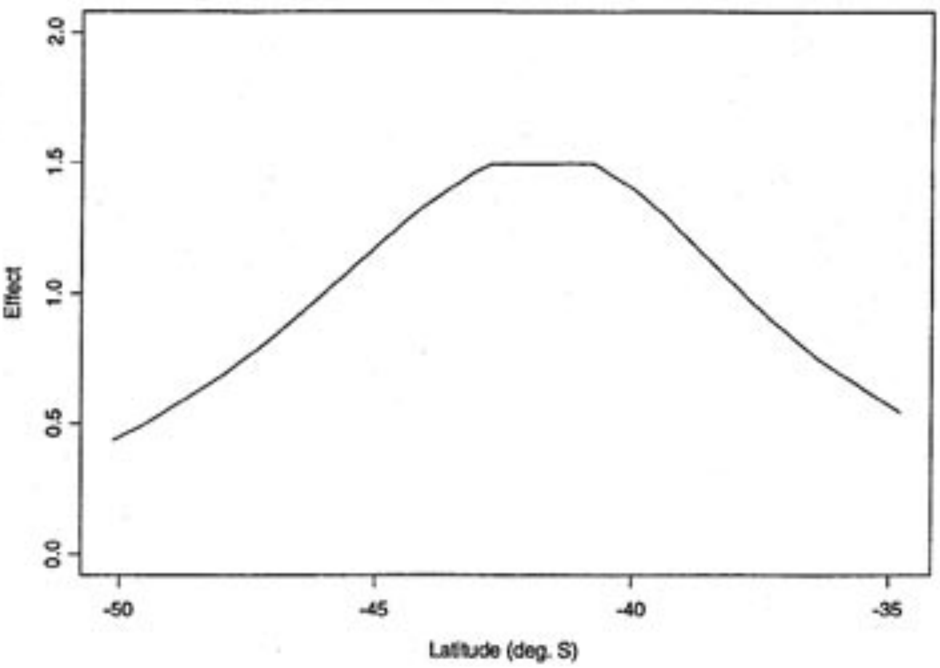


FIGURE 3

Effect of latitude on orange roughy abundance by region

The height of the curve indicates the relative abundance of orange roughy at that latitude, all else being equal. The x-axis is restricted to the range of latitudes in which most of the data set lies.



For a new region, using the region effect predicted by the region regression model, then

Predicted region effect = exp(intercept + latitude effect + association effect)

where the intercept is 0.73 and the region, depth of top, and slope effects are given in Clark, Bull and Tracey (2001).

4. CONCLUSIONS

Data on the physical features of a seamount can be informative in predicting possible stock size. Simple formulae can be used to obtain estimates of biomass, although predictions are approximate only, as the data show a wide scatter. However, it appears they can be useful in helping guide initial management of a developing fishery on a seamount.

5. ACKNOWLEDGEMENTS

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How old are these deep-sea species? Applying improved techniques to validate longevity

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Careful resource management is required for deep-sea fish due to their great longevity (and thus low productivity) and late maturation. Age estimation, required for such management, in the deep-sea environment has historically been difficult. There is growing confidence in the current age interpretations of deep-sea fish species. Their characteristic of high longevity is likely to be a resilient adaptation to the deep-sea environment, with its assumed low productivity and, or, episodic recruitment. Here we describe two advances in deep-sea age estimation – radiometric age determination and bomb carbon age validation.

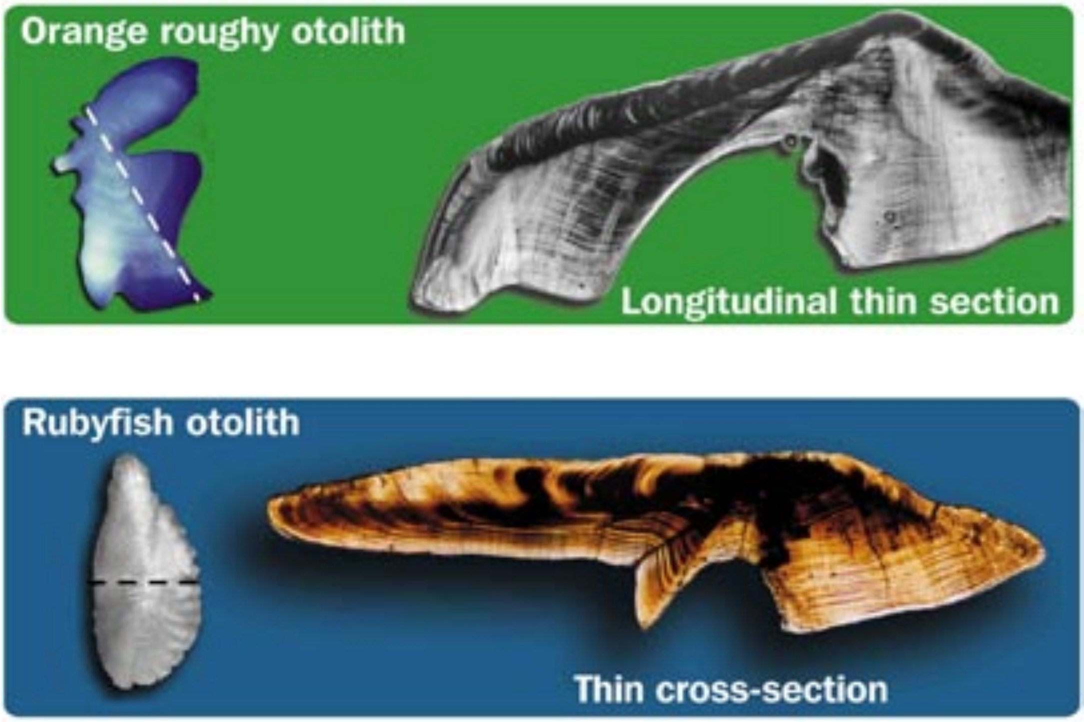
The otolith growth rings of many deepwater fish species are often closely spaced and difficult to count. Although ring-counting is likely to remain the most common procedure, other techniques should be used to validate the ages of these species. The techniques used for shallow-water species (e.g. size frequency analysis, tagging, otolith-edge growth patterns and otolith weights) are not suitable for deepwater species. The two most promising validation techniques, radiometric and bomb radiocarbon analyses, are difficult to carry out, but have the advantage of being independent of the otolith's appearance.

Ageing studies of New Zealand's deepwater species have been based on otolith growth ring counts. The assumption is that these zones, although narrow and somewhat different from those of more near-shore species, and often are particularly difficult to read, represent annual growth. As found elsewhere, recent age readings are giving higher, rather than lower, ages.

The following are examples of deepwater species that have been investigated: black cardinalfish (*Epigonus telescopus*), black oreo (*Allocyttus niger*), smooth oreo (*Pseudocyttus maculatus*), orange roughy (*Hoplostethus atlanticus)*, ridge-scaled rattail (*Macrourus carinatus*), rubyfish (*Plagiogeneion rubiginosum*), sea perch (*Helicolenus* spp.), and bluenose (*Hyperoglyphe antarctica*). Most of these species have high ring counts, and three have maximum ages of at least 100 years. Ages at maturity can be as high as 36 years. The slow growth rates, high longevity, low levels of sustainable yields, and slow recovery rates make them particularly vulnerable to overfishing. Figures 1a and 1b provide examples of growth zones present on orange roughy and rubyfish otolith thin sections.

FIGURES 1A AND 1B

Images of whole orange roughy (top) and rubyfish (bottom) otoliths and their respective longitudinal and transverse thin sections showing annual growth zones



Currently, more emphasis is being placed on validation studies that include radioisotope ratios ($^{226}Ra/^{210}Pb$) and the time-specific, bomb-produced, radiocarbon (^{14}C) marker. We are carrying out further applications of these techniques, which we are optimistic will resolve issues with previous age validation studies of our deepwater species.

Radiometric age determination is based on measuring the activity of pairs of radionuclides present in the otolith, which are known to decay from one into the other at a known rate over time; for example ^{226}Ra (radon) into ^{210}Pb (lead). They are incorporated at equilibrium into the otolith core when it is formed and their ratio then changes over subsequent years. Earlier radiometric studies of orange roughy and oreos used pooled samples of whole otoliths, which caused a problem of between-individual variability in otolith mass growth rates. In an attempt to overcome this problem, otolith cores and a refined radiometric technique were used. Very small core samples were analysed using thermal ionization mass spectrometry at Moss Landing Marine Laboratories.

Results indicate that the application of the refined radiometric technique is feasible to varying degrees for oreos, cardinalfish, and orange roughy, but most successful for the latter two. For the orange roughy pilot study, calculated radiometric age was in close agreement with zone count age for three of the four samples. Estimated and radiometric age data for orange roughy are shown in Figure 2. There was strong agreement for the oldest sample (77 y), indicating that this is a long-lived species. For cardinalfish, a juvenile group and an old aged group of otoliths were analysed; the calculated radiometric age agreed closely with zone count age.

The bomb-radiocarbon age validation approach uses the sudden pulse of radiocarbon (^{14}C) released into the atmosphere from nuclear testing in the 1950s. In one procedure, the radiocarbon level in otolith cores demonstrates whether the fish was born pre-bomb or post-bomb, and if born during the period of radiocarbon increase (1950–1970) an age can be assigned. In this development, radiocarbon levels can be measured across an otolith, and the position of the bomb pulse compared with the counted age.

Bluenose and rubyfish have otoliths with complex growth zones. From zone counts, maximum age estimates for bluenose have ranged from 15 to 50 years. Rubyfish have a maximum age from zone counts of 80+ years. The bomb chronometer procedure was used to determine whether these ages were realistic. The ^{14}C level in carbonate samples drilled from otolith cores confirmed that the selected fish (five of each species) were born 'pre-bomb' era. Samples were then drilled in a sequence across otolith cross-sections to locate the position of the 1950–60 rise in ^{14}C. This position defined a known time interval that was compared with same time interval as determined by zone counts. Results of the bomb radiocarbon study for bluenose and rubyfish are shown in Figure 3. We consider that this procedure has advantages over the core-only method. Consideration was given to the time-lag issue, i.e., the time required for ^{14}C to move from surface waters down to the depth (500–1 000 m) at which the adults of both these species reside. Zone counts for rubyfish matched well with the bomb carbon curve, confirming the reliability of the zone count method. However, while the maximum age for bluenose has been shown to be in excess of 40 years, the poor match of zone counts to the bomb carbon curve indicate that problems with ageing of this species have yet to be fully resolved.

This research was funded by the New Zealand Ministry of Fisheries under projects DEE200202, INS200002.

FIGURE 2
Plot of estimated and radiometric age data for orange roughy

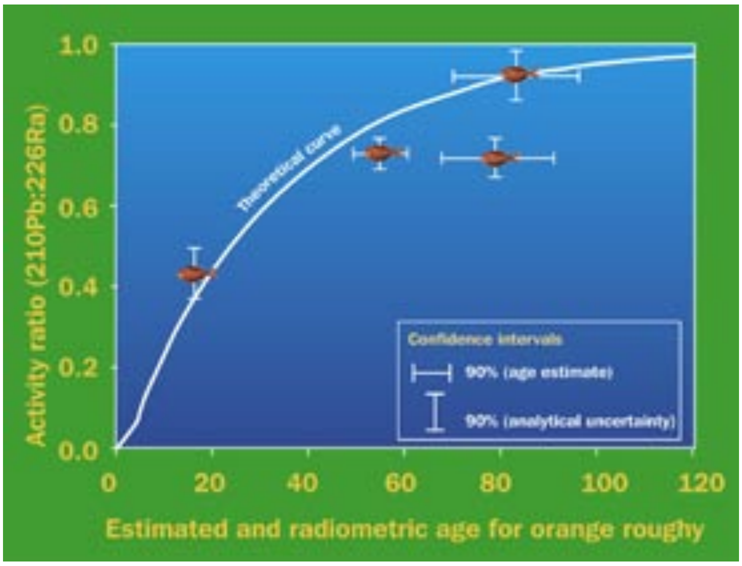
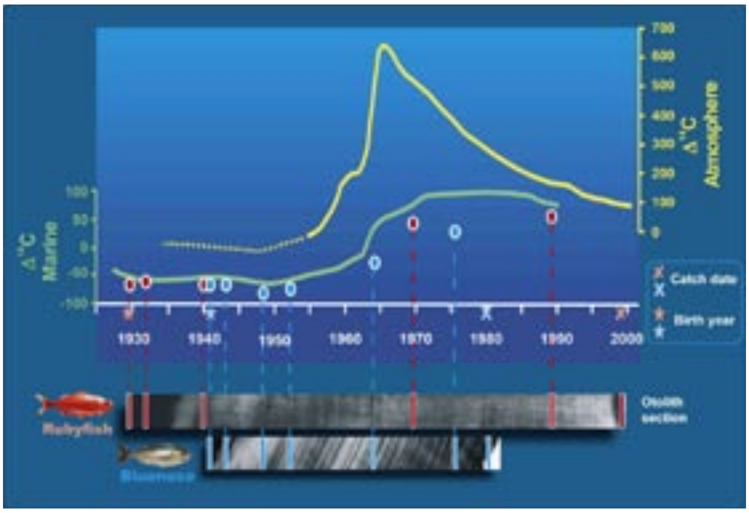


FIGURE 3
Results of the bomb radiocarbon study for bluenose and rubyfish



An overview of the orange roughy (*Hoplostethus* sp.) fishery off Chile

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1. INTRODUCTION

There are several orange roughy fisheries in different parts of the world: New Zealand, Australia, Namibia, South Indian Ocean and the North East Atlantic. Several reviews have been published on these fisheries: Clark (1996) summarizes the methods used for biomass estimation; Tracey and Horn (1999) review the age determination and Branch (2001) summarizes fisheries, estimation methods, biology and stock structure in Namibia and worldwide. However, Chilean orange roughy information is only available in technical reports and no comprehensive review exists. Therefore, the purpose here is to provide an overview of this rather new orange roughy fishery in Chilean waters, including catch, effort, catch rates, biology, stock assessment and management information.

The first commercial aggregations of orange roughy in Chilean waters were discovered in 1997–1998 by a fishing industry assisted by a New Zealand captain. Because of this finding the Chilean government through its Fishery Development Institute (IFOP) made a scientific exploration for this resource in 1998. This survey used both the **R.V. Abate Molina** and a commercial vessel (Lillo *et al.* 1999). Orange roughy were found in three main areas of seamounts: Juan Fernandez archipelago (JF), Bajo O'Higgins (BO) and Punta Sierra (PS) (Figure 1). Hence, in 1998 according to Chilean fishery law, the orange roughy fishery was declared as a "Fishery Development Regime" (FDR), which means that the annual quota is fixed and allocated between fishery industries by means of an auction system.

From its beginning the fishery has been monitored by the IFOP using scientific observers onboard the commercial vessels. This monitoring system has been collecting logbooks, which have permitted analysis of spatial and temporal fishing activities. The observers also collected biological information concerning the catches.

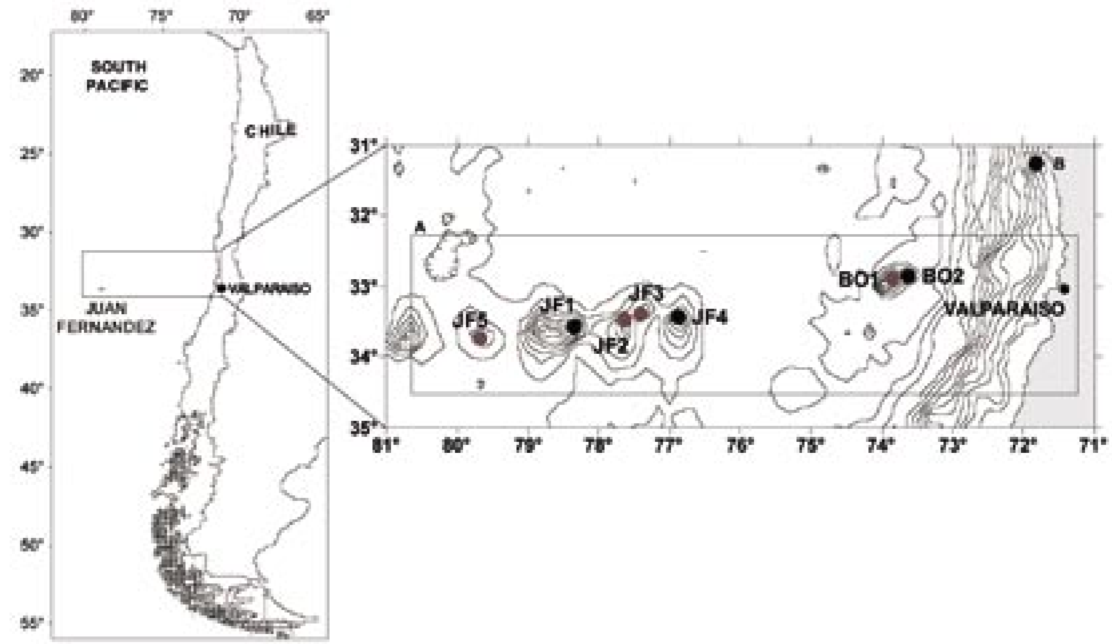
The fishery is based on good catch rates taken during spawning aggregations that occur in June-July above seamounts. Spawning behaviour has been analysed using gonad indices and histological studies. Age and growth studies were carried out in 2001 using NIWA (National Institute of Water and Atmospheric Research Ltd, New Zealand) ageing techniques (Gili *et al.* 2002). However, no juvenile otoliths were available, so growth models were fitted integrating Chilean data with juvenile data from New Zealand (Gili *et al.* 2002). In this review we include updated growth models fitted with Bayesian inference incorporating only Chilean data.

The Chilean Undersecretary for Fisheries contracted NIWA in 1999 to advise on the development of a fishery monitoring, stock assessment and management of orange roughy fishery (Clark 2000). More recently the IFOP received cooperation from the NatMIRC (National Marine Information and Research Centre; Namibia)

FIGURE 1

Orange roughy fishing grounds by areas

(JF=Juan Fernandez Archipelago; BO= Bajo O'Higgins and; PS: Punta Sierra)
Frames A and B enclosed the areas showed in Figure 2.



to learn from Namibian orange roughy experiences (Montecinos, Payá and Canales 2003). However, there have been several difficulties in developing an Chilean orange roughy stock assessment model, the most important being the short time series, the lack of knowledge of spatial and temporal stock dynamics, the unreliability of abundance indices based on catch rates and the lack of acoustic surveys. There is also concern about the results of stock assessments in others countries because Chilean orange roughy displays the same general pattern that has been observed in most of the orange roughy fisheries in the world, i.e. after a few years of exploitation the catch rate and total catch decrease strongly but the length structure of fish in the catch does not change too much. Therefore, hypotheses of fishing-driven disruptions; habitat perturbation and intermittent spawning as possible causes of local abundance depletion that have been postulated for this species by McAllister and Kirchner (2002) and should be tested in Chile.

The precautionary approach suggests that a fishing effects hypothesis that is risk averse should be used until other hypotheses have been tested. However, Namibian experience on the Frankies ground showed that local abundance could recover in only two years after banning the fishery (Boyer, Hampton and Kirchner pers.com.). Therefore we have suggested that a fishery exclusion experiment should be done in Chile.

During 2003 the first acoustic surveys was made by industry and the results will soon be released, enough information will then be available to make a full stock assessment. Nevertheless, the research focus should be on testing the perturbation hypothesis and producing reliable abundance indices from commercial catches and acoustic surveys.

2. MATERIAL AND METHODS

2.1 Monitoring system

Fishing activities have been monitored from the beginning of the fishery by IFOP observers onboard commercial vessels. The observers carry out three types of sampling: logbooks; length structure and biological samples. Logbook records include: target species; haul number; geographic satellite position (GPS) at the beginning and the end of haul; depth of net at the beginning and at the end of trawling; time at the beginning and at end of trawling; catch by species, sea surface temperature; sea bottom temperature; and net types. Length frequencies are collected by random sampling and recorded data includes: haul number; fork length; sexes and maturity stages in females. Biological sampling is size stratified and includes recording haul number, fork length, total fish weight, gutted fish weight, gonad weight, stomach contents, identification of sex ratios, maturity stages, and collection otoliths and bycatch species.

2.2 Fishing grounds

The fishing grounds were represented on a contour map of sea bottom based on data downloaded from GEBCO and GEODAT. The haul locations from 1999 to 2003 were included in a 3D representation of Juan Fernandez archipelago, Bajo O'Higgins and Punta sierra bottom topography. This topography was raised in situ during the 1999 scientific exploration survey (Lillo *et al.* 1999, Young *et al.* 2000).

2.3 Environmental information

The fishing ground environment was characterized by comparing water masses with fishing haul frequency by 50 m depth intervals. The water mass classification proposed by Silva (1985) was used. Haul frequency by 0.5°C bottom temperature recorded by net sensor was calculated. Both frequencies were computed using all fishing hauls recorded from 1999 to 2003.

2.4 Fishing activities

The evolution of fishing activities was analysed in terms of catch, fishing effort (trawling hours) and catch rates (tonnes/trawling hour) by year and fishing ground. Catch rates (R) were calculated using a ratio estimator

$$\hat{R} = \frac{\sum_{i=1}^{n} C_i}{\sum_{i=1}^{n} E_i}$$

where C is catch, E the fishing effort and i the index of hauls number.

In order to check that orange roughy were caught during spawning concentration, fishing season was characterized in terms of historical (1999–2003 mean) patterns of catch, catch rates and gonadic index by month. The evolution of length of fishing season was analyzed computing catch per 10-day intervals during different years.

2.5 Spawning time

To characterize the relationship between spawning and fishing season, historical means of female gonadic indices (GI) were calculated by

$$GI = \frac{gonad\ weight}{gutted\ \ fish\ weight} \times 100$$

To investigate a possible time sequence of spawning throughout fishing grounds the GI were analysed by 10-day intervals for each fishing ground.

2.6 Size structure

Fork length frequency distributions by sex were calculated from samples weighted by catch. Distributions were analyzed by years and fishing areas for the Juan Fernandez archipelago, Bajo O´Higgins and Punta Sierra. Because of similarity of the distributions over years, the distributions were characterized by their modes and proportion of individuals >45 cm for males and >50 cm for females. These proportions do not have any special biological meaning, but represent the larger fish of stocks that could be removed first under heavy fishing pressure.

2.7 Age, growth and natural mortality

Gili *et al.* (2002) undertook age determinations from sectioned otolith rings applying the same technique developed by New Zealand scientists. Data analyses were based on samples taken in 2001, which did not have any juvenile fishes. Gili *et al.* (2002) fitted a preliminary growth model complementing Chilean orange roughy data with juvenile data from New Zealand orange roughy. This procedure assumed that Chilean orange roughy and New Zealand orange roughy have the same growth parameters. This is unlikely because Chilean orange roughy are larger than those from New Zealand (Branch 2001).

In this work we determined the ages of otoliths from 315 males and 364 females sampled in 2002. Combining these samples with samples read in 2001, the total number of otoliths available was 611 males and 675 females. Consistency of the age determination technique and criteria were assured because the otolith reader, Mr Luis Cid, has been member of the reading team from 2001 (Gili *et al.* 2002).

Neither 2002 data nor 2001 data included juvenile fish, therefore we applied a Bayesian inference for estimating the parameters in the von Bertalanffy (1938) growth model:

$$\hat{L}_t = L_\infty(1 - e^{(-K(t_0 - t)})$$

where $\hat{L}_t$ is the standard length estimate at age t and L_∞, K and t_0 are model parameters. The log of data likelihood to maximize is:

$$LD = -0.5\, n \ln(res / n)$$

$$res = \sum_{i=1}^{n} (\hat{L}_i - L_i)^2$$

where n is the total number of observations and L_i is the standard length of fish in the samples which were transformed from fork length (FL) using the Young *et al.* (2000) equations

$L^m = 0.416 + 0.9FL^m$ for males
$L^f = 0.467 + 0.902FL^f$ for females

A normal prior distribution was used for the t_0 parameter, therefore the log of prior likelihood is

$$LP = \frac{0.5}{(c.v.\, u)^2}(t_0 - u)^2$$

where u is the t_0 estimated for New Zealand orange roughy by Doonan (1994) and currently used in stock assessment (Annala *et al.* 2002). The coefficient of variation (c.v.) was assumed to be 0.9. Male u is -0.44 and female u is -0.6. For L_∞ and K, prior distribution uniform distributions from $-\infty$ to $+\infty$ were used. The maximum total likelihood, $LT= LD+LP$, was found by minimizing $-LT$ by a quasi-Newton algorithm.

Natural mortality was estimated by Gili *et al.* (2002) using different methods based on the growth parameters. In the current work we estimated natural mortality using updated growth parameters and applying the same methods used by these authors. Alajarata (1984), for whom natural mortality is function of the longevity T_{max}, used the relation

$$M = -\ln(0.01)/T_{max}$$

where the longevity is estimated by Taylor (1958) as

$$T_{max} = t_0 - \frac{\ln(0.05)}{K}$$

Alverson and Carney (1975) based M on the time of cohort that maximized the weights and longevity.

$$M = \frac{3 * K}{e^{T_{max}\ K\ 0.25} - 1}$$

Taylor (1958) based M on the parameters K and t_0

$$M = \frac{2.966\ K}{2.966 + K\ t_0}$$

A Chapman and Robson (1960) catch curve method was also applied. This method was used because it is more precise and less biased than lineal regression methods (Dunn, Francis and Doonan 2002). Natural mortality was supposed to be similar to total mortality (Z), because of the unfished conditions of the stock in the early years of the fishery and the low level of catches, i.e.

$$Z = \ln(\frac{1 + a - 1/n}{a})$$

where a is mean age (over the recruited ages) and n is the sample size. The variance is given by

$$V(Z) = \frac{(1 - e^{-Z})^2}{ne^{-z}}$$

This method was applied to catch-at-age data, which was calculated using length-frequency data and 5-year age-length key.

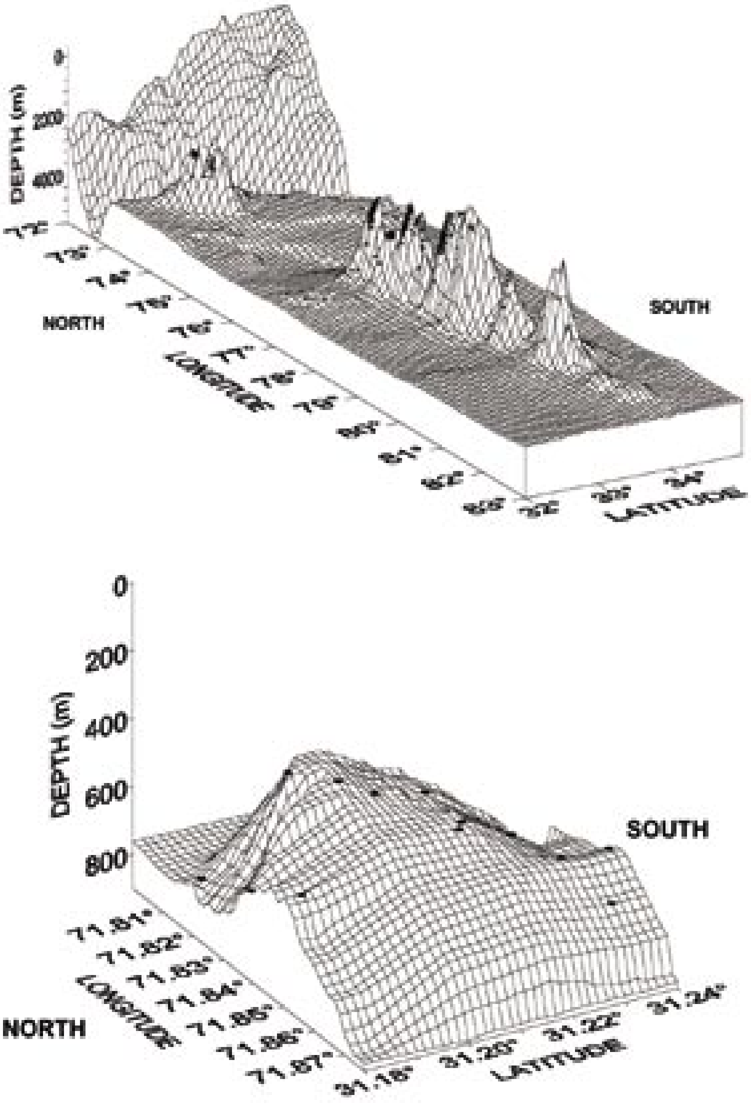
3. RESULTS

3.1 Distribution of fishing grounds and environment

Two exploratory surveys were made in August-September 1998, which covered the area from Nazca (25° 00′ S) to Mocha Island (37° 00′ S) (Lillo *et al.* 1999). A total of 23 seamounts were explored but orange roughy were found on only five, located in the Juan Fernandez archipelago, Bajo O'Higgins and Mocha Island. A third exploratory cruise was made in October 1999 from 24° 00′ S to 28° 00′ S where eight seamounts were explored but orange roughy were not found. The fourth exploratory survey was conducted in September 2000 from 31° 01′ to 31° 30′ S where one seamount was explored, which later was exploited by a fishery (Young *et al.* 2000). The last exploratory survey was made in July 2003 and covered from 37° 48 ' S to 41° 09' S, where two seamounts were found but orange roughy was practically absent; it composed only 0.1 percent of the research catches (Young *et al.* 2004). All the orange roughy detected have been adult fish and the juvenile distribution areas remain unknown.

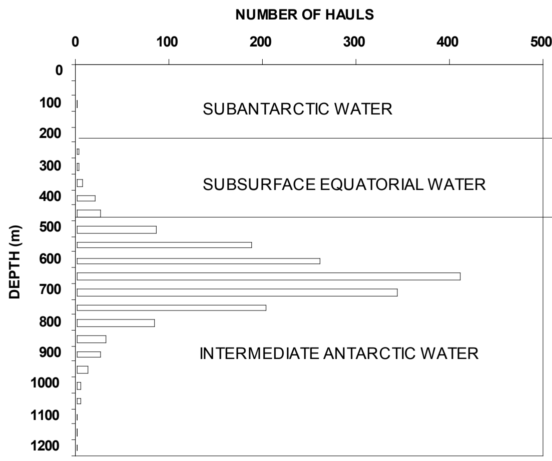
The known distribution of orange roughy is limited to spawning areas where fishes form dense aggregations and are easily caught by trawlers. No juveniles have been available to the fishery. Fishing grounds are distributed along three main areas (a) Juan Fernandez archipelago area, which has five fishing grounds (JF1 to JF5) in four seamounts, JF2 and JF3 are located in two crests of the same seamount; (b) Bajo O'Higgins area that has 2 fishing grounds (BO1 and BO2) in one seamount and (c), Punta Sierra, which is a fishing ground on only one seamount (Figure 2). During these years the fishing hauls have been located to the north or north-east of the seamount, suggesting that some specific conditions could occur in those places that concentrate the spawning fishes.

FIGURE 2
Fishing hauls recorded from 1999 to 2003 over the seamounts located in Juan Fernandez and Bajo O'Higgins areas (upper image) and Punta Sierra (lower image)
Both images have a 30x vertical exaggeration.



Oceanographic knowledge of these three areas is scarce. However, the Juan Fernandez archipelago, which is the main fishing area, is located in a transition zone between warm equatorial waters and cool Sub-Antarctic waters (Silva 1985). Below this zone there is the intermediate Antarctic water mass characterized by 4–7°C temperatures, 34.3–34.5 ‰ salinity, 3–4 ml/l O2 and low nutrient contents. Of all hauls that have been made since 1999 97 percent have been located below 450 m in intermediate Antarctic waters (Figure 3).

FIGURE 3
Haul frequency and water masses by depth

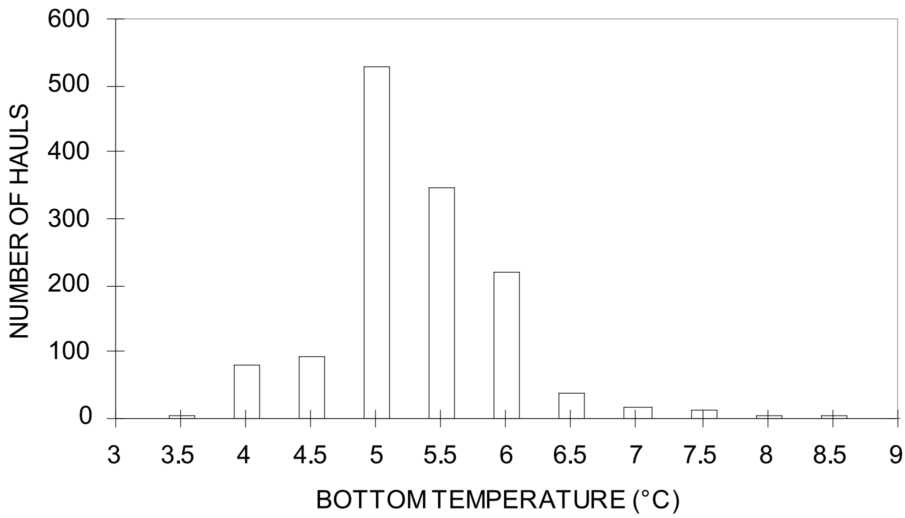


WATER MASS

T°C	Salinity (‰)	O_2 (ml/l)	Phosphate (µM)	Nitrate (µM))
10-19	34.0-34.4	4-6	0.1-1.5	0-10
7-10	34.3-34.5	1-4	1.5-2.5	10-25
4-7	34.3-34.4	3-4	<2.5	<25

Bottom temperature recorded from fishing hauls were made in 1999–2003 in the Juan Fernandez archipelago, Bajo O'Higgins and Punta Sierra and have fluctuated between 4 and 7.5°C and the most frequent values has been 5–6°C (Figure 4).

FIGURE 4
Haul frequency by bottom temperature recorded in the net



3.2 Fishing activities

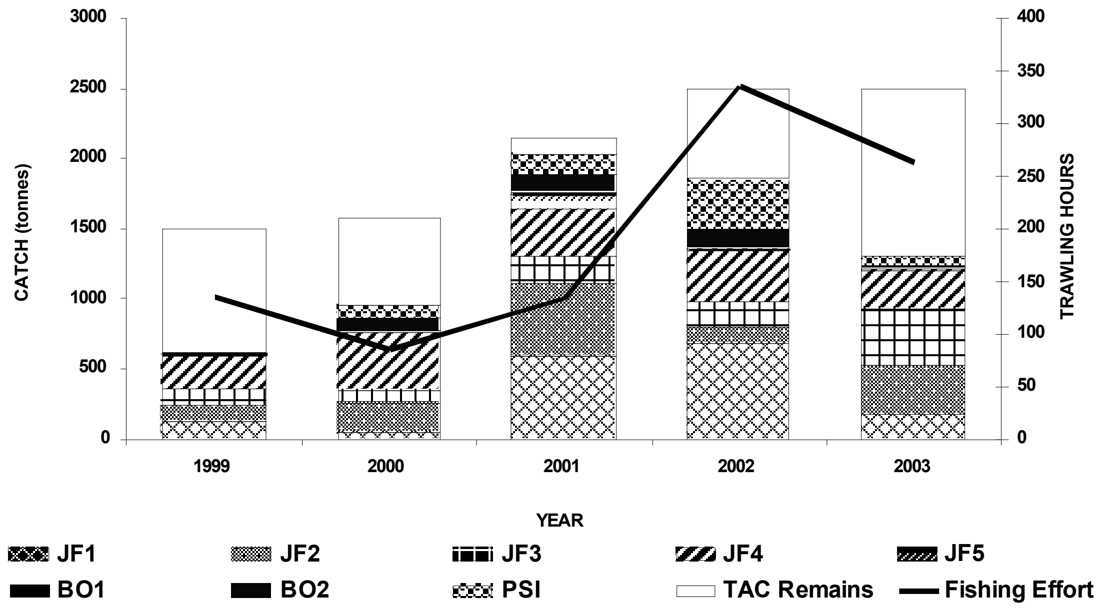
The fishery fleet consisted of 5–8 'ice' trawlers but most orange roughy has been caught by only four vessels. The length of the vessels is 44 m. Total annual catches increased from 779 t in 1999 to 1 868 t in 2001 and then decreased to 1 514 t in 2002. For 2003, the preliminary catch is 1 246 t (Table 1). Total annual catches have always been lower than the TAC (Figure 5). In the first year, 48 percent of TAC remained uncaught. This uncaught TAC decreased to 6 percent in 2001 but increased to 50 percent in 2003.

TABLE 1
Total allowable catch (TAC) and annual catch officially reported by SERNAPESCA

Year	TAC (t)	Catch (t)	TAC remains (t)
1999	1 500	779	721
2000	1 580	1 482	98
2001	2 140	1 868	272
2002	2 500	1 514	986
2003*	2 500	1 246	1 254

* = Preliminary data.

FIGURE 5
Annual catch by fishing ground and TAC remaining at the end of the fishing season
Right ordinate – fishing effort



From 1999 to 2003, orange roughy have been caught mainly (84%) in the JF area, followed by PS (10%) and BO (6%). Relative importance of fishing grounds has changed through years. The most important fishing grounds have been JF4 (40%) in 1999–2000; JF1 (29%) and JF2 (25%) in 2001; JF1 (37%), JF4 (20%) and PS (20%) in 2002; and JF3 (35%) in 2003.

The evolution of fishing effort through the years is the result of several interacting variables (Figure 5). In the first year there was obviously a learning component, some vessels searched for the resource in February, June and October, but the fishery season was concentrated between July and September and most fish were caught in August (65%). In 2000 trawling hours decreased and the fishing season started in May and finished in August, however most of fish (72%) were caught during June-July (Young *et al.* 2000). The maximum fishing effort was in 2002 and then decreased in 2003 because one vessel had operational problems and could not fish.

Catch rates increased from 5 tonnes/h in 1999 to 15 tonnes/h in 2002 and then fell to 6–4 tonnes/h in the last two years. This decline was observed for all the fishing grounds, except JF2 (Figure 6). Historically, the seasonal pattern of catch rates is strongly related with spawning behaviour. The best catch rates are achieved during June–July when the gonad index reached a maximum and the resource is most concentrated (Figure 7). Consequently, greater catches are made during these months. The length of the fishing season has fluctuated between 3 to 4 months in different years (Figure 8). The shortest season occurred in 1999 and the largest in 2002. The peak fishing season moved from 21–30 August in 1999 to 1–10 June in 2002 and then returned to 1–10 August in 2003.

FIGURE 6
Catch rate by fishing ground in Juan Fernandez area and total catch rate over years

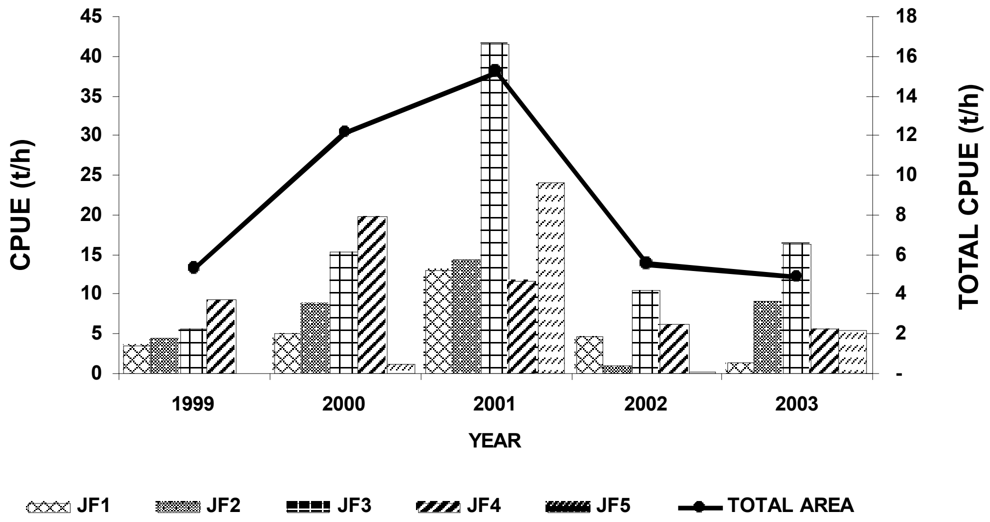


FIGURE 7
Total catch, catch rate and gonadic index by month

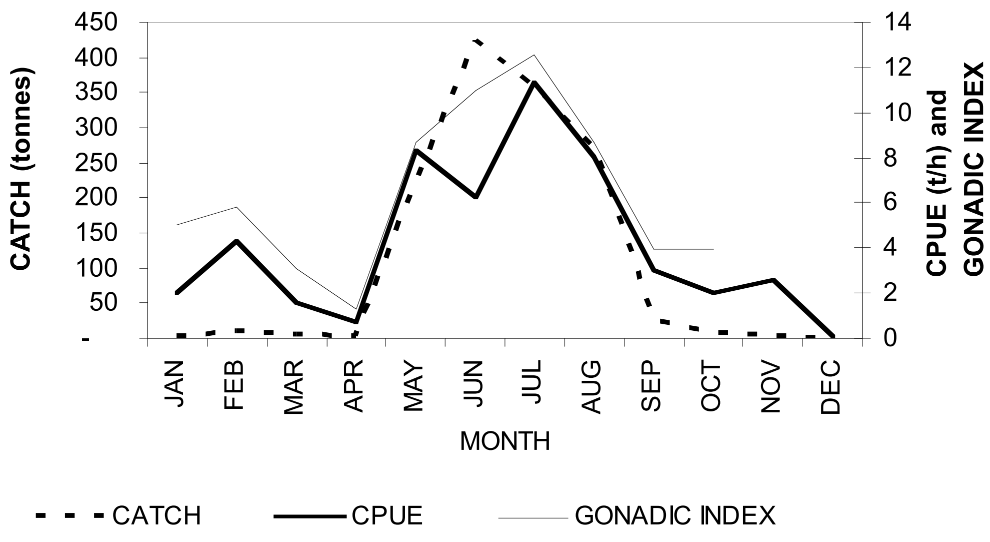
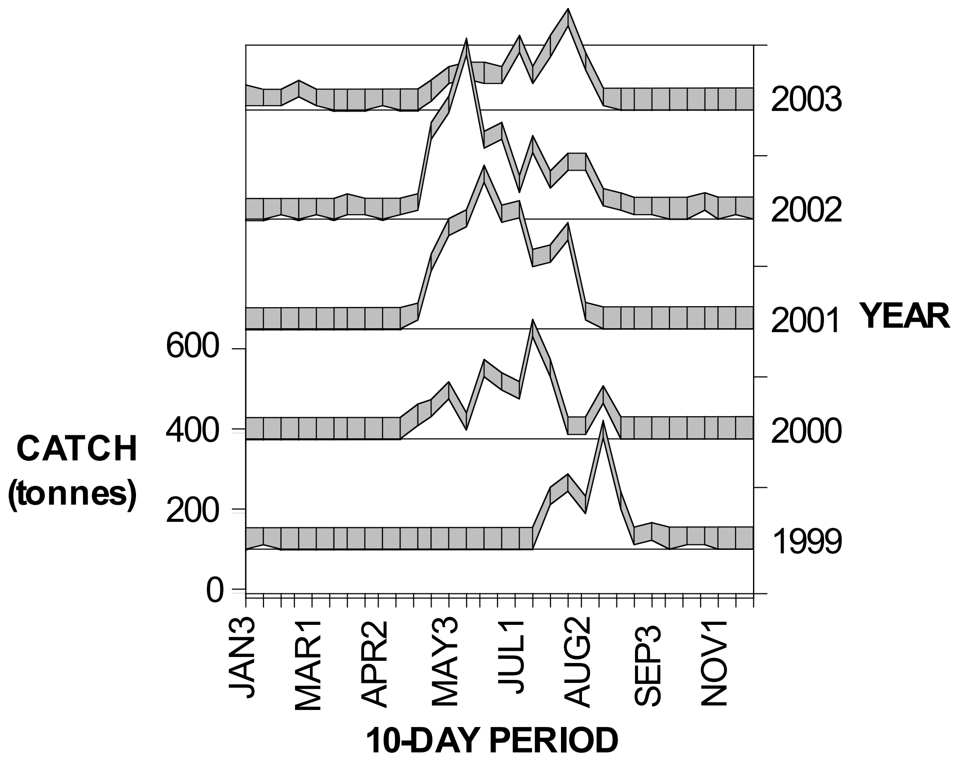


FIGURE 8
Length of fishing season based on catch by 10-day periods



3.3 Reproductive behaviour

The annual reproductive cycle and maturity stages of fish concentrated on the fishing grounds have been studied by gonad index and macroscopic maturity scales, which were validated by histological analysis (Young *et al.* 2004). These authors postulated a spawning sequence by fishing grounds in Juan Fernandez archipelago: late May in JF1, late June in JF2, early July in JF4, and first half of August in JF3. There is enough information of gonad indices in JF2, JF3 and JF4 to support this spawning sequence, but there is not enough information for JF1 because there are no samples in July (Figure 9). Because of samples are spatially restricted to fishing operations, spawning timing on the other fishing grounds are unknown.

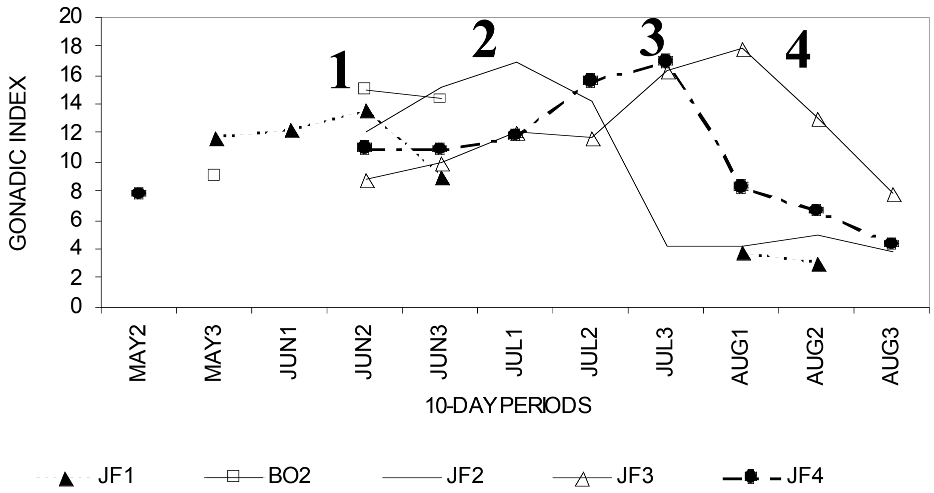
It has not been possible to estimate the age of 50% maturity because all samples consist of adult fishes. Juveniles were absent in the fishery. Using the relationship between the transition zone of the otoliths and age of first maturity (Francis and Horn 1997), Gili *et al.* (2002) made a preliminary estimation of age of first of maturity of 30 years for males and 32 years for females, which corresponds to a 30 cm fork length. However these estimations are biased because there are no juveniles in the samples.

Young *et al.* (2000) estimated an absolute fecundity of 33 669–379 216 eggs and a relative fecundity of 16 056–115 944 eggs/kg body weight.

3.4 Length composition of catch

Females are larger than males in all fishing areas and there is an increasing of size from Juan Fernandez to Punta Sierra, indicating an increasing trend toward the coast (Figure 10). The distribution of fork lengths through years seems relatively stable, however some changes in the modal fork length have occurred (Figure 11). The overall male mode decreased 2 cm from 1999 to 2003, except in the Punta Sierra area. This

FIGURE 9
Sequence of spawning by fishing ground based on gonadic index behaviour by 10-day periods
The sequence is JF1, JF2, JF4 and JF3.



decline is not clear in females because the mode decreased 4 cm from 1999 to 2001 but increased 3 cm in the last year; however the mode decreased 2 cm in Bajo O'Higgins and Punta Sierra.

The fraction of large males (arbitrarily fishes larger than 45 cm) decreased from 25 percent in 1999 to 10 percent in 2003 in Juan Fernandez area and occurred in all areas (Figure 12). The fraction of large females (fish larger than 50 cm) in Juan Fernandez area decreased from 24 percent in 1999 to 11 percent in 2003, but this decrease was smaller over the total area.

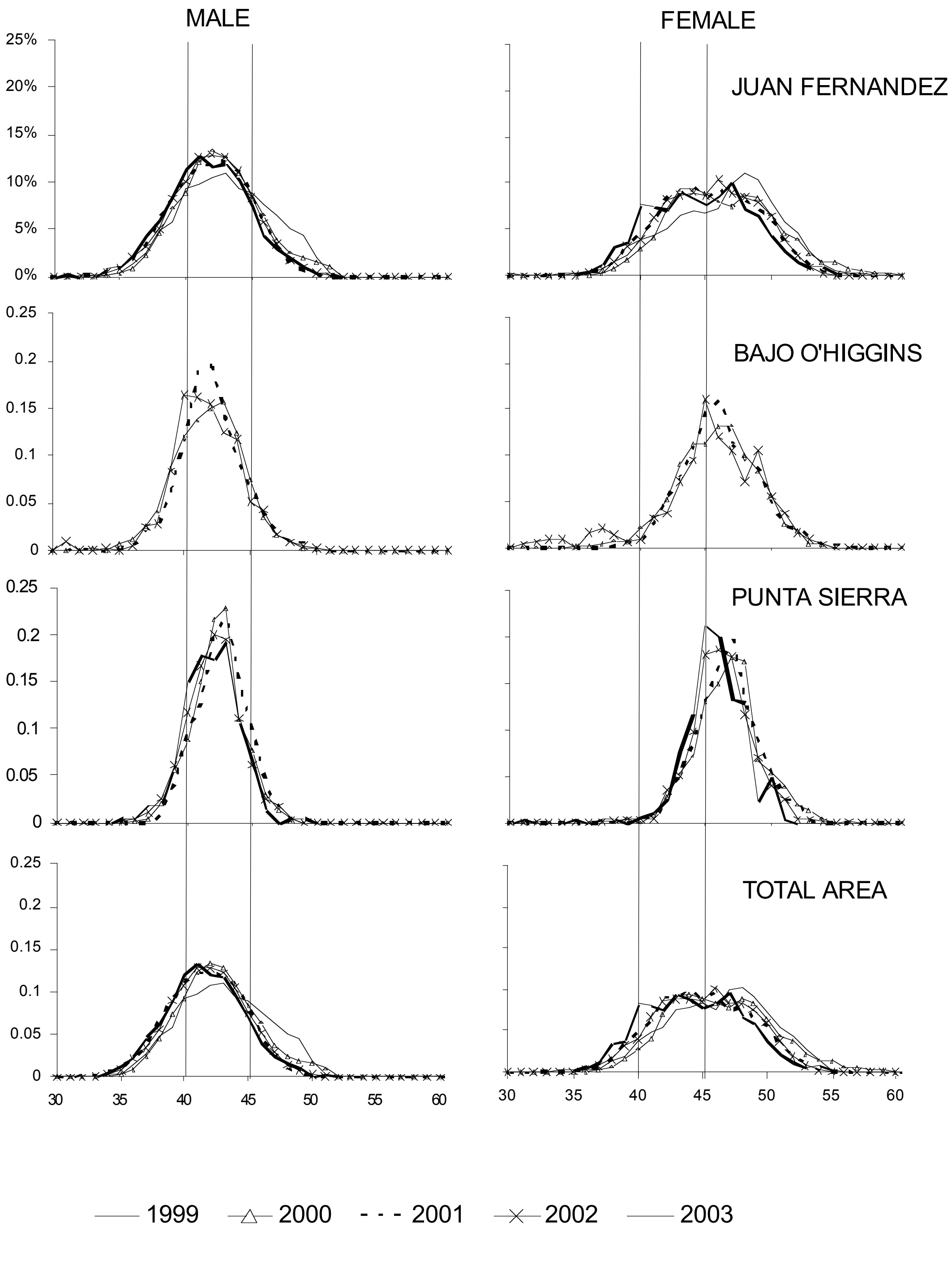
3.5 Age, growth and natural mortality

New growth models that included 2001 and 2002 data were fitted by Bayesian inference and produced L_∞ and k parameters similar to those estimated by Gili *et al.* (2002), but gave a smaller t_0 value (Table 2 and Figure 13). Consequently, natural mortality estimated by different methods was similar to those estimated by Gili *et al.* (2002) (Table 3). In this work we did not use the method of Rikheter and Evanof (1976) and Roff (1988), which require the maturity curve or age of 50 percent maturity because these parameters are biased due to the absence of juveniles in the samples.

TABLE 2
Growth parameter models estimated in this work and by Gili *et al.* (2002)

Sex	Parameter	This work	Gili *et al.* (2002)	Prior distribution
Males	Loo	43.4598	43.68	U~(-inf,+inf)
	K	0.037299	0.037	U~(-inf,+inf)
	t_0	-0.63384	-1.639	N~(-0.44,0.9*-0.44)
Females	Loo	48.733	49.0	U~(-inf,+inf)
	K	0.030569	0.030	U~(-inf,+inf)
	t_0	-1.1324	-1.97	N~(-0.60,0.9*-0.60)
Both sexes	Loo	47.0244	47.51	U~(-inf,+inf)
	K	0.0320	0.030	U~(-inf,+inf)
	t_0	-0.6060	-2.0	N~(-0.3,0.9*-0.30)

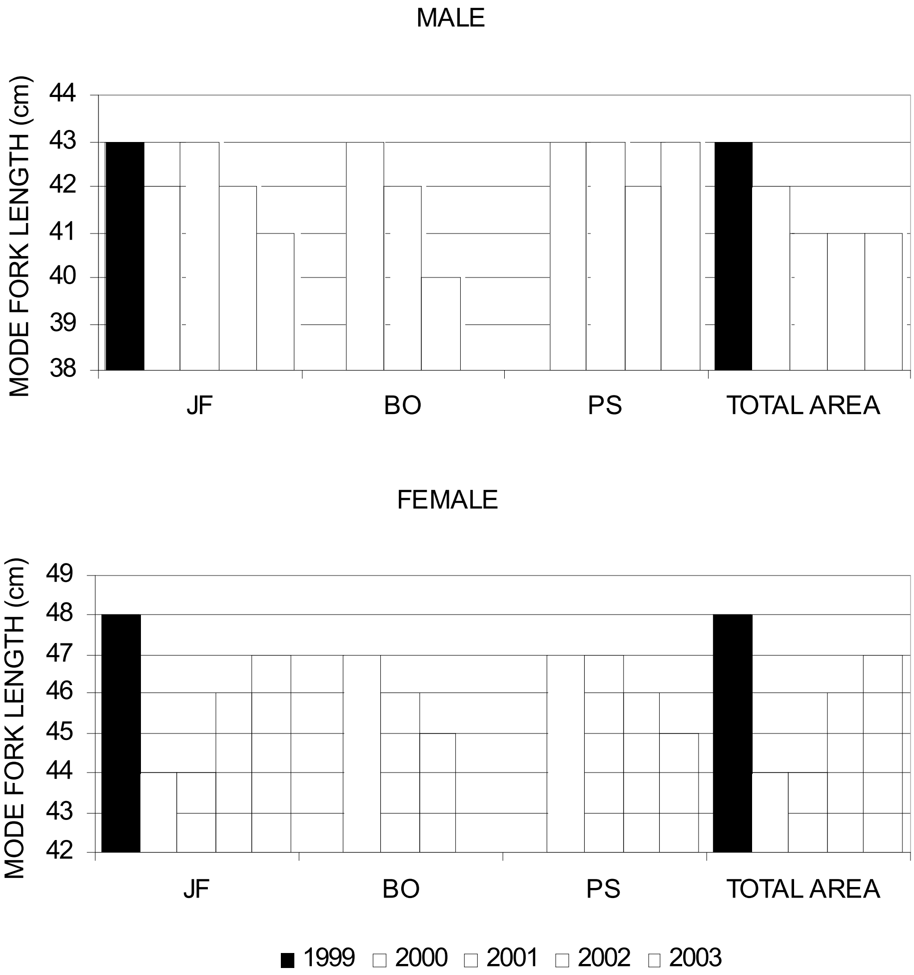
FIGURE 10
Fork length composition of catch by sex, fishing areas and year
Vertical lines are shown only for helping visualization and have no biological meaning.



3.6 Stock assessment

Stock assessment models have not been applied to Chilean orange roughy for several scientific and management reasons. In the beginning of the fishery there was little knowledge of the biology of the resource and most of the information available came from other stocks around the world. Therefore, the Chilean Under-Secretary for Fisheries organized a workshop in 1999 in which fisheries entrepreneurs, IFOP researchers, managers and a panel of international experts composed by Andy Smith (Private consultant, New Zealand), Graham Patchell (Sealord Group, New Zealand)

FIGURE 11
Mode of fork length by sex, fishing area and year



and Malcom Clark (NIWA, New Zealand) participated. The main recommmendations (Clark 2000) follow.

i. Monitoring of the whole fishery season should be done by IFOP to collect biological and fishery information required for characterizing the catches.

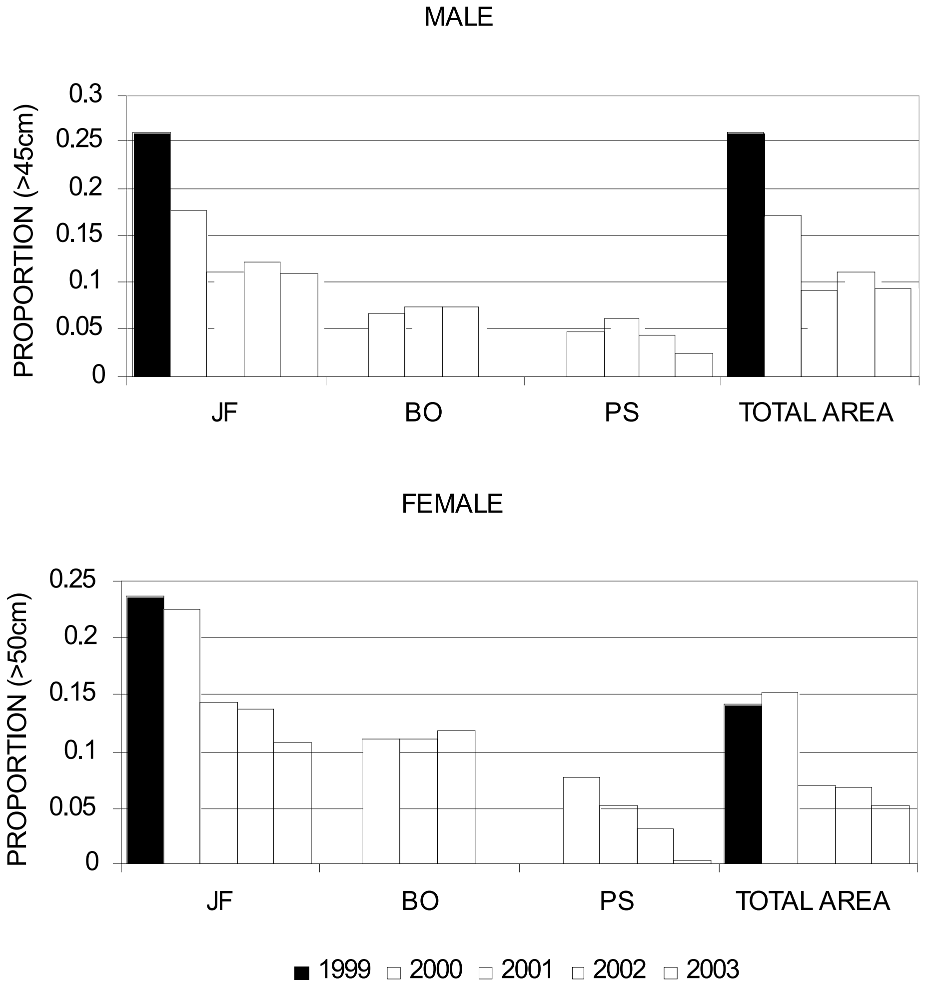
ii. In the mid-term an acoustic survey should be designed and implemented. A preliminary hypothesis of number of stocks should be postulated based on spatial and temporal analysis of spawning stock distribution and structure by size/age.

iii. In the long term a stock assessment model should be developed based on at least four annual acoustic surveys and fishery and biological information of catches.

Following recommendations a series of studies have been made to monitor the fishery (Tascheri *et al.* 2001, 2002), to estimate fecundity and maturity (Young *et al.* 2000) and to estimate age and growth and natural mortality (Gili *et al.* 2002).

A technical Committee was established in 1999 with members of the fishing industry, IFOP researchers and managers, which has been undertaking fishery monitoring and quota discussions. The fishery industries have been cooperative and a medium term Collaborative Research Program (CRP) has been agreed to between government and fishery industries. Researchers contracted by the industry have been developing a low-cost acoustic monitoring system based on acoustic data recorded onboard fishing vessels. This system should be operative in 2004. They also contracted South African

FIGURE 12
Proportion of males larger than 45 cm and females greater than 50 cm by fishing area and year



scientists (Ian Hampton and Dave Boyer) to conduct the first acoustic survey on Chilean orange roughy, which was done in 2003. The results will be soon available.

3.7 Resource management

The orange roughy fishery has been managed from the beginning. In accordance with Chilean fishery law in 1998 this fishery was declared an "Incipient Development Regime". Therefore new fishing authorizations were no permitted and the rights for quota allocation by fishery industries were fixed by means of an auction. The fishing law states (<*http://www.subpesca.cl/pagina%20juridica/ Leyes.htm*>):

> *"An extraordinary fishing permit shall be granted to the successful bidders that shall give them the right to catch annually, for a 10-year period, a maximum amount equivalent to the result of multiplying the appropriate annual global catch quota by the fixed coefficient awarded in the respective fishery unit, and it shall begin to apply as of the calendar year following the year the award is made.*
>
> *So that auctions shall be held during all the years this system is in effect, in the first public auction the total of the annual global catch quota shall be awarded for a period of ten years, granting extraordinary fishing permits with a variable coefficient, which shall decrease by ten percent every year. As of the second year the first award is in effect, ten percent cuts*

shall be auctioned annually, which shall be obtained during the first ten years through the proportional discount from all the successful bidders that possess the original extraordinary fishing permits granted for this purpose. The successful bidders at these auctions shall be granted extraordinary fishing permits with the same characteristics indicated in the preceding clause."

Nine fishing companies were successful bidders at the first auction and five shared 99 percent of total quota: Pesca Chile, Friosur, El Golfo, Bio-Bio and Emdepes (Figure 14). However, in 2003 95 percent of annual catch was made by only three companies: Pesca Chile, El Golfo and Bio-Bio. El Golfo had a small catch in 2003 because its vessel could not fish due to operational problems. Emdepes never caught any orange roughy because of an agreement with another company to fish their quota. However, in the last year the other company was unable to catch their own quota and therefore did not catch Emdepes's quota either.

The annual quota is fixed each year and does not include any allocation by area. Thus, industries can catch their quota wherever and whenever they want. Annual quotas have not been estimated quantitatively. The first quota in 1999 was based on a qualitative analysis of the relative productivity of stocks in the world based on a precautionary approach (Young *et al.* 2000). Later quotas were increased to encourage industry cooperation with government in the fishery monitoring and research activities.

TABLE 3
Natural mortalities estimated in this work and by Gili *et al.* (2002)

Sex	Method	This work	Gili *et al.* (2002)	Observation
Male	Rikheter & Evanof	-	0.66	Requires age 50% maturity that is not available
	Alagaraja	0.0578	0.058	
	Alverson & Carney	0.1015	0.103	
	Roff	-	0.042	Requires maturity curve that is not available
	Taylor	0.0375	0.038	
	Chapman & Robson	0.041 (0.037-0.046)		95% Confidence intervals in bracket
Female	Rikheter & Evanof	-	0.057	Requires age 50% maturity that is not available
	Alagaraja	0.0464	0.048	
	Alverson & Carney	0.0809	0.084	
	Roff	-	0.031	Requires maturity curve that is not available
	Taylor	0.0312	0.031	
	Chapman & Robson	0.046 (0.041-0.051)		95% Confidence intervals in bracket
Both	Rikheter & Evanof	-	0.058	Requires age 50% maturity that is not available
	Alagaraja	0.0489	0.049	
	Alverson & Carney	0.0853	0.086	
	Roff	-	0.047	Requires maturity curve that is not available
	Taylor	0.0322		

FIGURE 13
Growth models fitted with Bayesian inference
(line= model; dotted line= Gili *et al.* (2002)

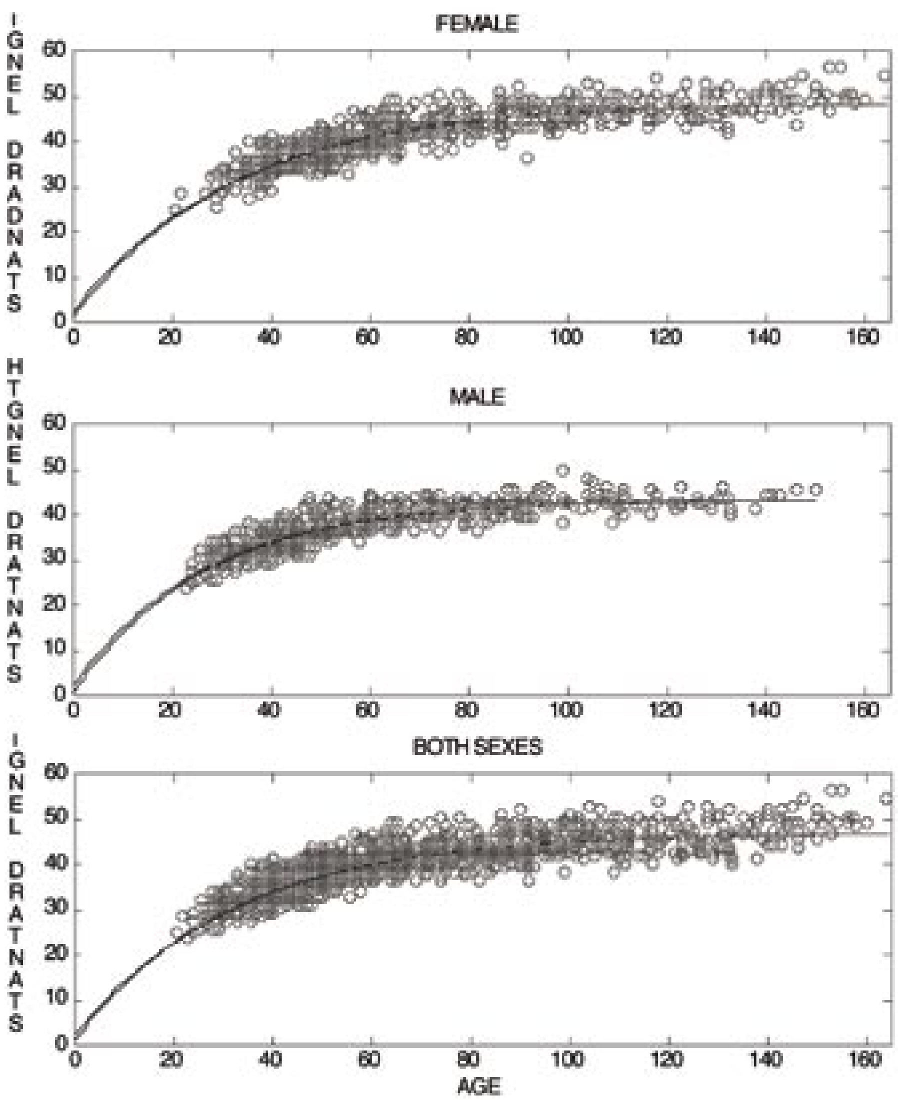
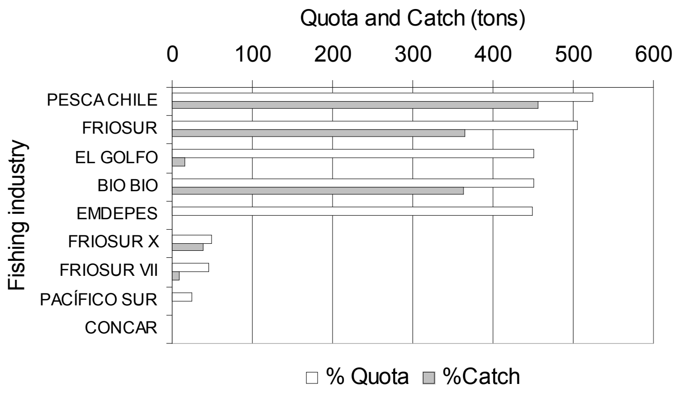


FIGURE 14
The 2003 quota allocation and annual catch by fishing industry



4. DISCUSSION

4.1 Distribution of fishing grounds and environment

The known distribution of Chilean orange roughy is restricted to seamount areas where fishes concentrate to spawn. Although 34 seamounts have been explored by five surveys, orange roughy have been found on only seven of them. So far no juveniles have been found in Chilean waters. This seems to be a worldwide characteristic of orange roughy fisheries, except for three locations where juveniles of 0 and 1 age classes were found: off the west coast of north Island, New Zealand at 250 m of depth; on the north Chatham rise of 50–175 km from the main spawning aggregation and on the Frankies ground in Namibia (Branch 2001). The occurrence of Chilean orange roughy in other habitats described for this species, e.g. canyons and soft flat bottom, have not been explored because this species is normally highly dispersed in such habitats.

Chilean orange roughy aggregations are distributed in waters of mainly at 4.0–6.5 °C. This temperature range is similar to the 4.5–6.5 °C range described for worldwide orange roughy distribution (Clark 1999, Branch 2001). This tight range of water temperature is considered more important than depth in determining orange roughy occurrence (Branch 2001). Orange roughy off Chile are distributed mainly from 500 to 800 m, which is similar to the depth range of 600–800 m described for orange roughy off Namibia (Boyer and Hampton 2001), but more shallow than in Australia, New Zealand and the North-East Atlantic where orange roughy are distributed from 800 to 1 200 m (Branch 2001). Chilean orange roughy are distributed mainly in Antarctic Intermediate Water as are orange roughy off New Zealand (Clark *et al.* 2000).

Small scale circulation studies of habitats where orange roughy spawn have not been done in Chile. However, such analysis are needed to understand why fishing hauls, and therefore fishable spawning aggregations, are always located to the North-East of seamounts. Gubbay (2003) recently reviewed this kind of study and summarized "seamounts can interrupt the flow of water and therefore affect the hydrography and current system in the vicinity as well as further afield. Tides can be amplified creating fast currents, and eddies may form and be trapped over seamounts in closed circulations known as Taylor columns. Other effects include locally enhanced turbulent vertical mixing and the creation of jets".

4.2 Fishing activities

So far, commercial catch rates of Chilean orange roughy have not been standardized because the understanding of fishing behaviour and fishing tactics is too poorly known to show that catch rates are related to stock abundance. In the first year, fishermen were clearly learning how to fish orange roughy. In the second year with more experience, they increased their catch rates more than twofold and in the third year they increased them again. But, in the fourth and fifth years catch rates decreased to the levels recorded in the first year. Although the same catch rate patterns have been observed in orange roughy off Namibia (McAllister and Kirchner 2001 and 2002), New Zealand (Annala *et al.* 2002) and Australia (Wayte and Bax 2002), there are doubts that this decline is related to stock abundance. Four hypotheses have been postulated to explain the declining of abundances showed by commercial standardized catch rates and acoustic biomass in orange roughy off Namibia (McAllister and Kirchner 2002):

i. Catch removal. The observed declines were mainly attributable to catches.
ii. Fishing. The observed declines resulted from the dispersion of orange roughy aggregation by fishing.
iii. Intermittent aggregation. The observed declines were caused by temporary factors unrelated to fishing. Orange roughy may aggregate on an intermittent basis depending on various environment conditions. Fish will re-aggregate on fishing grounds, but when they will do remains unpredictable.
iv. Mass emigration or mortality. The observed declines were caused by either mass mortality or mass emigration, and the original large abundance observed on the fishing grounds is unlikely to be re-established in the near future.

Recent Namibian experience on the Frankies fishing ground supports the '*Fishing and, or, Intermittent aggregation*' hypotheses. Commercial fishing activities in Frankies started in 1995. Standardized commercial CPUE indices decreased from 4.028 (relative to mean value) in 1995 to 0.441 in 1998. The first acoustic survey in

1987 estimated a biomass of 29 567 tonnes. The second gave an estimate of 478 tonnes in 1998. Therefore, Frankies was closed to commercial fishing activities in April 1999, however only three years later the acoustic biomass estimate was 25 839 tonnes, i.e. a recovery to the level of 1987 (Brandão and Butterworth 2003).

4.3 Length composition of catch

Chilean orange roughy shares several worldwide characteristics in the length compositions of commercial catches. Frequencies are strongly unimodal, juveniles are absent, females more common than males and catch length frequencies do not change over time (Clark *et al.* 2000, Branch 2001).

Chilean orange roughy are the second largest in the world after those found in the North-East Atlantic. The fork-length range in Chilean orange catches was from 35 to 55 cm, which corresponds to 32–49 cm standard length. The orange roughy of the North-East Atlantic had a standardized size range of 40–58 cm which was greater than for orange roughy off New Zealand and Australia, which had a size range of 20–50 cm. The orange roughy off Namibia had a size range of 20–32 cm (Branch 2001).

4.4 Age, growth and natural mortality

Growth parameters fitted using prior distributions for t_0 based on t_0 values for orange roughy from New Zealand had similar parameters that were estimated by Gili *et al.* (2002). This means that the results from the approximation used by these authors, which included juvenile data from orange roughy off New Zealand, were comparable to the results obtained using Bayesian inference. It seems that the growth increments in adult fishes from both countries are similar, so the t_0 parameters reflect mainly the juvenile growth patterns. The procedures that have been applied to estimate growth model are interim procedures until Chilean juvenile data become available.

Natural mortality values were estimated using different methods were similar, except to that of Alverson and Carney (1975). Values of M estimated by the Chapman and Robson (1960) method were similar to values estimated by methods based on growth parameters. Values of M for Chilean orange roughy are close to the value of 0.045 used in the New Zealand and 0.055 used for Namibian orange roughy stock assessments (Annala *et al.* 2002; Brandão and Butterworth 2003).

4.5 Stock assessment and management

So far, a complete stock assessment using a model specific for Chilean orange roughy has not been done. The main difficulties for stock assessment have been the short time series of fishery data, lack of knowledge of spatial and temporal stock dynamics, unreliable abundance indices based on catch rates and lack of acoustic surveys. Now, acoustic survey results will be soon available and sufficient information should be available to provide a stock assessment. However, the research focus should be on testing the perturbation hypothesis and producing reliable abundance indices from commercial catches and acoustic surveys.

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The crystal crab fishery in Western Australia: first steps in the development of a sustainable deepwater crab fishery

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1. INTRODUCTION

In Western Australia several large crab species occur in the offshore waters. However, only three, the giant crab, (*Pseudocarcinus giga*), the champagne crab (*Hypothalassia acerba*) and the crystal crab (*Chaceon bicolor*) are of commercial importance.

The biogeographical boundary separating the cool water of the south coast of the state from the warmer waters of the west coast has provided a logical boundary between crustacean fisheries in Western Australia (Figure 1). These fisheries are managed as the South Coast Deep Sea Crab Fishery (SCDSCF) and the West Coast Deep Sea Crab Interim Managed Fishery (WCDSCIMF). Permit holders in the West Coast Deep Sea Crab Interim Managed Fishery are entitled to take champagne, giant and crystal crabs but not rock-lobsters. The WCDSCIMF operates along side Australia's largest rock-lobster fishery, the West Coast Rock-lobster Managed Fishery (WCRLMF), where fishing generally occurs in 0–200 m. Although managed separately licencees in the WCRLMF are permitted to retain 12 deep-sea crabs, primarily champagne crabs, per day per boat. On the other hand, licencees in the South Coast Deep Sea Crab Fishery are entitled to take champagne, giant and crystal crabs and as a result of the licensing framework surrounding the development of this fishery most fishers are also entitled to take southern rock lobster (*Jasus edwardsii*).

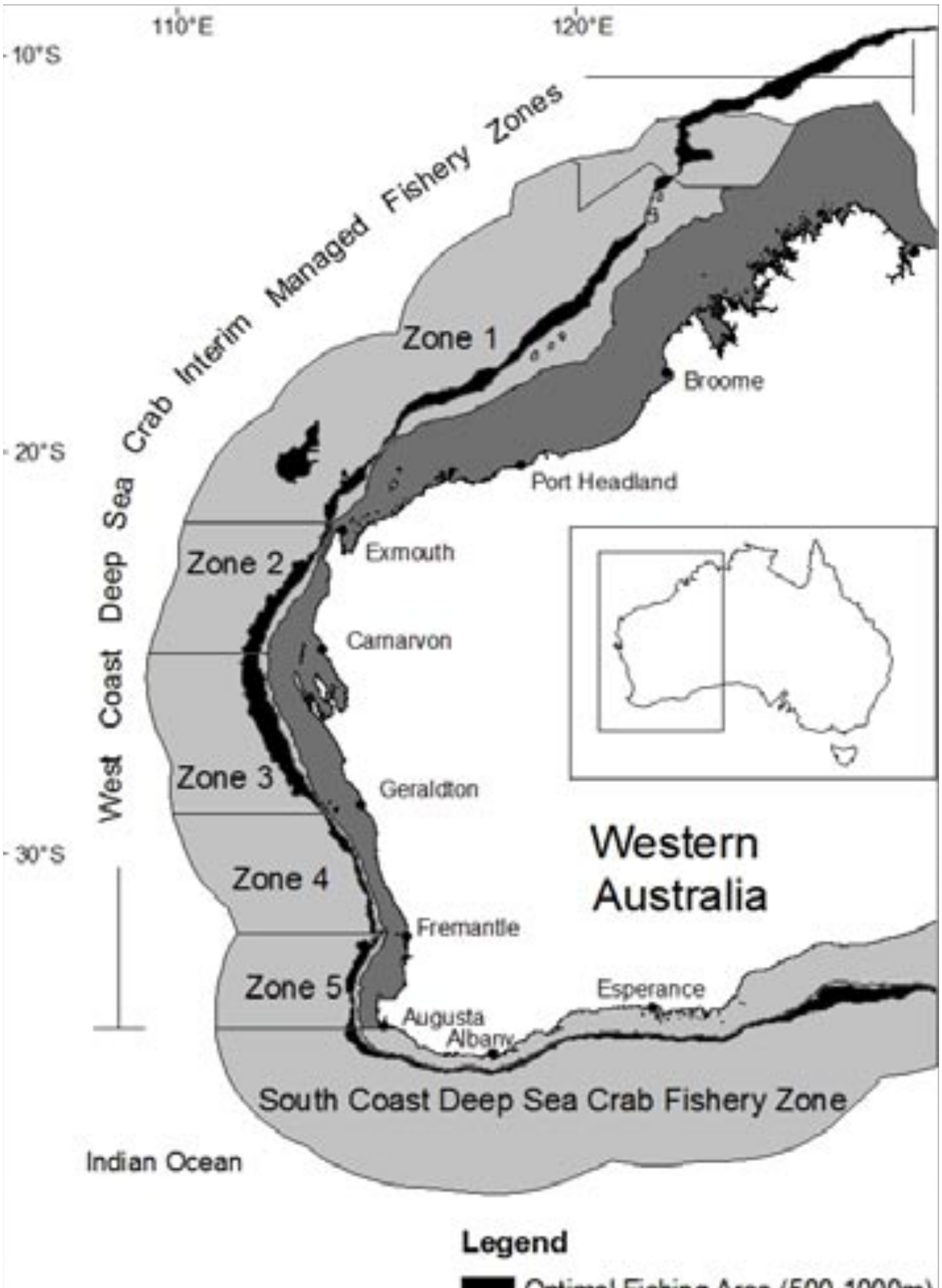
The Department of Fisheries have records of various fishers from the 1960s, 1970s and 1980s expressing interest in establishing commercial fishing operations based on champagne, giant and 'deep-sea crabs' on the west coast. Although most of these proposed ventures did not go any further, some small-scale exploratory fishing targeting champagne crabs by rock-lobster fishers was undertaken between 1985 and 1990 with some rekindled interest in the 1990s. Champagne crab catches peaked between 30 and 45 tonnes from 1997 to 1999, before decreasing to negligible levels (<100 kg) from 2001 onwards. The decrease in catches was in part due to a decline in champagne crab stocks, however low beach prices and increased interest in the more valuable crystal crab also contributed (K. Smith, Murdoch University, Australia, pers.

comm.). Therefore, on the west coast, management of giant and champagne crabs is primarily focused on ensuring biological sustainability and maintaining breeding stocks of the species rather than developing a viable commercial fishery.

Crystal crabs have only been targeted on the west coast since the late 1990s and the WCDSCIMF is now almost entirely dependent on the size and productivity of the crystal crab resource.

FIGURE 1

Map of the W.A. coastline showing the crystal crab management zones and depth contours between 500–1000 m



Both giant and champagne crabs landings have been larger and more regular in the South Coast Crustacean Fishery than on the west coast. Since 1990 the combined giant and champagne crab catch has, in most years, been in excess of 30 tonnes, with occasional annual catches reaching 40 to 50 tonnes. In the past, crystal crabs have not formed a significant contribution to the South Coast Crustacean Fishery, apart from one year (2002) when over 10 tonnes were landed before a moratorium was placed on targeting the species pending further research. The size and distribution of the fishable stock in this region is unknown.

In 1991 it was recognized that with increasing interest in deep-sea crabs of all species there was a need to move to more formal management. In January 1992 following a request for expressions of interest, the Minister for Fisheries issued a press release announcing that by 1 April 1992 a plan would be in place to develop the fishery. This resulted in more than 80 expressions of interest for endorsements to take deep-sea crabs outside the rock-lobster fishery. In response, in June 1993, 53 endorsements were approved (49 on the south coast and four on the west coast). A one-tonne catch per year minimum performance criteria was placed on each approved vessel. Following a review of these allocations, in May 1993 a further three endorsements were granted on the west coast. In 1992 a commercial fisherman working in cooperation with the Commonwealth Scientific and Industrial Research Organisation (CSIRO, Hobart, Australia) conducted some limited research fishing. The fishing focused on champagne and giant crabs, but was of limited success due to the size of the fishing vessel used and lack of gear suitable for fishing in depths greater than 150 m.

New complexities were introduced into the management of both the SCDSCF and WCDSCIMF when permit holders realized the potential quantities of crystal crab available and the species' commercial value. The dilemma is one that besets the managers of many new fisheries: i.e. on one hand faced with a previously unfished resource that has a potentially long term yield, together with an industry geared up and keen to exploit it; while on the other hand having no catch history, biological information, or information on the spatial extent of the fishery. Given the current focus in Western Australia on the exploitation of crystal crab, this paper deals only with a description of crystal crab catches on the west and south coasts of Western Australia and the proposed management of this resource.

Crystal crabs belong to the family Geryonidae. Other members of this family are widely distributed on continental shelves throughout the world, generally occurring in depths between 200 – 1 200 m (Hastie 1995). Over the years there have been several fisheries in various locations for deep-water crabs of this family, e.g. the north eastern coast of North America, the central and southern coasts of the South American east coast, the west coast of Africa, the east coast of southern Africa and the Gulf of Mexico. Only the *Chaceon* (previously called *Geryon*) fishery off Namibia, on the west coast of southern Africa, has produced large catches (5 000–10 000 tonnes a year) over a sustained period (Melville-Smith 1988). However, even landings in that fishery have decreased to 20% or less of what they were during their peak (Haufiku, Namibian Fisheries Department, Swakopmund, Namibia, pers. comm.). One of the primary reasons for the lack of sustainability of these fisheries is that the crabs live in cold unproductive waters (generally 3–8^{o} C) and are slow growing and long lived making them vulnerable to overexploitation.

Crystal crabs occurring off the Western Australian coast are considered at this stage to be *Chaceon bicolor*, a species which is also found in the central Pacific from the Emperor Seamount Chain to eastern Australia (Manning and Holthuis 1989) and along the west and north coast of Australia (Jones and Morgan 1994). At this stage *Chaceon* appears to have a wide distribution, although some systematics experts have suggested that further work may show that the pale coloured specimens found off the Western Australian coast are a different species to the purple, tan and yellowish coloured specimens of *C. bicolor* found in the Pacific. The depth distribution of *Chaceon* species is reported to be between 275 and 1 600 m (Manning and Holthuis 1989). However on the Western Australian coast the species has only been reported in commercial catches from 450 to 1 220 m (Lance Hand, Bellenden Nominees, Geraldon, Australia, Western Australian Museum records).

2. INTERIM MANAGEMENT CONTROLS IN WESTERN AUSTRALIA'S CRYSTAL CRAB FISHERIES

2.1 The West Coast

Until 1995 the take of deep-sea crabs seaward of the 200 m isobath was the responsibility of the Australian Commonwealth Government and some 22 vessels were licensed by the Commonwealth to fish for deep-sea crabs in Commonwealth managed waters off Western Australia. However, under the Offshore Constitutional Settlement Agreement of 1995, and on the basis of the links with the State managed rock-lobster fisheries, management of deep-sea crab fisheries became a State Government responsibility.

The fishery for crystal crabs began in 1997–1998 when one fisher undertook exploratory fishing for deep-sea crabs on the west coast between 34° 24' and 22° 19 S' in depths of 540 to 1 080 m. The promising catches of crystal crabs by this exploratory fishing trip generated more interest in commercially exploiting this fishery on the west coast and by the end of 1999 the catch had increased to almost 25 tonnes.

The fishery was originally open to all 595 West Coast Rock-lobster fishers as the fishery had historically taken small quantities of deep-sea crab (mainly champagne crabs) as byproduct in their rock-lobster traps. However, to take deep-sea crabs out of the rock-lobster fishing season (15 November to 30 June) a specific fishing boat licence endorsement was required. In April 1999, 26 vessels on the south coast and six vessels on the west coast had acquired these licence endorsements as a result of earlier interest and activity related to deep-sea crabs.

The need to more formally manage these fisheries arose in 1998 in addressing reporting requirements that Environment Australia proposed to impose as a condition of export approval under Section 10A of *the Wildlife Protection (Regulation of Exports and Imports) Act 1982.* The downturn in the Asian economy and concerns about its impact on rock-lobster export prices also resulted in increased targeting of deep-sea crabs by rock-lobster fishers during the 1998–1999 rock-lobster season and increased interest from rock-lobster fishers wanting to target deep-sea crabs outside the rock-lobster fishery. There was also increased attention from rock-lobster processors interested in processing and marketing champagne crabs and other deep-sea crabs. In April 1999 these issues culminated in the existing endorsement holders, through the Western Australian Fishing Industry Council (WAFIC), asking the Minister for Fisheries to restrict the catch of deep-sea crabs by rock-lobster fishers.

In May 1999, in order to prevent overexploitation, the Department indicated its intention to separately manage the crystal crab fishery and obtained support from the Minster for Fisheries to consult with existing licencees regarding how this fishery should be managed. Existing licencees were subsequently advised of the Department's intentions by letter. This letter in part said: "It is envisaged that, depending on the number of applicants, access will be granted to those who best demonstrate a financial and personal commitment to the ongoing development of their nominated fishery." A subsequent letter of 18 June 1999 referred to access being granted to "those who best demonstrate a personal and financial commitment to developing a sustainable, market-orientated snow (crystal) crab fishery."

The Department subsequently warned fishers that investment in the crystal crab fishery was at their own risk. A number of risks have been associated with the initial process. Those with an interest in the fishery may have demonstrated their financial commitment to fishing for crystal crabs by arranging to buy, build or otherwise secure vessels suitable for deep-sea crab fishing. Basing eligibility for access to the fishery on financial commitment created the potential for over-capitalisation in an unproven fishery of unknown capacity. Ultimately seven permit holders were authorized to take crystal crabs on the west coast (the original six plus one who secured an endorsement through a formal objection process).

In December 1999 regulations were gazetted preventing fishers bringing ashore or selling only parts of a deep-sea crab. These regulations were designed to discourage the increasing practice of rock-lobster fishers retaining only the large claws from champagne crabs. While these fishers believed that this practice was conserving the breeding stock, the Department was of the view that there was likely to be a high mortality in crabs that had their claws removed.

In August 2000, to ensure the west coast fishery was not overexploited during this development period, the Minister for Fisheries agreed in principle to the Department negotiating arrangements that would allow only three of the seven west coast endorsement holders to fish full time while the other four could fish for a maximum of three months. The intention of this arrangement was to give all fishers the opportunity to fish for deep-sea crabs should they so wish with the understanding that whether they fished or not, all seven permit holders would have equal access at the end of the developmental phase. The proposal also provided for the fishers to contribute aggregate funds of around $A22 000 a year for research to ascertain the capacity of the fishery. It also incorporated a voluntary management policy that was agreed to by the majority of the seven west coast fishers on the understanding that the Department would subsequently develop a formal interim management plan. These arrangements also provided for the existing zoning of the fishery. The proposal was eventually agreed to by the fishers and formalized by being signed by the majority of fishers in May 2001.

It was recognized that, while documenting the agreed arrangements for operation of the fishery, the signed agreement might be unenforceable in law. During 2001 and 2002 the Department continued to liaise with west-coast fishers and other stakeholders about incorporating these arrangement into a formal interim management plan.

An interim Management Plan for West Coast Deep-Sea Crab Fishery was introduced in January 2003. The plan divides the fishery on the west coast into five zones (Figure 1):

Zone 1 – from the WA/NT border to North West Cape (south of Exmouth)
Zone 2 – from North West Cape to Carnarvon
Zone 3 – from Carnarvon to Geraldton
Zone 4 – from Geraldton to Fremantle and
Zone 5 – from Fremantle to Cape Leeuwin (north of Albany).

The Interim Management Plan endeavours to place limits on fishing pressure while distributing effort as widely as possible over the grounds to expand the knowledge of the fishery's extent. At the end of the interim management phase it is anticipated that data on the biology, spatial extent of the stock and its robustness to fishing pressure, will enable a rational approach towards exploitation of the resource.

Under the Interim Management Plan there are seven permits. Permits are issued as a full time, 'Class F', or part time, 'Class P' permit, in the latter case prohibiting the holder from fishing more than three months in the year. The Interim Management Plan restricts operations in the fishery to permit holders, creates five zones in the fishery (Figure 1), restricts the number of permit holders in each zone (a maximum of one Class F and one Class P or two Class P), provides for annual permit fees and controls the type and number of the traps used. Fishers are only permitted to retain deep-sea crabs. Although this part of the Interim Management Plan is currently being contested at this stage there is remarkably little bycatch. There is also provision for the Executive

Director to close all, or part, of the fishery for any period during the operation of the Interim Management Plan.

Under the interim plan the masters of authorized boats in the fishery are required to supply the Department with daily records detailing the number of traps used, location fished, catch details (numbers, weight, size and sex) and species caught (including bycatch). Fish processors are also required to provide records related to crab processing to the Department.

Currently the interim plan expires on 31 December 2004. At that point the Department will review the management arrangements and long-term sustainability prospects for the fishery before proposing any replacement legislative instruments for the ongoing management of the fishery.

2.2. The South Coast

Development of the crystal crab fishery on the south coast of the state has taken a different course to the west coast. The south coast has a long history of diversified fishing operations. Rock-lobster licencees generally hold other fishing authorisations and rarely depend on a single fishery for their livelihood. This contrasts with the west coast rock-lobster fishery where many rock-lobster vessels are exclusively used for rock-lobster fishing. With crystal crab resources unproven on the south coast there was initially little interest in creating a separate crystal crab or deep-sea crab fishery. Most of the 26 endorsement holders were satisfied with deep-sea crabs remaining an incidental by-product of rock-lobster fishing operations. This changed in 2002 when one of the west coast licences was reported as being on the market for a price in excess of $A2 million and a number of south coast licences were sold to those interested in exploiting the southern crystal crab stock.

A sudden interest in fishing for crystal crabs on the south coast led managers to become concerned about the considerable latent effort in the fishery. It was apparent from the inquiries received that potential investors had very optimistic views about the earning potential of the fishery; some saw this potential new fishery as comparable to the large North American snow crab fisheries. It was also apparent that some of the existing south coast endorsement holders, realizing that the fishery might only be able to support a few full-time vessels, and being aware of the growing outside interest in the fishery, wanted to take steps to secure "pioneer rights" in the fishery. Together these factors were creating a 'gold rush' scenario with a number of operators scrambling to secure licences and gear up for crystal crab fishing. While the current size limits ensure maintenance of breeding stock and biological sustainability it was recognized that without well-considered controls in place there was the potential that the crystal crab fishery would be rapidly depleted to levels that were not economically viable. It also appeared that many of the existing 26 endorsement holders would seek to transfer the endorsement to new licencees who were planning to acquire new vessels to fish for crystal crabs on the south coast and there was a serious risk of substantial overcapitalisation in the fishery.

Without any knowledge of the size or productivity of the crystal crab resource to provide a base for setting management controls, fishing for crystal crab was suspended for one year and since then a second year (until 14 November 2004). This moratorium is to allow research fishing to be undertaken to assess the spatial extent of the resource, which in turn will allow appropriate catch or effort limitations to be determined for the fishery. It also dampened interest in new investment in the fishery and helped reduce the risk of overcapitalization.

Funding has recently (September 2003) been approved for a fishing protocol involving a series of cross-shelf slope transects along each line of longitude using traps at 50 m depth intervals, from 300 to 1 500 m. The commercial fishers who assist with the research will be able to fish for a limited time period between the lines of longitude that have been surveyed. This will allow for the relative abundance of crystal crabs to be assessed over the potential commercial fishing ground in this zone and will provide some income to participants in the offshore transect surveys. Three fishers have undertaken to participate in these surveys and they will be required to comply with the same minimum size and trap-type restrictions in place on the west coast. Subsequent management arrangements relating to this fishery will be dependent on the results from the planned experimental fishing.

3. FISHING METHODS

Under the WCDSCIMF plan, fishers are restricted to a maximum of 700 traps in the water at any time. Fishers use moulded plastic rock-lobster traps with a 5 kg flat piece of metal wired to the base of the trap to provide ballast. A side slat is removed to provide one or more escape gaps (56 mm high and 137 mm long) for undersized crabs to escape. The traps are usually set on longlines of approximately 100 traps a line and are baited with fish. The traps are generally left soaking for three to seven days before retrieval and approximately 400–500 traps (four to five longlines) are pulled a day.

Biological restrictions require that all crabs smaller than 120 mm carapace width (approx 700 g), as well as egg bearing females, must be returned to the sea. As most females are below the legal minimum size and the catch in the crystal crab fishery is male-dominated. Fishers are required to submit daily log book catch and effort data for each line of traps fished.

4. RESEARCH

4.1 Objectives

Research objectives have been directed towards obtaining relevant information that will enable decisions to be made on the future of the fishery on the west coast once the interim management period is over and on the south coast once the moratorium period is over. On the west coast this means that research has focused on:

i. the collection of detailed information on catch and effort of commercial sized crabs, as well as undersize and egg-bearing females
ii. the tagging of several thousand legal and sub-legal sized crabs to provide data on movement and growth patterns and
iii. spreading effort and catch in an organized way (by way of the five management zones) to record the longshore extent of the fishery and test its robustness to fishing pressure.

4.2 Distribution and reporting of catch and effort

Commercial crystal crab fishing has focused on the central and southern portion of the grounds. Since 2000 there have been three boats fishing full time and two have operated irregularly on a part-time basis, although this is currently (November 2003) changing, with some previously dormant part-time licences being activated. Most of the fishing has taken place in Zones 2 to 5. There have been a few relatively short trips by permit holders to Zone 1 and although some crystal crabs were landed in that zone in the vicinity of Exmouth (Figure 1), the quantities were non-commercial. Results form exploration in this zone have been inconclusive in providing a solid basis for evaluating the zone's potential, therefore it has not been considered further in the analysis presented here.

Fisheries law in Western Australia requires that all commercial fishers complete monthly catch and effort statistics (CAES) using a 60 X 60 nautical mile grid system to report catch locations. Since 1999 fishers in this fishery have, in addition to CAES data, also been required to complete log books which record accurate global positioning system (GPS) line start and end positions of the longlines, discarded catch (i.e. numbers of undersize, ovigerous, soft and dead animals); bycatch and surface current speed and direction. Catch and effort data presented is a combination of these two data sources.

4.3 Extent of the grounds by zone

To date (November 2003) most commercial fishing for crystal crabs in Western Australia has been within the 500 to 1 000 m depth range. In most years, over 90% of the catch has been made in the 500 to 800 m depth range.

A comparison of the area of available fishing ground has been provided in Table 1 for Zones 2 to 5. The area of ground between the 500 and 1 000 m depth contours has been estimated in square kilometres by GIS software for each of the management zones on the west coast and for the SCDSCF (Table 1). The percentage of available ground has also been calculated by dividing the total area available in the west coast fishery by the area potentially available in each individual zone on the basis of depth. No attempt has been made to provide the proportion of available fishing ground for Zone 1, or for the SCDSCF, because in both of these zones there is a lack of evidence of the grounds having an extensive presence of crystal crabs. The amount of fishing ground in all of the zones is variable (Table 1). Of the total area of Zones 2–5, Zone 3 contains about half the area of the fishery, i.e. seabed between 500–1 000 m.

TABLE 1

Estimated areas ('000 km^2) covering the 500–1 000 m depth zones in Zones 1 to 5 of the WCDSCIMF and SCCF in Western Australia, and the proportion of fishing ground in Zones 2 to 5 of the crystal crab fishery on the west coast

Area calculations for Zone 1 exclude rises in the 500–1 000 m zone offshore from the shelf break.

WCDSCIMF

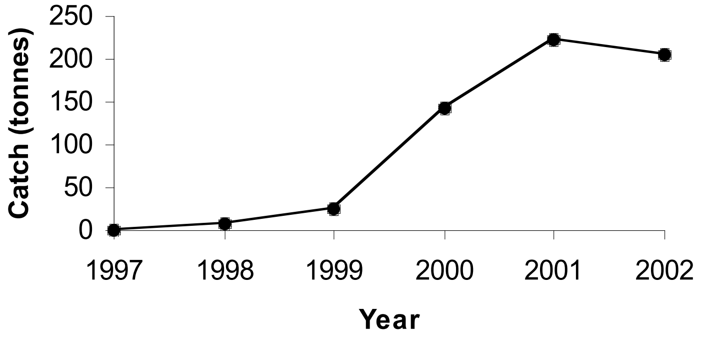
Zone	Area ('000 km^2)	% of available ground
1	65	-
2	13	26.5
3	24	49.0
4	6	12.2
5	6	12.2
Total	114	
SCDSCF	31	-

4.4 Total catch, effort and CPUE

Significant landings of crystal crabs started in 1998 on the west coast (Figure 2). Effort has to a large extent tracked catch. The only years with crystal crab landings of any consequence on the south coast were 2001 and 2002 when 0.7 and 10.8 tonnes respectively were landed.

FIGURE 2

Annual catches of crystal crabs 1997 to 2002 in the WCDSCIMF



Catch per unit effort (CPUE)for the WCDSCIMF is presented in Figure 3. Reliable effort data is only available from 1999 onwards, therefore CPUE data are also limited to this period. Catch rates started low while fishers learned the optimal fishing depths and the best way to deploy gear. Catch rates peaked in 2000 and have since declined.

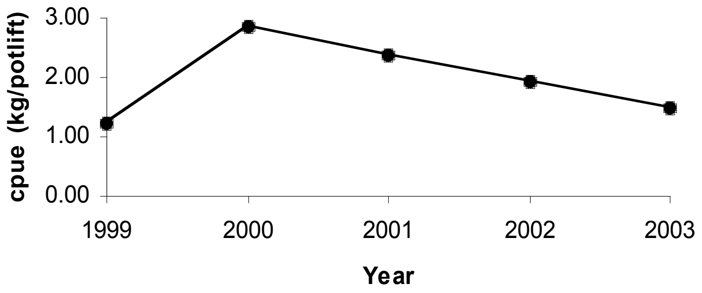
4.5 Depletion and tagging studies

Attempts at depleting locations by repeatedly setting traps over a relatively small area of the grounds (1.7 km^2), have shown that there is rapid localized movement of crabs into depleted areas. It appears that crabs move over the grounds and do not remain within specific home ranges. Preliminary tagging results have shown that there are extensive movements, with some tagged individuals being recorded as moving over 100 km within a year. Growth is likely to be slow, with many tagged crabs having been at large for well in excess of a year without recording a moult.

FIGURE 3

Annual CPUE for crystal crabs 1999 to 2002 in the WCDSCIMF

Catch rates in 2003 are based on incomplete data.



4.6 Deciding on future catch or effort levels for crystal crab

At this stage, without data, nothing can be stated about possible total allowable catch (TAC) or effort limitations on crystal crab fishing on the south coast. In terms of crystal crab fishing in the WCDSCIMF, existing data will at least provide the basis for establishing future management arrangements. For example, several facts seem clear.

i. Based on current information that includes only limited fishing effort in Zone 1 of the fishery, the commercial fishery essentially extends from Zones 2 to 5, with the major portion of the stock in Zones 2 and 3 (data excluded to protect the confidentiality of individual fishers).
ii. Quantities of commercial-sized crystal crabs appear to be restricted to the 500–1 000 m depth zone.
iii. Relative area of grounds encompassed by Zones 2 to 5 are variable, with Zone 3 covering approximately half of the available fishing ground.
iv. The current large legal minimum size (120 mm CW) makes this a highly male dominated fishery. With size at maturity for both sexes being well below the legal minimum size (size at maturity for females is 89.6 mm and for males 84.1 mm CL [Kim Smith, Murdoch University, Australia, pers. comm.]), there would appear to be little chance of recruitment overfishing of the stock whilst the current minimum size is maintained.

It now appears, in the light of the declining catch rates over time as recorded in Figure 3, that the size and potential productivity of this fishery may be limited. The WCDSCIMF is, as a way of acquiring basic commercial information (e.g. catch rates, product marketability and market prices) and biological information (e.g. fishing localities and depths, size composition/sex ratio data, movement patterns and response of the stock to fishing pressure), necessary for long-term management arrangements.

Landings to date suggest that the fishery is not capable of supporting seven full-time fishers. Markets for the crabs have been shown to be good, but limited. Fishing operations show that there are benefits on the open sea to maintaining zones that separate fishers and thereby avoid gear entanglement.

Setting an appropriate total allowable catch (TAC), or a notional TAC with an associated total allowable effort (TAE), designed to achieve the TAC at the end of the interim management phase will be difficult and an adaptive management regime will be required. The time series of fishing is too short to apply traditional biomass-dynamic models leaving only less sophisticated sustainable-yield models. In addition, crabs tagged in this project appear to have extended intermoult periods and therefore the growth information available will be incomplete.

One preliminary indication of the likely maximum sustainable yield (MSY) for crystal crabs in the WCDSCIMF has been made using Gulland's (1971) adaptation to the Schaefer (Schaefer 1954) model:

$$MSY = 0.5(M)B_0$$

where

M = natural mortality

B_0 = biomass of an unexploited population.

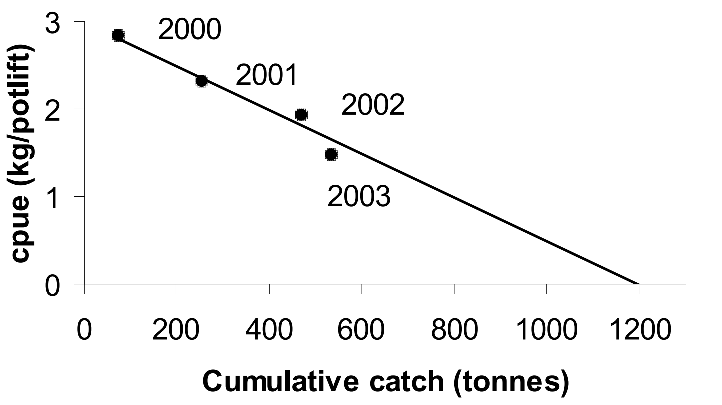
This method of estimating maximum sustainable yield has been, and continues to be, used by fisheries managers working in data-limited situations (Sparr, Ursin and Venema 1989), despite the acknowledged shortcomings of the assumptions behind the relationship (Beddington and Cooke 1983, Garcia, Sparre and Csirke 1989).

An initial estimate of B_0 for the exploitable portion of the WCDSCIMF biomass has been made by treating four years of catch and effort data as a depletion experiment (DeLury 1947) and by assuming that minimal recruitment and mortality has occurred over these years. For the purpose of this estimate of B_0, catch and effort data prior to 2000 has been excluded. This has been justified on the basis of catches prior to this date being comparatively small compared to subsequent years as well as to the fact that the low CPUE values prior to 2000 were probably due to fishers learning how, and where, to fish for this species. If changes in CPUE since 2000 are accepted as reflecting depletion of the unharvested biomass, then extrapolation of the rate of depletion would suggest that the original fishable biomass might have been of the order of 1 200 tonnes (Figure 4).

FIGURE 4

CPUE for 2000–2003 for Zones 2 to 4, plotted against the cumulative catches reported for those zones

Year 2003 is based on incomplete data.



There is no certainty regarding the natural mortality rate for this species. However, tagging results and temperature measurements taken using archival temperature recorders show this to be a cold-water species that is likely to be slow growing and long lived and therefore likely to have a low rate of natural mortality. Cobb and Caddy (1989) have suggested a general value of M for long-lived crabs and lobsters of around 0.1; other authors working on *Chaceon maritae*, a species with apparently similar maximum size and growth characteristics to *Chaceon bicolor*, have used a range of natural mortalities. Melville-Smith (1988) used 0.05 to 0.15 for both sexes, while Le Roux (1997) used 0.05 to 0.15 for males and 0.15–0.25 for females. This fishery targets large, predominantly male animals, and therefore a low value of natural mortality (M=0.05) has been assumed to be most realistic for the maximum sustainable yield (MSY) estimates reported below.

Given the above estimates for B_0 and M, then using Gulland's (1971) process for calculating MSY, one may estimate that this fishery might have an MSY of around

30 tonnes a year. It should be noted that estimates of depletion from CPUE over four years (Figure 4) would have led to an overestimate of B_0, because an obvious incorrect assumption has been made that there was no recruitment to the size classes being fished over this period. Further, it is generally accepted (Garcia, Sparre and Csirke 1989) that this method is likely to overestimate MSY. However, countering this possible overestimate of MSY is the fact that fishers tended, at least in the first few years of fishing, to treat crabs of some sizes that were well within the accepted size limit as discards and release them live back onto the grounds. Also, M has been assumed to be negligible over the four-year period of depletion.

It is important to stress that the above estimate of MSY for crystal crabs in the WCDSCIMF should be viewed as no more than a preliminary reference benchmark. The estimate for natural mortality is particularly crucial to the above result. For example, if $M = 0.1$ and B_0 is kept at 1 200 tonnes, then using the same equation, MSY would be as high as 60 t; however if $M = 0.025$, then MSY would be only 15 tonnes.

In the light of the limited information available, this fishery would appear to be capable of withstanding exploitation levels of around 30 tonnes a year and unless different information becomes available before then, a TAC or effort controls to produce landings of this level are likely to be proposed when the interim fishery is reviewed in December 2004.

5. FUTURE MANAGEMENT SCENARIOS FOR THE WEST AND SOUTH COAST FISHERIES

The Department of Fisheries' current proposal for the WCDSCIMF is that once the Interim Management Plan has run to term, all existing permit holders will have equal access to the fishery. Those that are fishing during the interim management period are seen as enjoying the benefit of profits from a previously unfished stock as well as bearing the risks of capital expenditure in a fishery with unknown capacity. Those permit holders that do not participate during the interim management period have none of the potential benefits or risks, yet maintain their stake in the fishery should it turn out to be a profitable venture in the future. From a management point of view this has been beneficial as it has encouraged enough effort to explore the fishery but has prevented the gearing up of additional fishing capacity without justification, yet has allowed fishers with existing rights to retain their stake in the future fishery by not fishing in the early exploratory years.

The allocation of fishing rights for crystal crab in the SCDSCF is yet to be determined. If any new fishing area for crystal crabs were allocated to existing participants in the SCDSCF an increase in fishing effort would be unlikely to threaten the biological sustainability given the existing minimum size. However, there is the potential for catch rates to be reduced to levels that are not economically viable to fish on an annual basis.

A number of lessons have been learnt from the WCDSCIMF and there are problems that will require addressing when the fishery moves to full management. These follow.

(i) Issuing one full-time licence for each zone has been successful and has provided good information on which to base future management decisions; the issue of additional licences – in this case for fishing by part-time operators – has been less successful and although it has given all seven licence holders the opportunity to fish, it has created the potential for gear entanglements at sea (a particular problem because of the many kilometres of rope used in this fishery) and dissent between part and full-time fishers in those zones. Alloving more than one fisher for each zone where the fishery spans a narrow margin of the continental shelf within a fishing zone has not been successful and would not be readily applied in the future.

(ii) As a measure to ensure compliance with s250 of *the Fish Resources Management Act 1994*, the Department of Fisheries Western Australia has a policy precluding the release of data to which fewer than five fishers have contributed, without their consent. It will be necessary to resolve confidentiality issues to ensure an effective consultation process in the consideration of future management options and ongoing management of confidential information concerning the fishery.

(iii) The current minimum size is relatively large and was chosen by the industry because crabs of this size and above were considered to be the most marketable. Though crabs smaller than 120 mm CW can be sold, the price is low (Denis Gaunt, Pristine Fisheries Pty Ltd., Australia, pers. comm.). The current minimum size may not be optimal in terms of yield-per-recruit, but may be optimal based on economic value. At this time there are no plans to change the minimum size.

(iv) Given the indicative landings in the future (around 15–60 tonnes compared to around 200 tonnes a year at present, it will not be feasible for seven fishers to fish full time. Several options therefore exist as to how future sustainable yields might be split up and fished by participants in a management plan. To get to that point, however, it will be necessary to consult with the permit holders as to whether they wish to fish the stock on the basis of small but regular annual landings or larger, but less frequent, episodes of pulse fishing.

6. ACKNOWLDEDGEMENTS

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Diets and feeding habits of three halibut species in the northwestern Pacific

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1. INTRODUCTION

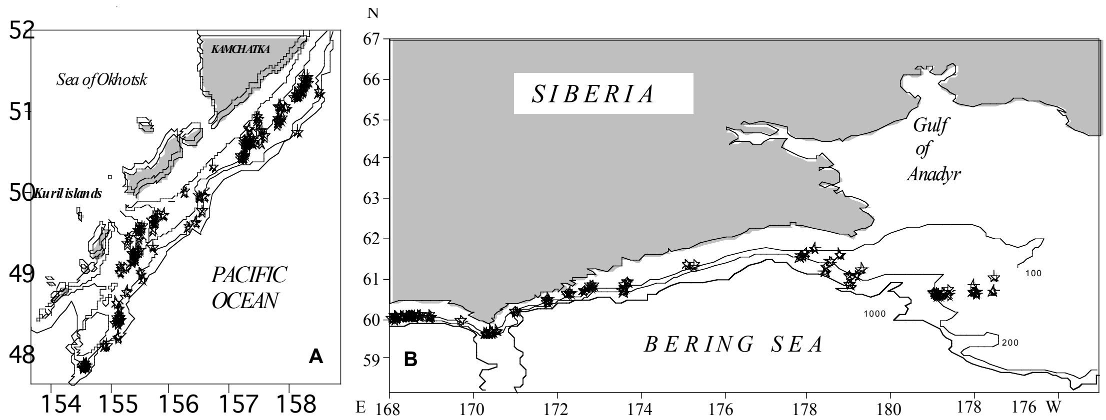
Pacific black (Greenland) halibut (*Reinhardtius hippoglossoides matsuurae*), Kamchatka flounder (*Atheresthes evermanni*), and Pacific halibut (*Hippoglossus stenolepis*) are important fishery species in the North Pacific Ocean (Fadeev 1984, Kramer *et al.* 1995) that consume commercially important species, e.g. walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), saffron cod (*Eleginus gracilis*), Pacific herring (*Clupea pallasii*), Japanese sardine (*Sardinops melanostictus*), capelin (*Mallotus villosus*), Pacific sand lance (*Ammodytes hexapterus*), Atka mackerel (*Pleurogrammus monopterygius*), sandfish (*Trichodon trichodon*), arrowtooth flounder (*Atheresthes stomias*), yellowfin sole (*Limanda aspera*), sculpins (Cottidae), salmons (*Oncorhynchus* spp.), eelpouts (*Lycodes* spp.), snailfishes (*Liparis* spp.) and invertebrates (Fadeev 1984, Best and St-Pierre, 1986, Brodeur and Livingston, 1988, Livingston *et al.* 1993, Yang 1996, Yang and Nelson 2000, St-Pierre and Trumble 2000). They play an important trophic role in ecosystems of the North Pacific basin though the ecology of these species in the western Bering Sea and in Pacific waters off the northern Kuril Islands and southeastern Kamchatka is poorly known.

The feeding habits of halibut in the western Bering Sea have been investigated by Vernidub and Panin (1937), Vernidub (1936, 1938), Novikov (1974) and Shuntov (1966). Recently published papers on feeding and ecology of four halibut species in the western Bering Sea deal mostly with food rations and seasonal changes of feeding intensity (Napazakov and Chuchukalo 2001) or the diet of Pacific halibut (Chikilev and Palm 2000). Other publications have dealt with the feeding habits of the species in the Kuril-Kamchatka area (Novikov 1974, Orlov 2000). However, descriptions of diet in these papers were based on the frequency of occurrence of dietary components in stomachs. A recent paper by Moukhametov (2002) mostly concerned food rations of Pacific halibut. No studies have been conducted recently of the feeding of Greenland halibut, Kamchatka flounder, and Pacific halibut based on quantitative data on stomach contents in the northwestern Pacific. This paper describes diets depending on size, sex, depth of capture and area, of three halibut species inhabiting the western Bering Sea (WBS) and Pacific waters off the northern Kuril Islands and southeastern Kamchatka (NK).

2. MATERIAL AND METHODS

The stomach contents of Pacific black halibut, Kamchatka flounder and Pacific halibut were sampled aboard the Japanese trawlers **Kayo Maru No. 28** and **Tomi Maru No. 82** during the summer and autumn of 1997. The study area in the western Bering Sea (WBS) was between 168° E and 178° E and off the northern Kuril Islands and southeastern Kamchatka (NK) between 47° 55´ N and 51° 40´ N (Figure 1). The trawl had a soft ground rope; vertical and horizontal openings were about 5 and 25 m respectively. Fishing was carried out around the clock. Stomach contents were sorted, identified to the lowest possible taxonomic level and weighed to the nearest 0.1 g. Prey groups were described in terms of percent total stomach content weight (%W) and frequency of occurrence (%FO). The frequency of occurrence was calculated as the number of stomachs that contained that prey group divided by the number of stomachs that contained food. Fishes showing signs of regurgitation, flaccid or water-filled stomachs or net-feeding were excluded from the analysis. Fork lengths (FL) were measured throughout.

FIGURE 1
Study area showing bottom trawl stations (hollow asterisks) where stomachs of Greenland halibut, Kamchatka flounder, and Pacific halibut were sampled
A – northern Kuril Islands and southeastern Kamchatka, B – western Bering Sea (lines and numbers show isobaths in metres)



The number of stomachs used in the analysis was: Greenland halibut 589/411 and 203/93 in the WBS and NK, respectively; Kamchatka flounder 446/184 and 1443/300 in the WBS and NK, respectively; Pacific halibut 262/206 and 386/270 in the WBS and NK.

3. RESULTS AND DISCUSSION

3.1 General description of diets

The diet of all three species consisted of a wide spectrum of items (Table 1). Total number of identified organisms in stomach contents of Greenland halibut was ≥ 29, for Kamchatka flounder, ≥ 31 and of Pacific halibut, ≥ 45. The diet of Greenland halibut in the WBS consisted mostly of fish offal (44.4%W), fishes (42.5%W) and cephalopods (13.1%W). Walleye pollock was the major fish species consumed (30.8%W) followed by Pacific herring (8.9%W). Red squid (*Berryteuthis magister*) (11.2%W) was most common cephalopod prey. In the NK Greenland halibut consumed mainly cephalopods (73.6%W), small crustaceans (10.6%W), shrimps (8.5%W) and fishes

(7.3%W). Red squid (69.4%W) was most common prey among cephalopods but the northern smoothtongue (*Leuroglossus schmidti*) was the most important fish prey (3.3%W). Differences in diet composition between the areas may be explained by the larger size of WBS fish (69.30 cm vs. 58.62 cm) and regional faunistic distinctions.

During the period 1930–1960s walleye pollock composed the bulk of Pacific black halibut diet in the western Bering Sea (Vernidub and Panin 1937, Gordeeva 1954, Novikov 1974). There was no fishery offal in the diet because the Russian walleye pollock fishery there had not developed yet (Shuntov *et al.* 1993). Red squid was also the most important dietary component of this predator in the NK area (Novikov 1974, Orlov 2000).

The diet of Kamchatka flounder in the WBS consisted mostly of fish offal (53.4%W), fishes (33.3%W) – mainly walleye pollock (15.5%W) and Pacific herring (10.4%W) and cephalopods (12.7%W) mainly red squid (11.9%W). In the NK this species eat mainly shrimps (53.7%W), various fishes (26.3%W), and cephalopods (18.6%W). Walleye pollock (5.1%W) was the most important fish in the diet of Kamchatka flounder off the northern Kuril Islands and SE Kamchatka. Mesopelagic fishes ranked second (approximately 2.4%W) followed by spectacled sculpin (*Triglops scepticus*) (2.2%W). Differences in diet composition between the areas may also result from WBS Kamchatka flounders being considerably larger than NK fishes (54.83 and 49.37 cm, respectively).

TABLE 1

Stomach contents of Greenland halibut, Kamchatka flounder and Pacific halibut expressed as percent of frequency of occurrence (%FO) and weight (%W) sampled in the western Bering Sea (WBS) and Pacific waters off the northern Kuril Islands and southeastern Kamchatka (NK), summer–autumn 1997

Prey items	Greenland halibut				Kamchatka flounder				Pacific halibut			
	WBS		NK		WBS		NK		WBS		NK	
	% FO	% W	% FO	% W	% FO	% W	% FO	% W	% FO	% W	% FO	% W
Spongia	-	-	-	-	-	-	0.3	< 0,1				
Coelenterata												
Actiniaria	0.2	< 0.1	-	-	-	-	-	-				
Annelida												
Polychaeta	-	-	-	-	-	-	0.7	0.1	-	-	0.4	<0.1
Echiurida	-	-	-	-	-	-	-	-	-	-	0.4	0.1
Sipunculida	-	-	-	-	-	-	-	-	-	-	1.9	0.3
Crustacea												
Mysidacea												
Mysidacea gen sp.	0.5	< 0.1	-	-	0.5	0.1	1.0	0.6	-	-	-	
Gnathophausia gigas	0.2	< 0.1	-	-	-	-	-	-	-	-	-	-
Euphausiacea												
Euphausiidae gen sp.	-	-	15.1	1.4	-	-	3.0	0.3	-	-	-	-
Isopoda												
Isopoda gen. sp.	-	-	-	-	-	-	-	-	-	-	3.7	0.3
Amphipoda												
Amphipoda gen. sp.	-	-	2.2	< 0.1	-	-	0.7	< 0.1	1.0	<0.1	0.7	<0.1
Ampelisca sp.	-	-	2.2	< 0.1	-	-	-	-	-	-	-	-
Anonyx sp.	-	-	-	-	-	-	-	-	-	-	1.5	0.1
Decapoda												
Pandalus goniurus	1.2	< 0.1	-	-	1.6	0.1	-	-	1.9	0.1	0.4	<0.1
P. hypsinotus	0.2	< 0.1	-	-	1.1	< 0.1	-	-	-	-	-	-
Pandalus sp.	-	-	8.6	1.0	-	-	47.7	29.4	-	-	3.7	1.3
Pandalopsis dispar	0.2	< 0.1	-	-	-	-	-	-	-	-	-	-
Sclerocrangon sp.	-	-	-	-	-	-	0.7	< 0,1	-	-	0.4	<0.1

Prey items	Greenland halibut				Kamchatka flounder				Pacific halibut			
	WBS		NK		WBS		NK		WBS		NK	
	% FO	% W	% FO	% W	% FO	% W	% FO	% W	% FO	% W	% FO	% W
Pagurus sp.	-	-	-	-	-	-	0.3	< 0,1	8.7	1.2	27.0	5.8
Hyas coarctatus	-	-	-	-	-	-	-	-	0.5	<0.1	-	-
Chionoecetes angulatus	-	-	-	-	-	-	-	-	5.8	2.1	-	-
Ch.bairdi	-	-	-	-	-	-	-	-	1.0	0.1	0.7	0.3
Ch. opilio	-	-	-	-	-	-	-	-	10.2	2.4	18.9	6.1
Ch. tanneri	-	-	-	-	-	-	-	-	1.5	0.6	-	-
Majidae gen. sp.	-	-	-	-	-	-	-	-	0.9	0.1	-	-
Decapoda gen. sp.	-	-	-	-	-	-	-	-	-	-	0.4	<0.1
Mollusca												
Gastropoda												
Buccinidae gen. sp.	0.2	< 0.1	-	-	0.5	< 0.1	-	-	3.4	0.5	0.7	<0.1
Bivalvia												
Chlamys sp.	-	-	-	-	-	-	-	-	-	-	0.4	<0.1
Cephalopoda												
Berryteuthis magister	18.0	11.2	62.4	84.8	10.3	11.9	19.1	27.5	20.4	13.6	10.7	12.8
Galyteuthis phyllura	-	-	1.1	1.0	-	-	-	-	-	-	0.4	0.5
Gonatopsis borealis	-	-	-	-	-	-	0.3	< 0,1	-	-	-	-
Teuthidae gen. sp.	1.2	< 0.1	-	-	0.5	< 0.1	-	-	-	-	-	-
Octopus sp.	-	-	-	-	-	-	-	-	-	-	19.3	20.5
Benthoctopus sp.	-	-	-	-	-	-	-	-	-	-	1.5	3.0
Octopoda gen sp.	0.7	1.9	1.1	6.0	1.1	0.8	1.0	3.3	-	-	3.0	0.5
Echinodermata												
Ophiuroidea												
Ophiuroidea gen. sp.	-	-	-	-	-	-	-	-	0.5	<0.1	0.4	<0.1
Teleostei												
Clupea pallasii	12.4	8.9	-	-	8.7	10.4	-	-	15.5	12.9	-	-
Mallotus villosus	-	-	-	-	-	-	0.3	0.9	-	-	-	-
Leuroglossus schmidti	0.2	< 0.1	6.5	1.7	-	-	0.3	0.1	-	-	-	-
Myctophidae gen sp.	3.2	0.1	3.2	0.2	-	-	3.0	2.7	-	-	-	-
Stenobrachius leucopsarus	0.5	< 0.1	-	-	0.5	0.1	0.3	< 0,1	-	-	-	-
S. nannochir	3.4	0.3	-	-	-	-	-	-	-	-	-	-
Salmonidae gen. sp.	-	-	-	-	-	-	-	-	-	-	0.4	2.0
Theragra chalcogramma	19.2	30.8	1.1	3.0	13.0	15.5	2.3	8.9	18.5	18.7	12.6	21.8
Albatrossia pectoralis	0.5	0.9	-	-	-	-	-	-	0.5	0.3	-	-
Coryphaenoides cinereus	0.2	0.1	-	-	-	-	-	-	0.5	0.2	-	-
Leptoclinus maculatus	-	-	-	-	-	-	1.0	0.6	-	-	-	-
Lumpenella longirostris	-	-	-	-	1.1	0.7	-	-	-	-	-	-
Lycodes palearis	0.2	< 0.1	-	-	1.1	1.1	-	-	0.5	0.2	-	-
L. brunneofasciatus	-	-	-	-	-	-	0.3	0.3	-	-	0.4	0.7
Lycodes concolor	-	-	-	-	1.1	1.3	-	-	0.5	0.3	-	-
L. diapterus	0.7	0.2	-	-	-	-	-	-	0.5	0.2	-	-
Lycodes sp.	0.5	< 0.1	-	-	-	-	0.3	0.6	-	-	-	-
Zoarcidae gen. sp.	-	-	-	-	-	-	0.3	3.1	-	-	-	-
Pleurogrammus monopterygius	-	-	-	-	-	-	-	-	-	-	1.9	4.5
Artediellus sp.	-	-	-	-	-	-	0.3	< 0,1	-	-	0.4	<0.1
Icelus sp.	-	-	-	-	-	-	0.3	< 0.1	-	-	-	-
Gymnocanthus detrisus	-	-	-	-	-	-	-	-	-	-	0.4	0.8
Triglops scepticus	-	-	-	-	-	-	1.6	1.6	-	-	1.1	0.4
Cottidae gen. sp.	-	-	-	-	-	-	0.7	2.0	-	-	0.4	0.1

Prey items	Greenland halibut				Kamchatka flounder				Pacific halibut			
	WBS		NK		WBS		NK		WBS		NK	
	% FO	% W	% FO	% W	% FO	% W	% FO	% W	% FO	% W	% FO	% W
Dasycottus setiger	0.2	< 0.1	-	-	-	-	-	-	-	-	-	-
Malacocottus zonurus	-	-	-	-	1.1	0.7	0.3	0.9	1.5	0.3	-	-
Bathyagonus nigripinnis	-	-	-	-	-	-	-	-	1.0	0.2	-	-
Sarritor frenatus	-	-	-	-	-	-	0.7	0.1	-	-	1.5	0.4
Careproctus furcellus	0.2	< 0.1	-	-	-	-	-	-	-	-	-	-
Elassodiscus tremebundus	-	-	-	-	-	-	-	-	1.0	0.4	-	-
Liparidae gen. sp.	0.2	< 0.1	1.1	0.1	-	-	0.7	3.2	-	-	-	-
Hippogliossoides elassodon	0.2	0.2	-	-	-	-	-	-	0.5	0.5	0.4	<0.1
Unidentified teleosts	5.4	0.8	4.3	0.7	14.7	3.6	16.8	13.4	4.9	0.9	15.9	8.2
Fish eggs	-	-	-	-	-	-	0.3	< 0,1	-	-	-	-
Fishery offal	43.3	44.4	-	-	40.8	53.4	-	-	29.6	31.3	7.4	9.3
Unidentified organic material	1.2	< 0.1	-	-	5.4	0.2	-	-	-	-	-	-
Number of stomachs analyzed	589		203		446		1443		262		386	
Stomachs with food	411		93		184		300		206		270	
Length range, cm	43-102		28-91		37-84		23-78		47-154		35-134	
Mean length ± SE	69.30 ± 0.43		58.62 ± 0.99		54.83 ± 0.37		49.37 ± 0.25		73.92±0.76		61.40±1.00	
Weight range, g	730-14200		140-7700		450-6700		100-6600		1.05-56.00		0.33-33.00	
Mean weight ± SE	3537.0 ± 86.2		2385.2 ± 115.1		1828.0 ± 48.5		1452.7 ± 25.4		5.250±0.271		4.001±0.253	

In the 1930–1960s walleye pollock was the most important dietary component of Kamchatka flounder in the western Bering Sea (Vernidub 1938, Gordeeva 1954, Novikov 1974). No fishery offal was detected in stomach contents during previous studies for the same reason as for Greenland halibut. According to Novikov (1974) and Orlov (2000) the most important dietary components of Kamchatka flounder in the NK area were also shrimps, fish and cephalopods.

The diet of Pacific halibut consisted of a wide range of prey. The total number of identified organisms (excluding fishery offal) in halibut stomachs was ≥ 25 in the WBS and 32 in the NK. The diet of Pacific halibut in the WBS area comprised mostly fishes (35.1%W), fish offal (31.3%W) and cephalopods (26.6%W). Walleye pollock represented the major fish consumed (18.7%W) followed by Pacific herring (12.9%W). The most common mollusks were red squid (13.6%W) and octopi (13.0%W).

In the NK, Pacific halibut consumed mainly fishes (38.9%W) and cephalopods (36.8%W). Fish offal in the diet of halibut was less import than in the first area (9.3%W). As was similar to the WBS area, walleye pollock (21.8%W) was most important prey among fishes and octopi were the most significant cephalopod prey (23.5%W). Some differences in Pacific halibut diet composition between the areas may also be explained by the considerably larger size of WBS fish (73.92 cm vs. 61.40 cm).

In the 1930-1960s (Vernidub 1936, Gordeeva 1954, Novikov 1974) walleye pollock composed the bulk of Pacific halibut diet in the western Bering Sea though Vernidub (1936) found crustaceans to be the most frequent prey items. These authors found the occurrence of cephalopods in halibut diet to be insignificant. According to Novikov (1974) the main food items of Pacific halibut in the NK area were fish (27.1%FO), Tanner crabs (16.7%FO) and cephalopods (10.4%FO). Recent studies (Orlov 2000) showed that the most important dietary components were fish following by cephalopods and crustaceans. Most significant prey items among cephalopods were octopi and red squid. Walleye pollock was the most important fish prey species.

3.2 Feeding habits versus size

Diet composition of all three species changed with size (Figure 2). In the WBS, increase in Greenland halibut size was accompanied by an increase of fishes and fish offal and decrease of cephalopods in the diet. In the NK, larger Greenland halibut (size groups 46–80 cm) ate more cephalopods (86.6%W). The role of cephalopods in the WBS fish's diet of the same size group was considerably lower (only 28.0%W). Small NK individuals (FL<45 cm) ate mostly euphausiids, shrimps and fish. The role of fish offal in the diet of WBS Kamchatka flounder increased with size. Fish prey were important for all size groups. Cephalopods played an essential role (34.6%W) in the diet of specimens 41–50 cm long. In the NK an increase in Kamchatka flounder size was accompanied by a decrease in consumption of shrimps and increase of cephalopods and fish.

Considerable changes in the Pacific halibut diet occurred with increasing fish size for both study areas. In the WBS, increase in size of Pacific halibut was accompanied by increased consumption of fishes and decrease of fish offal. The proportion of cephalopods was approximately equal in the diets of various length categories though the importance of red squid decreased and octopi increased with increase of halibut length.

In the NK area variations in length of Pacific halibut were significant. Small fish (<50 cm) ate mostly hermit crabs, small crustaceans (isopods and amphipods), Tanner crabs, shrimps and fish. Hermit crabs in halibut diet decreased with increase in predator length and became insignificant when halibut reached 60 cm in length. Tanner crabs were important in halibut diet in all length categories though their average proportion comprised only 2%W of stomach contents of fish larger than 70 cm. The role of cephalopods, fishes and fishery offal rose with an increase in predator size. The largest fish almost exclusively ate octopi.

Shuntov (1966) documented differences in the occurrence of squids, fishes and invertebrates in stomachs of various size groups for Greenland halibut and Kamchatka flounder. Size-dependent diet differences of Pacific halibut in the western Bering Sea were first described by Napazakov and Chuchukalo (2001) and Novikov (1964) showed differences in the occurrence in stomachs of fishes and invertebrates for three halibut size groups: 30–60, 60–90 and >90 cm. Orlov (1977) reported on distinctions in diet depending on fish size for all three halibut species in the Pacific waters off the northern Kuril Islands and southeastern Kamchatka.

3.3 Feeding habits as a function of capture depth

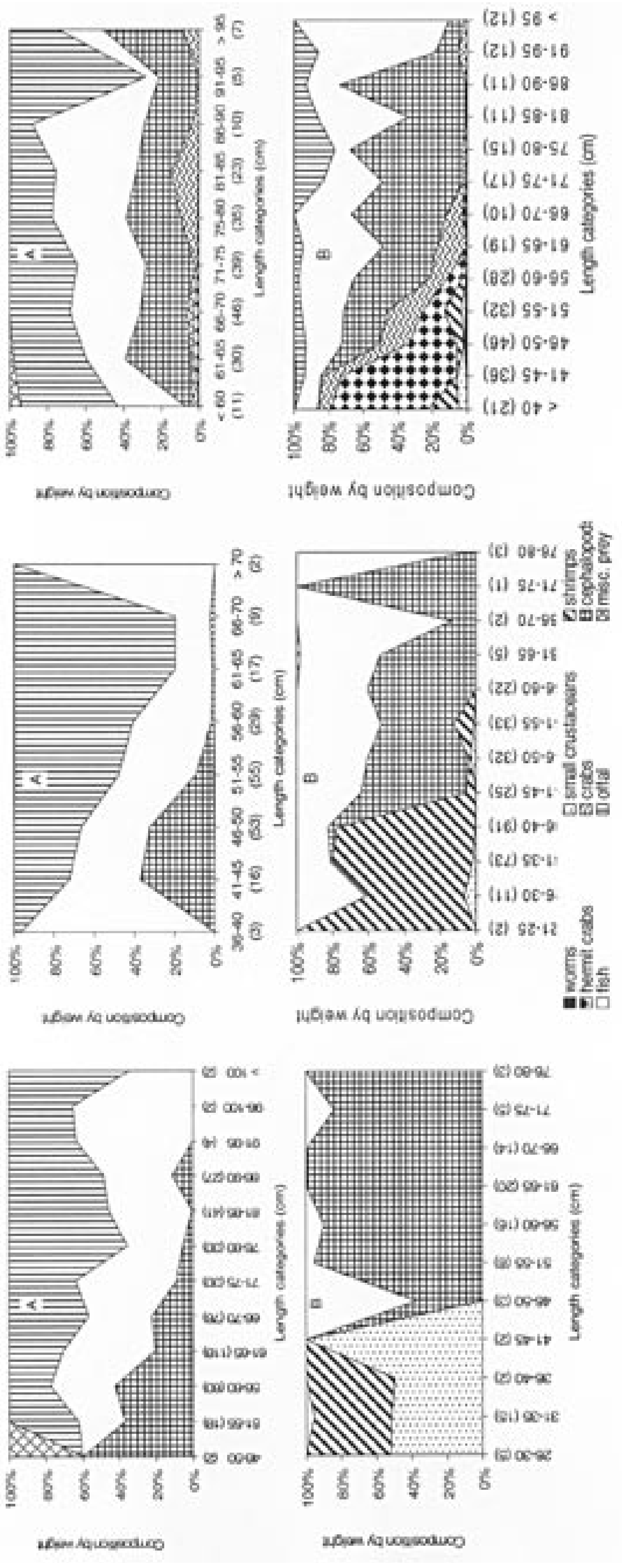
Differences in fish diet by depth were detected (Figure 3): the stomach contents of WBS Greenland halibut at shallower depths consisted mostly of fish offal and fish, mainly of walleye pollock. With increasing depth fish offal decreased from 63.1%W at 201–300 m to 33.1%W at 401–500 m while cephalopods increased from 5.0%W to 26.3%W. In the NK area at shallower depths Greenland halibut ate mostly euphausiids and shrimps and at greater depths, mainly red squid and predominantly mesopelagic fish.

Kamchatka flounders eat mostly fish offal at shallower depths (201–400 m) and mainly Pacific herring, walleye pollock and other fish at greater depths. In the NK this species fed predominantly on shrimp and fish at shallower depths (101–300 m); at greater deeper depths they ate mainly red squid and fish.

The stomach contents of WBS Pacific halibuts at shallower depths consisted mostly of fish offal and fish – mainly walleye pollock. Fish offal decreased from 63.8%W at 251–300 m to 17.5%W at 401–450 m and cephalopods increased from 9.1%W to 47.5%W. The proportion of fishes in the diet of Pacific halibut increased from 23.5%W at 251–300 m to 56.8%W at 351–400 m and subsequently declined to 9.4%W at greatest depths. In the NK increasing depths were accompanied by decreasing fractions of fish in the diet of Pacific halibut while that of cephalopods increased. Fish offal comprised

FIGURE 2

Variation in the main food items of Greenlan halibut (left column), Kamchata flounder (center column), and Pacific halibut (right column), by predator size A - western Bering, B - northern Kuril Island (sample size is shown in parentheses)



9.5–11.1%W of stomach contents at 151–300 m. Hermit crabs were important within all depth ranges (3.7–13.6%W).

3.4 Feeding habits vs. sex

Differences between male and female diets were detected for all three halibut species (Figure 4). Female Greenland halibut in the WBS ate more fish offal (47.5%W) and walleye pollock (35.5%W). Males fed mostly on fish offal (35.2%W), red squid (25.3%W) and Pacific herring (17.6%W). In the NK area Greenland halibut females consumed more fish and red squid while males ate larger amounts of shrimps – 12.3%W vs. 3.5%W for males and females, respectively.

Female Kamchatka flounders in the WBS fed mostly on fishery offal (64.4%W) while males consumed more fishes (50.6%W), especially Pacific herring – 25.1%W and red squid (22.2%W). In the NK, females ate more shrimps (59.8%W) and large fish (27.4%W) while males fed mostly on red squid (26.6%W) and small fish species (25.0%W). Nevertheless, the most abundant prey items of male diets by weight were shrimps – 45.8%.

Female Pacific halibut in the WBS ate more fish offal (36.9%W), fish (31.2%W) and cephalopods (27.1%W) while in male fish diets fish represented 38.0%W, fishery offal – 27.2%W, and cephalopods – 26.2%W. Males consumed no less than nine species while female stomachs contained only four species; the most important components for both sexes were walleye pollock (18.2%W and 19.5%W for males and females, respectively) and Pacific herring (15.2%W and 9.8%W for males and females, respectively). Differences in the proportions of red squid and octopi in male and female diets were also observed – Pacific halibut males eat more red squid then octopi (16.1%W vs. 10.1%W respectively). Females preferred octopi (16.8%W vs. 10.2%W, respectively). In the NK area, Pacific halibut females consumed more cephalopods (42.5%W), fish (31.2%W) and fishery offal (10.8%W) while males ate considerably more fish (45.1%W); cephalopods ranked second in male halibut diets (33.3%W). As for the WBS region, fish found in male halibut stomachs were larger; the main prey of both sexes was walleye pollock. No major differences were detected between male and female consumption of cephalopods, as in the WBS area.

Differences in the diet between males and females are mostly related to size; average size of males in both areas were shorter than females: 63.5 vs. 74.1 cm and 53.8 vs. 55.7 cm for Greenland halibut in WBS and NK, respectively; 52.3 vs. 56.6 cm and 40.9 vs. 42.9 cm for Kamchatka flounder, respectively; and 72.5 vs. 75.9 cm and 59.9 vs. 62.3 cm for Pacific halibut, respectively.

3.5 Feeding habits vs. area

Regional differences were observed in the diets of all three halibut species in the two study areas (Table 2). Fishes (61.4%W) and cephalopods (37.2%W) were more important in the diet of Greenland halibut caught in the western part of WBS while fish offal (59.9%W) and fishes (35.6%) were the most significant dietary components in the eastern part. The diet of Greenland halibut in the NK area changed with increasing importance of small crustaceans and shrimps in the diet and decreasing importance of cephalopods and fishes from south to north.

The diet of Kamchatka flounders in the western part of WBS consisted mostly of fish (71.2%W) and cephalopods (22.7%W); in the eastern part they ate mainly fish offal (73.6%); fish prey ranked second. In the NK area, the importance of cephalopods decreased from south to north while the reverse was true for shrimps. Thus, in the southern part of the study area cephalopods were the most important dietary component (53.7%W), in the mid-part they were second in importance (22.4%W) but in the north, cephalopods were negligible (1.6%W). Shrimp presence increased from 8.6%W in the south to 82.9%W in the north.

FIGURE 3

Variations in the food items of Greenland halibut (left column), Kamchatkaflounder (center column), and Pacific halibut (right column), by depth range A - western Bering Sea, B - northen Kuril Islands (sample size is shown in parentheses)

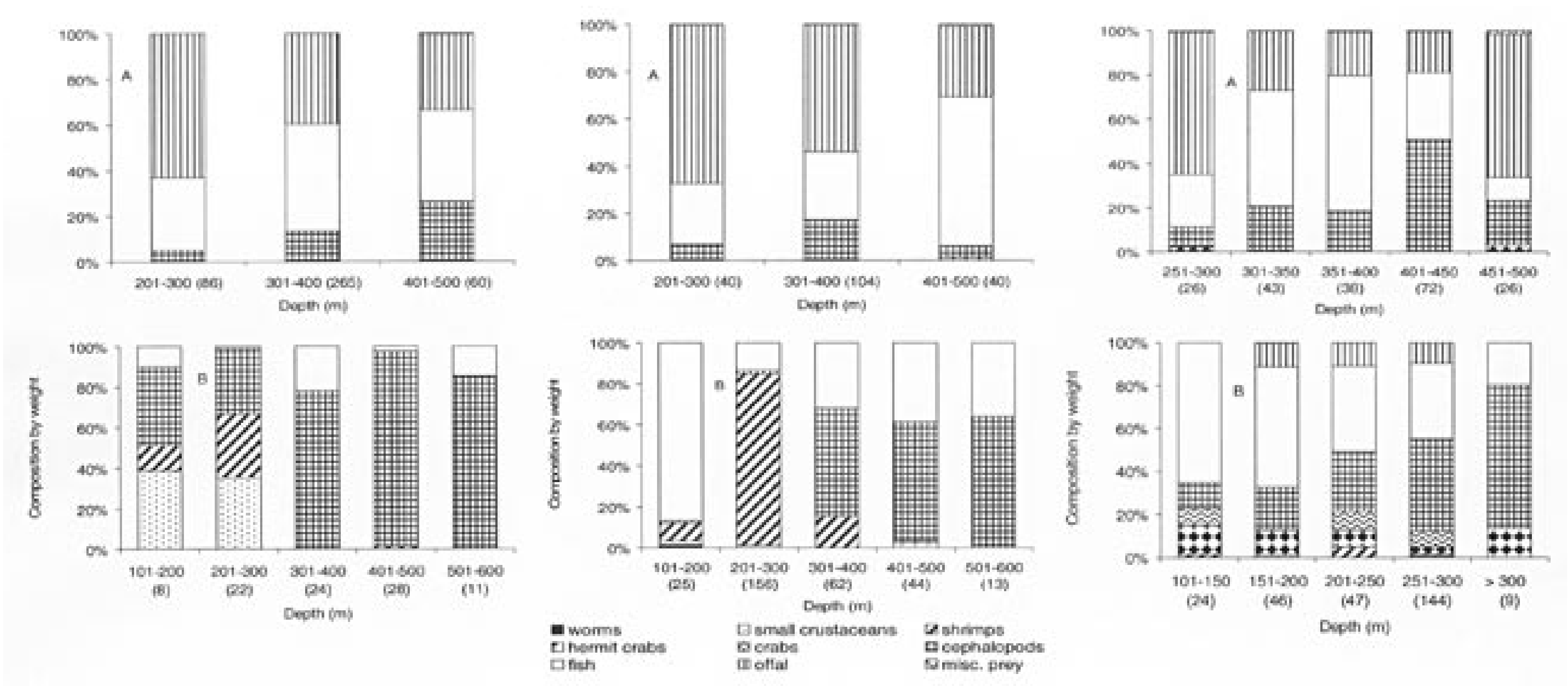
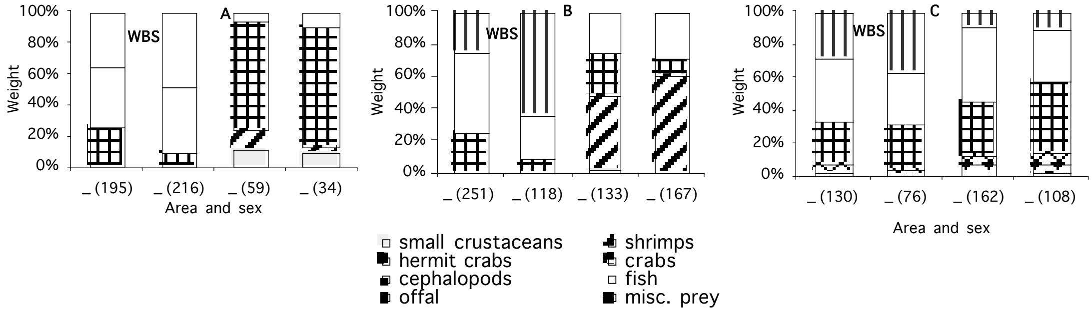


FIGURE 4

Variations in the main food items of Greenland halibut (A), Kamchatka flounder (B) and Pacific halibut (C), by sex

WBS – western Bering Sea, NK – northern Kuril Islands; ♂ – males, ♀ – females (sample size is shown in parentheses)



Fishes (43.9%W) and cephalopods (42.9%W) were more important in the diet of Pacific halibut caught in the western part of WBS while fish offal (67.9%W) and fishes (23.5% W) were the most significant dietary components in the eastern part, where the share of cephalopods in the diet was only 5.3%W. Considerable differences occurred in consumption of crabs in the western and eastern parts of WBS area (8.2%W vs. 1.4%W). The consumption of fish and cephalopod by Pacific halibut in the NK area changed from south to north (fish increased while cephalopods decreased). In the southern NK area, fishes represented 12.6% of the diet, third after cephalopods (46.2%W) and fish offal (19.1%W). In the central area fishes ranked second in importance (37.2%W). In the northern part their significance increased to 41.0%W and they were the most important prey item of Pacific halibut. The importance of cephalopods decreased northward reaching 35.9%W in the northernmost area. Differences in consumption of hermit crabs and fishery offal were also found.

Differences in diet between various parts of NK study areas may be explained by differences in predator size (62.2, 55.2 and 39.4 cm for Greenland halibut; 51.9, 40.3, and 35.9 cm for Kamchatka flounder; and 52.7, 54.9, and 65.2 cm for Pacific halibut in the southern, middle and northern parts respectively) and probably by faunal differences.

Regional differences of halibut diets in the western Bering Sea were first considered by Gordeeva (1954), when the walleye pollock fishery in this area was not developed. Napazakov and Chuchukalo (2001) considered regional differences of halibuts in the western Bering Sea, however, they combined their data from areas east and west of 174 °E, which we consider separately. Moreover, they did not report fish offal among dietary components of halibuts. It is uncertain whether they excluded fish offal from analysis or included it in the category of unidentified fishes. The importance of offal in the diet of all three species in the eastern part of the western Bering Sea (this study) is probably related to the walleye pollock fishery in this area.

TABLE 2
Variations in the main food items of Greenland halibut, by area of samples

WBS – western Bering Sea, NK – northern Kuril Islands.
w – 168° – 174°E, e – 174°E – 178°W, s – 47°50´– 49°30´N, m – 49°35´–50°40´N, n – 50°50´–51°30´N

Food items	Greenland halibut					Kamchatka flounder					Pacific halibut				
	WBS		NK			WBS		NK			WBS		NK		
	w	e	s	m	n	w	e	s	m	n	w	e	s	m	n
Worms									1.1				2.3	0.5	0.2
Small crustaceans			1.4	3.2	40.3	0.5			3.2	1.4				0.3	0.5
Shrimps	0.1			13.2	23.1	0.3	0.2	8.6	11.0	82.9			5.5	0.2	1.4
Hermit crabs											1.2	1.2	9.0	15.0	2.6
Crabs											8.2	1.4	5.3	3.5	7.5
Cephalopods	37.2	4.4	90.0	75.3	33.6	22.7	8.6	53.7	22.4	1.6	42.9	5.3	46.2	40.2	35.9
Fish	61.4	35.6	8.6	8.3	3.0	71.2	17.6	37.5	62.4	14.1	43.9	23.5	12.6	37.2	41.0
Misc. preys		0.1				0.7	0.1				0.4	0.8		0.2	
Offal	1.3	59.9				4.7	73.6				3.4	67.9	19.1	3.0	10.9
Sample size	157	254	45	24	24	95	89	103	41	156	130	76	19	91	160

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Effects of artificial light on trawl catch and behaviour of Greenland halibut in front of trawl

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1. INTRODUCTION

Development of methods for visual surveying in deepwater often rely on the use of constant artificial light. Conclusions relating to vulnerability and other aspects of fish behaviour in front of trawls during normal fishing operations may be biased due to the fish reacting in response to the light. The purpose of this study was to evaluate the effect of light on catch level and catch composition of Greenland halibut (*Rheinhardtius hippoglossoides*) in trawl surveys, and also to determine how the light influences behaviour of individual fish in front of the trawl. We used flash-photos to record behaviour in dark conditions and compared the results with hauls using video and constant artificial light.

2. METHODS

In each of 16 locations, one bottom trawl haul was made with flash-photo equipment and another with video equipment. In addition, several hauls using both types of illumination were made on different locations. The actual angle of the cameras and the area and shape of the ground coverage varied between individual frames. For comparison of flash photos and video frames it was therefore necessary to establish a geographical coordinate image of the trawl from a reference image. Assuming that the shape of the trawl was fixed for all images, a set of corresponding points were established between the reference image and the individual photo and video images. Based on these points, the images were related to the geographical coordinates of the reference image using a non-linear least squares procedure. In addition some Russian data on fish angles of orientation were measured on actual pictures from vertically directed cameras.

3. RESULTS

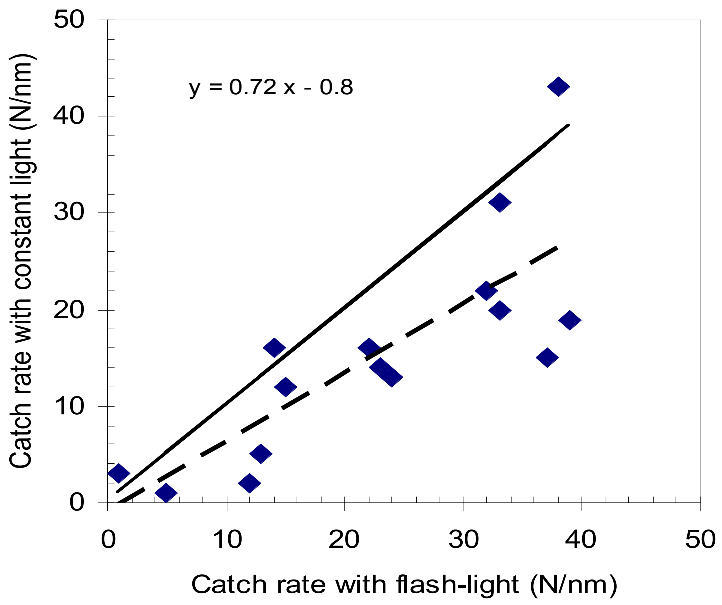
Catch rates, in terms of number of Greenland halibut caught per nautical mile (nm) were 30 percent lower when constant light was used compared with the flash-photo stations (Figure 1). Paired comparison of catches from the trawl experiment showed that the effect was highly significant. The proportional reduction in catch rate due to use of light is similar to the proportion that was observed (on video) escaping under the footrope (Albert *et al.* 2003a).

There was no difference in length or sex composition of the catches with constant artificial light and flashlight respectively (Figure 2). The trawl experiment showed no significant effect of light on mean length in catch.

FIGURE 1

Catch rates of Greenland halibut at individual localities when constant illumination was used (video-stations) as a function of the catch rates using flashlight (photo-stations)

The solid line represents 1:1 catch relation between the two forms of illumination and the hatched line is the fitted linear regression (i.e. correllation)



For Greenland halibut that were observed close to, or on, the bottom, there were no effects of constant light on position of the fish relative to the ground-gear (Figure 3). The Russian flashphotos show some weakening of ordered orientation in comparison with video, but even with the extreme low light levels at 800 m depths during the dark high latitude winter, Greenland halibut showed a distinct ordered orientation away from the trawl. This is not in accordance with previous investigations on flatfish and other ground fish in shallower waters (Glass and Wardle 1989, Walsh and Hickey 1993, Weinberg and Munro 1999). They show in general, and especially at low light levels, only weak ordered reactions of flatfish in relation to an approaching trawl.

There were more fish swimming across the trawl direction when constant light was used (Figure 4). It may be that this increased zig-zag swimming activity increased the probability of their finding an opportunity to escape beneath the ground-rope of the trawl and that this was the main reason for the reduced catch rates of Greenland halibut when using constant illumination.

4. DISCUSSION

Video recording of fish behaviour in deepwater necessitates use of artificial light. Since video generates data that are not possible to achieve with flash-photos, e.g. holding times and links between different observations for individual fish, it is a crucial question to what degree patterns observed on video have relevance to the normal situation, i.e. vulnerability to capture without use of light. The present work indicates that although light reduced catchability, it did not have any major effects on orientation and distribution of Greenland halibut in front of the approaching trawl. Thus, video techniques seems likely to be useful for studying spatial distribution (Albert, Harbitz and Høines 2003b), but they should be accompanied with other methods in catchability, i.e. vulnerability, studies.

The Institute of Marine Research is currently developing methodology for automatic detection and analyses of large amounts of visual data on fish occurrence, position and angles in video and still photography and relating these observations on a common set of true world coordinates. This technique may be potentially useful for quantifying differences in fish abundance in front of trawls when observed with video/constant light and flash-photos respectively and may thus be used to estimate the proportion that escape under ground rope in the absence of light. This may be due to higher escape rates under the foot-rope or to higher degree of avoidance of entering into the trawl mouth area. Previous video recordings have indicated length-dependent escape under ground-gear. If the reduced catch rates in the video hauls were due to large increases in escape rates one would expect reduced mean length in the video hauls.

FIGURE 2

Length and sex composition of Greenland halibut using bottom trawls with flash-light (photo) and constant artificial light (video) illumination respectively

Data from all sites combined.

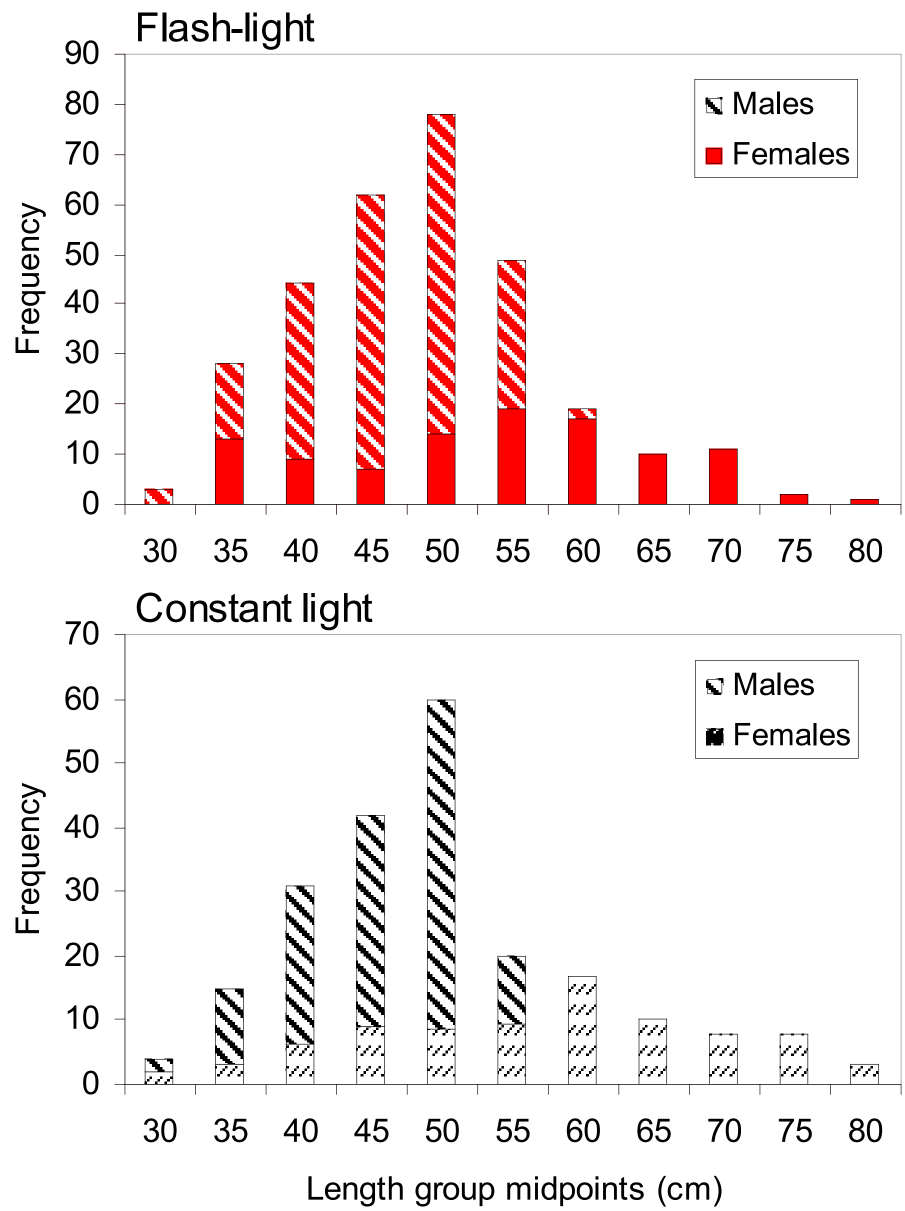


FIGURE 3

Position in real world coordinates of observed Greenland halibut individuals (dots) relative to the ground-gear (solid line)

Data were taken from all photo frames with observations (upper panel) and every fourth video-frame from a 20-minute video recording (lower panel). The shading in each part of the picture is proportional to number of frames covered and so lightening the corresponding part of the sea floor.

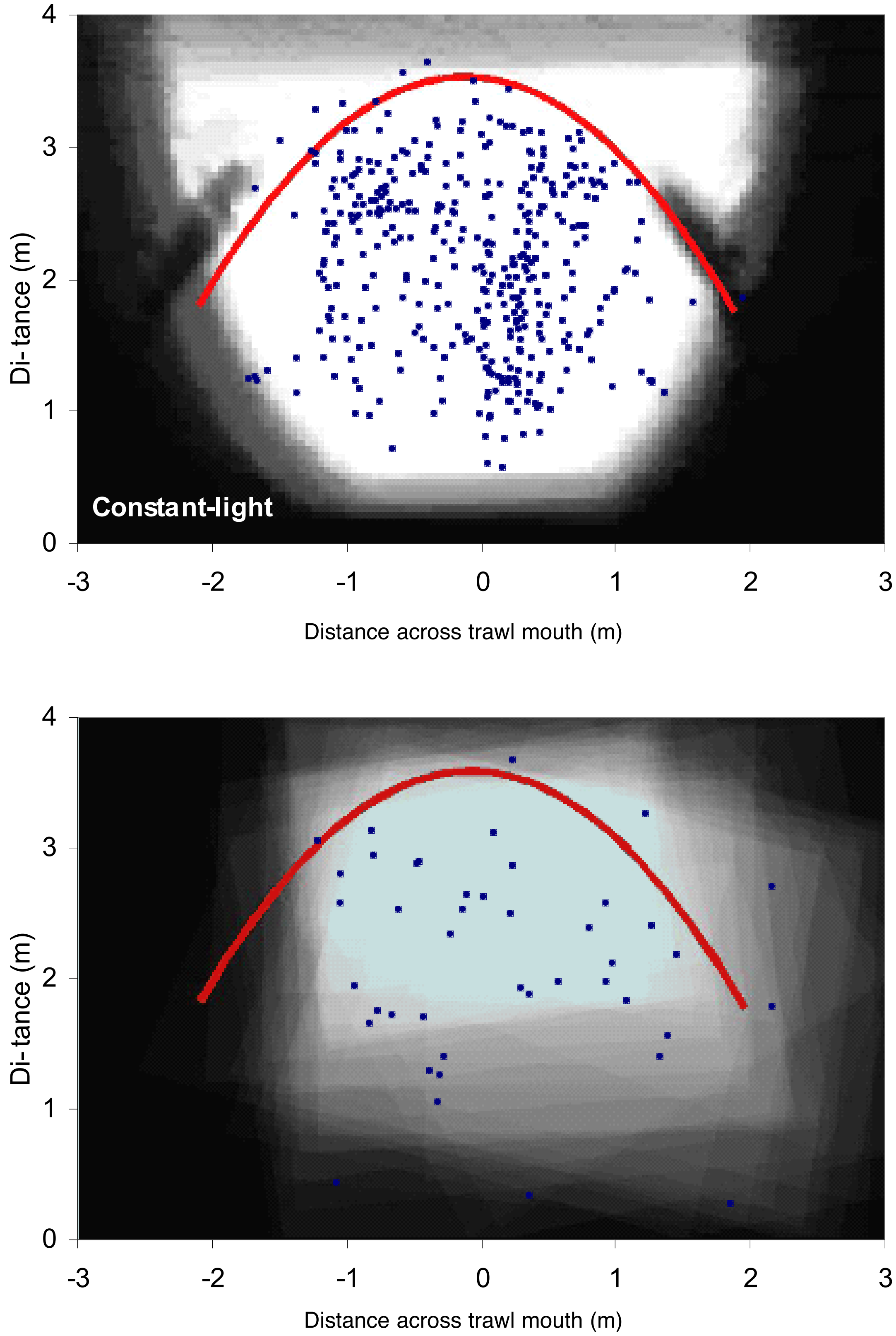
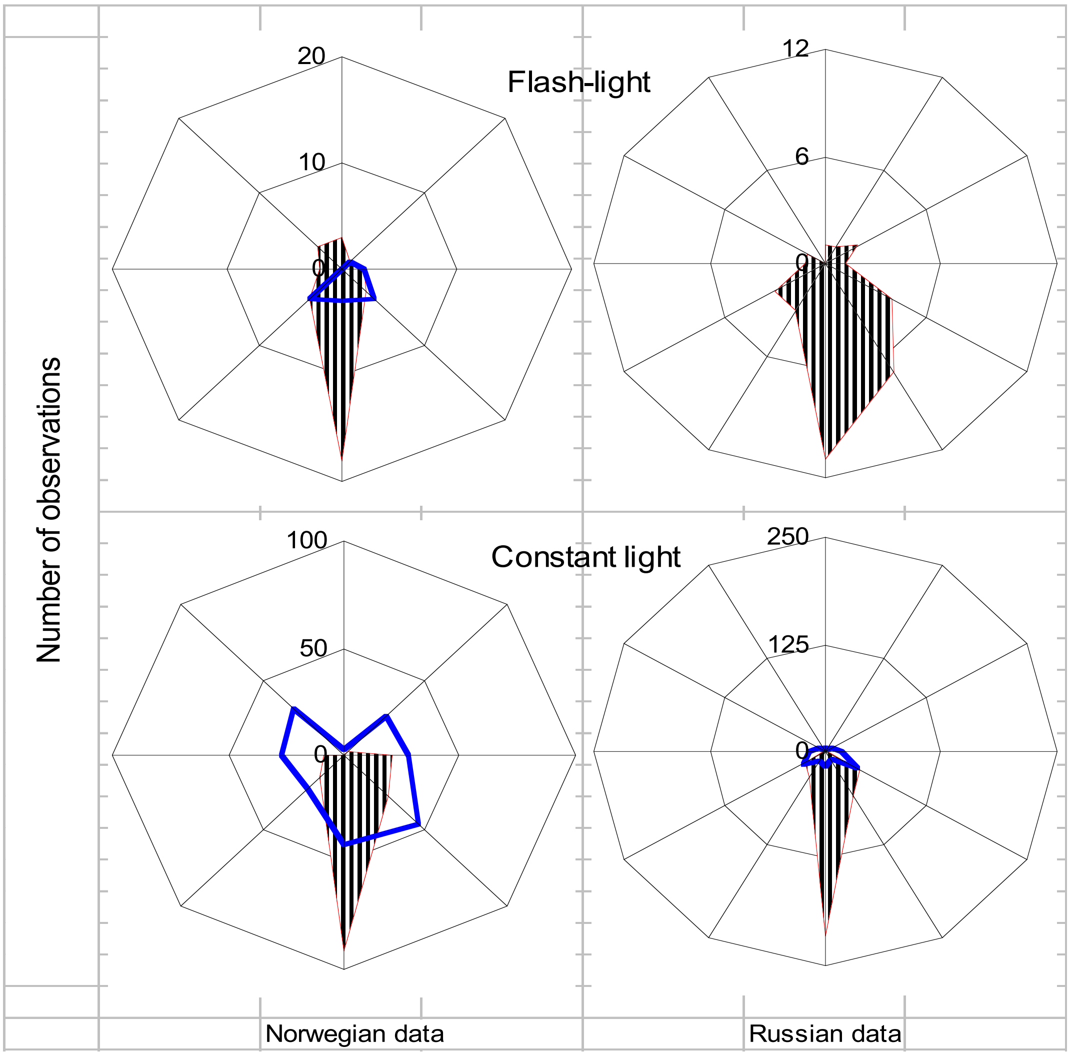


FIGURE 4

Distribution of orientation angle of individual Greenland halibut in front of ground-gear relative to the use of artificial light

Tow direction is towards the bottom of the page. Hatched areas represent individuals close to or resting on the sea bed and the solid lines represent fish swimming above the bottom (visible shadow).



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Spatial structure and encounter rate of Greenland halibut in front of bottom-trawls

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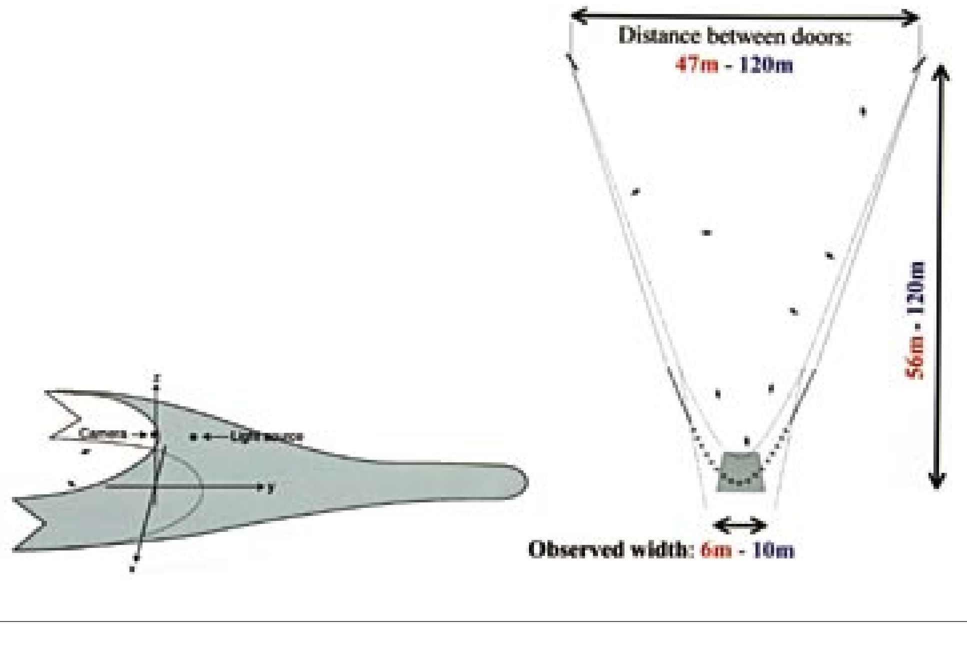
1. INTRODUCTION

Several studies have shown that the abundance of a fish species in the trawl mouth area may influence their vulnerability to capture. Generally the abundance of fish in a trawl mouth is a function of the overall abundance in the area and the distribution pattern of the species. For some large and fast-swimming fish species the behaviour is known to change with increasing abundance; when abundant even normally non-schooling species may form schools that influence their vulnerability to capture and thus the composition of the catch (Godø *et al.* 1999). Greenland halibut (*Reinhardtius hippoglossoides*) is a deepwater flatfish that is seldom observed live. It is generally conceived to be a vigorous swimmer and a roundfish-like flatfish. We made video recordings of this species in front of both a commercial groundfish trawl and a survey trawl at 500–800m depths (Figure 1) and analysed the distribution pattern along the

FIGURE 1
Video and trawl set-up. The dimensions given are for the Campelen survey trawl (first values) and the Alfredo-5 commercial groundfish trawl (last values) respectively.



trawl path to see if they tended to clump together at any particular level of abundance. We also analysed how the encounter rate varied within the trawl hauls. Previous video recordings of Greenland halibut are limited and they indicate that the encounter rate is higher at the start of the hauls (Albert, Harbitz and Høines 2003, Albert *et al.* 2003). This may potentially affect survey indices and understanding these mechanisms may facilitate development of improved assessment techniques.

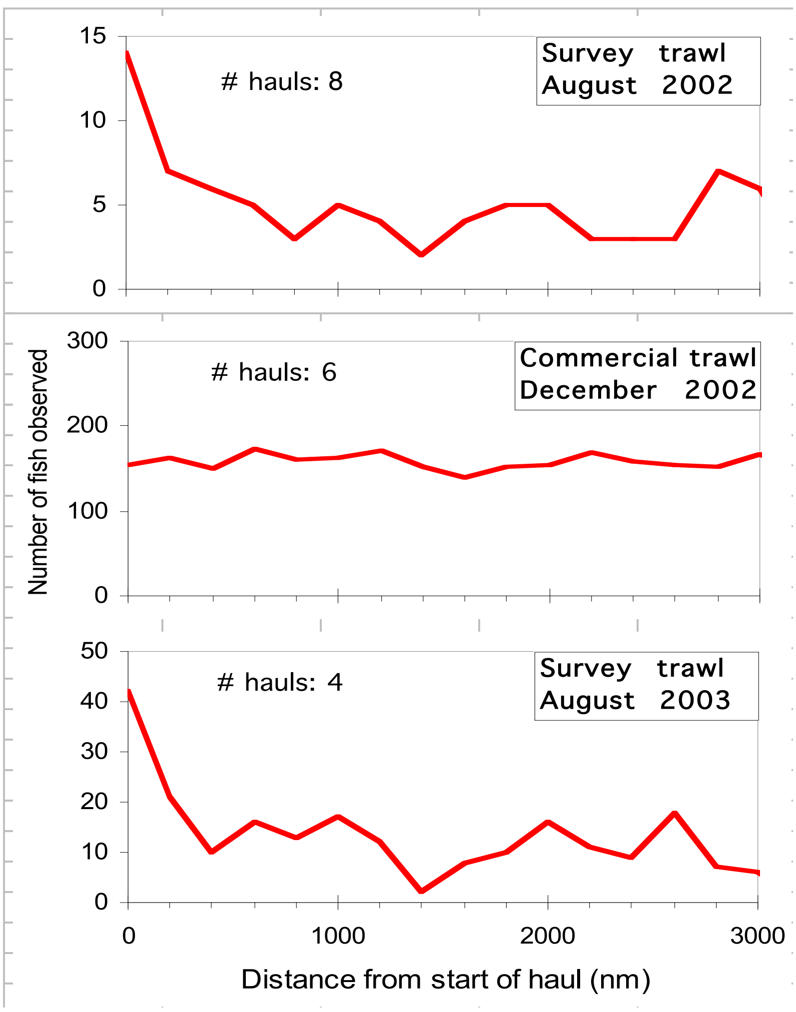
2. ENCOUNTER RATE

Observations from the research survey in August 2003 corroborate the previous observed pattern from the previous survey in August 2002 of higher encounter and catch rates at the very beginning of the tows (Figure 2). The number of Greenland halibut observed during the first 200 m of the hauls were 3–4 times as large as for subsequent 200m intervals. Encounters during the next 200 m interval (200–400 m after the trawl hit the bottom) were also significantly more numerous than in subsequent intervals. The individuals caught during the first few hundred meters were on average significantly larger than those caught later in the hauls.

This 'start-effect' may be related to some sort of surprise-effects on the Greenland halibut. Individuals distributed close ahead of where the trawl hits the bottom may be less able to establish their normal avoidance reaction towards the approaching trawl. If so, the question is if it is the encounter rate in the start, or after stabilizing, that best represents the true abundance in the survey area. With 20-minute hauls the start-effect of their encounter rate will affect 10–15 percent of the duration of each haul. Variation in this start-effect with, e.g. area, season, fish density and size-composition may potentially influence time series of abundance.

No such start-effect was observed during hauls with the commercial groundfish trawl (Figure 2). These hauls were made in the same area as the rest, but at a different time of the year, with different gear and at

FIGURE 2
Encounter rate of Greenland halibut from the time the ground-gear hit the bottom onwards

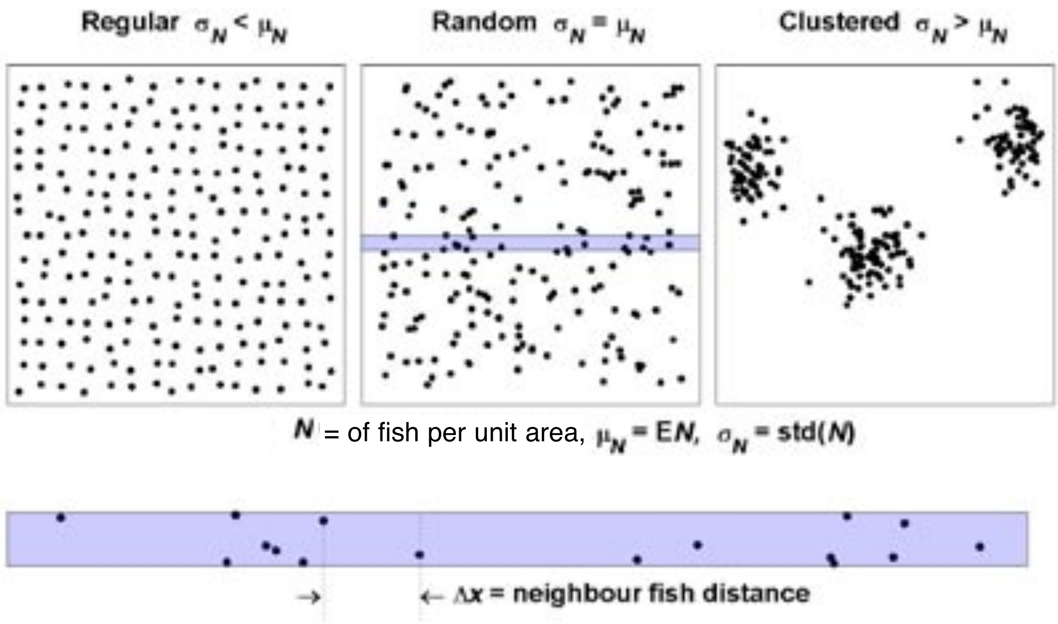


much higher abundance levels of Greenland halibut. Further studies are needed to reveal how the start effect is influenced by gear type and fish density.

3. SPATIAL STRUCTURE

Neighbour fish distance, D*x*, was defined as the estimated distance along the track between succeeding encounters of Greenland halibut determined by video recordings (Figure 3). For stations with low density (mean distance larger than 30m), the neighbour fish distances were standardized by dividing the mean in the respective hauls. The neighbour fish distances for the large density stations (mean distance less than 6 m) were standardized by dividing by the inverse of the estimated fish density trends along their respective hauls. The fish density based on video is a better measure of abundance than the catch rate since it encompasses those individuals that escape under the footrope of the trawl.

FIGURE 3
Definition of neighbour fish distance along the trawl path (lower panel) and theoretical examples of distribution patterns



To analyse the distribution of neighbour fish distance, the standardized values were lumped together separately for large and small fish densities (Figure 4). The exponential distribution gave a good fit in both cases. The data indicate that individual Greenland halibut behave randomly in space and independent of each other. There was no tendency of clumped distribution even for the largest densities. However, commercial catches may be four times or more dense than the largest densities we analyzed.

Although significant trends were found for the four tracks with the greatest abundance (more than 600 fish observed), the maximum estimated coefficient of variation of these trends was 15 percent as compared to a much larger "between track" variance of fish density over the entire study area, based on catch rates from survey trawls. This means that short and frequent trawl hauls will minimize the coefficient of variation of abundance estimates, though bias aspects, such as the start-effect of encounters, should be taken into account when developing new survey designs (Figure 5).

FIGURE 4
Frequency distributions of neighbour fish distance compared with the exponential distribution
Exponential distribution corresponds to random spatial distribution of individual Greenland halibut.

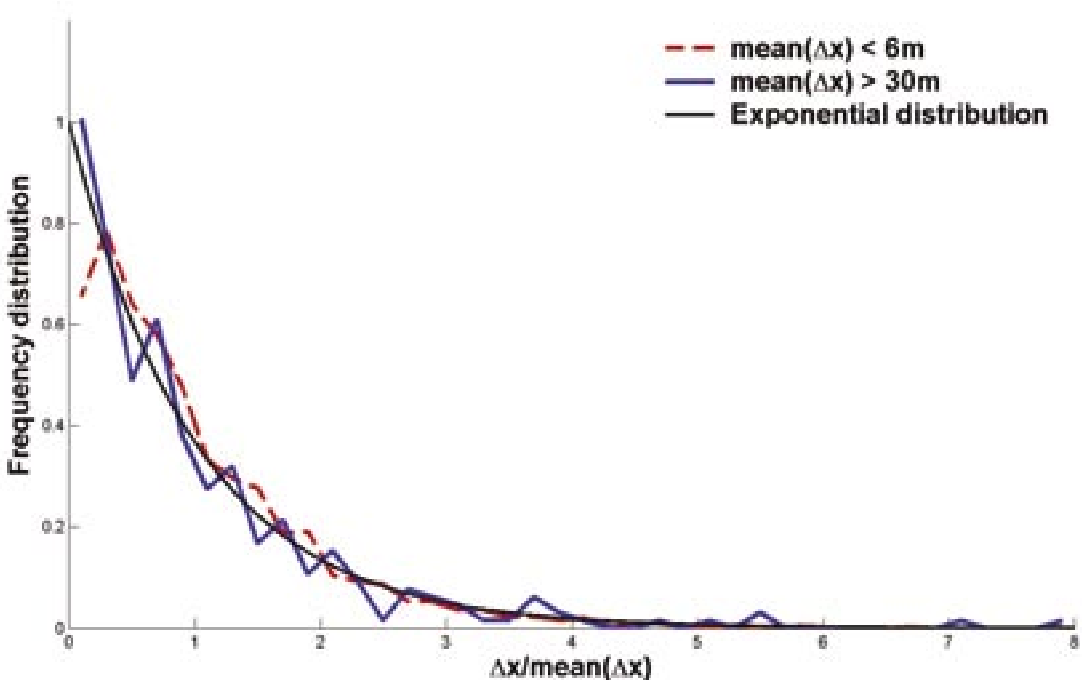
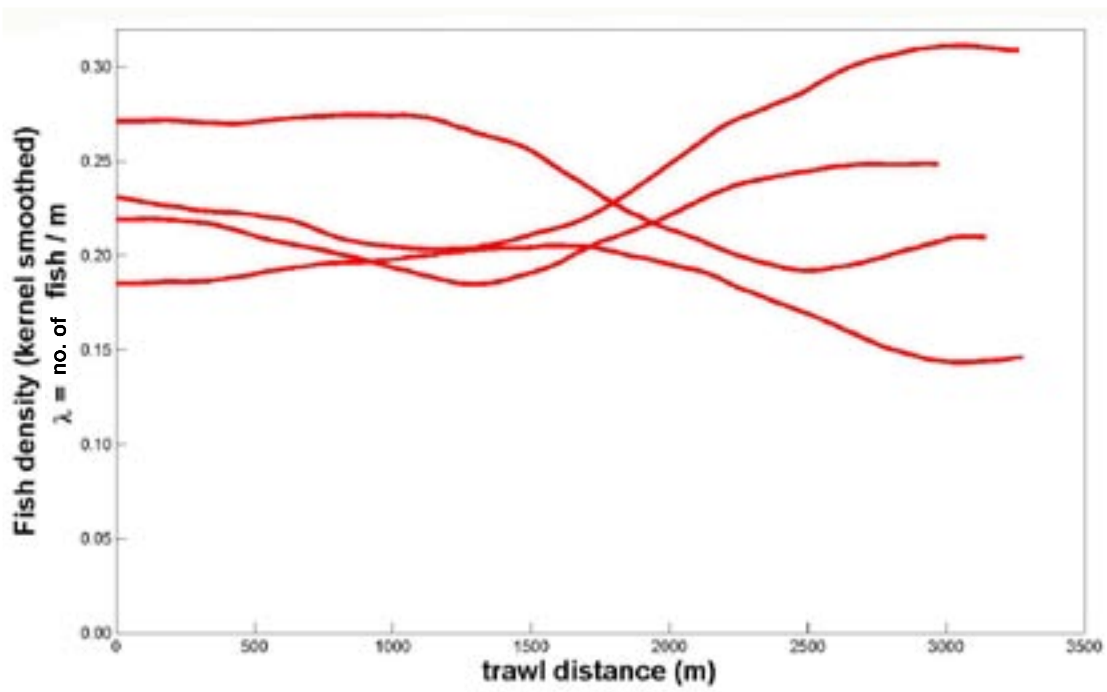


FIGURE 5
Variation in fish density along the trawl tracks
Data from hauls with high-fish density (N>600)



4. CONCLUSIONS

- Substantially larger encounter rates of Greenland halibut occur at the beginning of hauls with survey trawls (corroborates with previous studies).
- Video records show a random spatial structure and independent behaviour of individual Greenland halibut both at low and moderately high densities.
- The between-track variance of fish density dominates the within-track variance. The data should be further analysed to develop a sampling design that minimizes the variance of abundance estimates.

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A new approach to control and manage the Argentine fishery for Patagonian toothfish (*Dissostichus eleginoides*)

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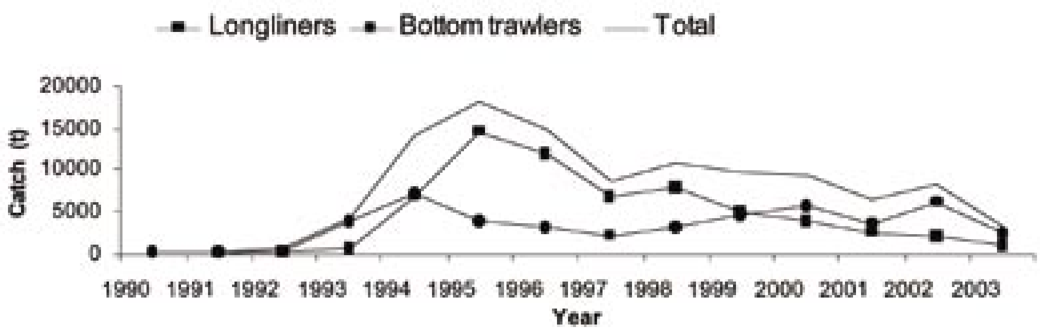
1. INTRODUCTION

The Patagonian toothfish (*Dissostichus eleginoides*) exploited by the Argentine fleet is distributed in shelf and slope waters between 37 °S and 56 °S. Argentine catches are taken using two different fishing gears: bottom trawl and longline. Longliners mainly catch adult fish, while bottom trawlers often catch more juveniles, due to difficulties in operating in deeper waters or on bottoms less suitable for trawling. It has been observed that size selectivity is more dependent on the depth of fishing than on the fishing gear (Prenski and Almeyda 2000).

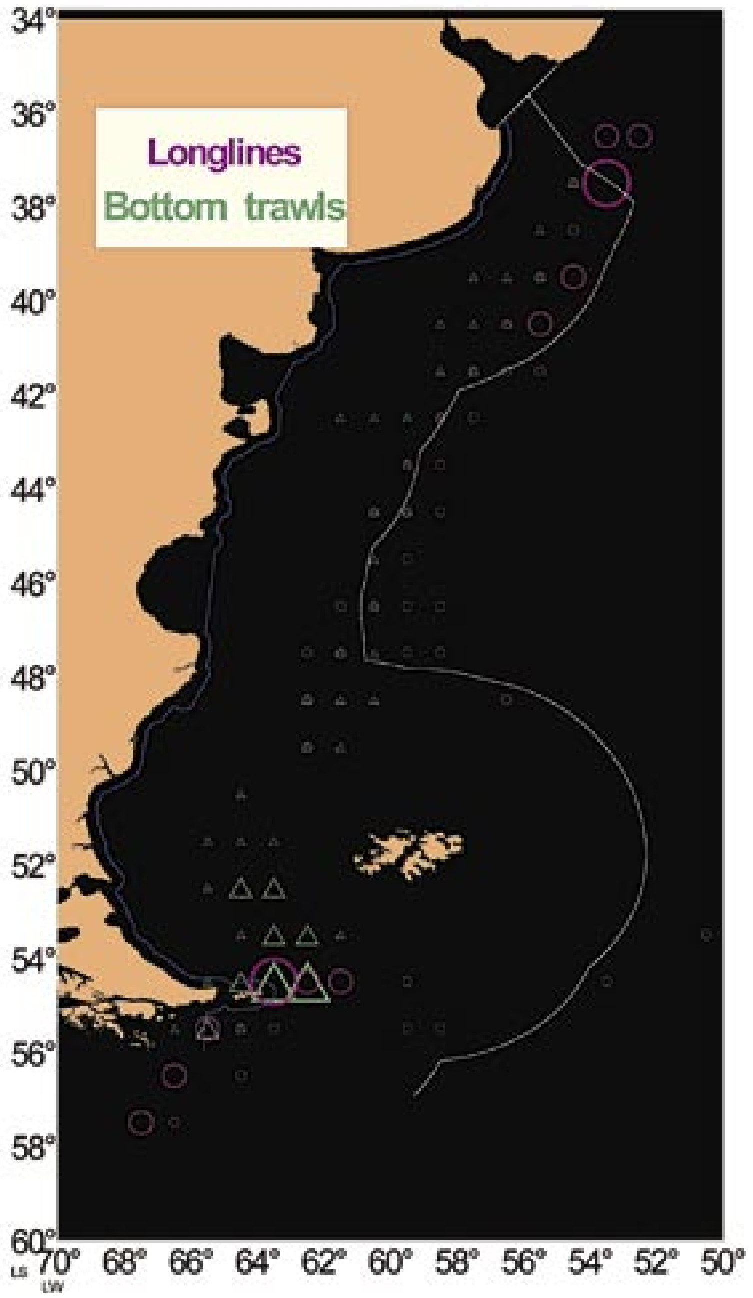
The Argentine fishery for Patagonian toothfish became important in the early 1990s (Figure 1). The largest catches of the species were obtained in 1995 (18 225 t), when large fishing boats were incorporated in the fleet, producing an expansion of the fishing grounds. Fishery statistics indicate that Argentine catches obtained by longliners have gradually declined from 1995. Trawler catches became more important in recent years, mainly since 1999, as a consequence of a management measure directed at other species. This resulted in a change in the fishing grounds by some of the larger trawlers and the subsequent change in the target species (Wöhler, Martinez and Giussi and 2001, Wöhler

FIGURE 1
Argentine catches of Patagonian toothfish obtained by bottom trawlers and longliners
Values of 2003 correspond to the period January–September.



and Martinez 2002). During the last years the highest catches of this species come from a small area, where more than 80 percent of the total trawl catches were obtained (Figure 2). This area, which is situated to the South between Isla de los Estados and the Burwood Bank (54–55 °S and 62–64 °W), has shown to be an important recruitment area where juvenile fish aggregate, though adult fish are also abundant (Wöhler, Martinez and Giussi 2001, Wöhler and Martinez 2002).

FIGURE 2
Fishing grounds and catches of Patagonian toothfish exploited by the Argentine fleet during 2002



2. THE MANAGEMENT OF THE FISHERY

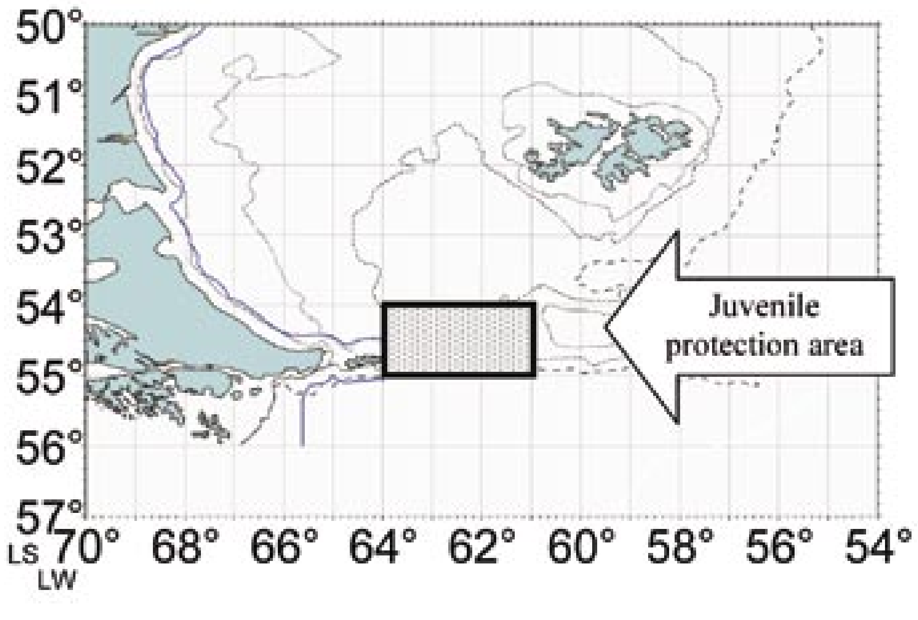
As a consequence of the declining trend in the CPUE obtained from adult fish (Wöhler, Martinez and Mari 2002) and the increase in the proportion of juveniles in the catches detected from 1999, and bearing in mind the biological characteristics that make the Patagonian toothfish susceptible to overfishing (high longevity, slow growth, considerable longevity and size of first maturity), the National Institute of Fishing Research and Development (INIDEP) suggested to the Argentine Fishing Authority that they establish precautionary measures to regulate toothfish exploitation with the aim of ensuring the long term sustainability of the fishery (Wöhler and Martínez 2002).

Since 2000, the Fishing Authority has enacted new management regulations that have been modified from time to time to enhance their efficiency. The main measures, implemented through different official resolutions, are listed below.

- Application of the catch document system (CDS) to the Argentine Fishery.
- Limitation of depth for targeting toothfish for longliners and trawlers: more than 1 000 m to the north of 54 °S and 800 m to the south.
- Increase the minimum hook size from 3.5 cm to 4 cm (hook width).

- Limitation of the toothfish catches as bycatch to three percent in the total catch of each fishing trip.
- Invalidation of the CDS when CCAMLR conservation measures were not applied.
- Set a minimum fish size of 82 cm TL (i.e. size at first maturity).
- Creation of an Advisory Commission for the Fishery for Patagonian toothfish (CASPMeN), integrating the Argentine Fishing Authorities, scientists and members of the fishing industry (October 2002).
- Creation of a juvenile protection area in fishing sectors 5462 and 5463 and prohibiting the targeted fishery in this area. Enlarging fishing area 5461 in November 2003 (Figure 3).
- Creation of a Subcommission for landings control (SCD) integrating the Argentine Fishing Authority and fishing industry members.
- Obligation to all vessels operating in the juvenile protection area (fishing for any species) to have a scientific observer and a fishing inspector onboard.
- Consideration as a serious infraction when the catches of juveniles exceed 15 percent of the total catch (in case of target fishing).
- Suspension of the prohibition of fishing Patagonian toothfish in the juvenile protection area for vessels targeting the species subject to the monitoring of the fishery evolution carried out by the CASPMeN and scientific advice.
- Establishing quarterly total allowable catches during 2003.

FIGURE 3
Juvenile protection area created by the Fishing Authority in October 2002 and enlargement in November 2003



3. THE NEW MANAGEMENT SCHEME

New management elements have been incorporated recently, one of them was the creation of an Advisory Commission for the Fishery, integrating different stakeholders, such as the administration, scientific research and the fishing industry (Figure 4). This Advisory Commission has the responsibility for advising the Federal Fishing Council and other fishing authorities about the best measures to efficiently implement the newly established management scheme. Another important element is the presence of the private sector in landings control and their participation in the Sub-Commission on landings control in addition to landing verification by government inspectors from the Fisheries Undersecretariat.

The Federal Fisheries Council has incorporated an adaptive fisheries management regime involving quarterly monitoring of the fishery, including the opening and closing of areas, penalizing those vessels that do not comply with the existing regulations and establishing a TAC for the next period. This adaptive management is based on real-time information from the fishery, obtained from three sources (Figure 5). This information is analyzed and controlled by the CASPMeN, with the objective of detecting management needs and correcting deficiencies. These activities include the following.

FIGURE 4
Structure of the Advisory Commission for the Argentine Fishery of Patagonian toothfish

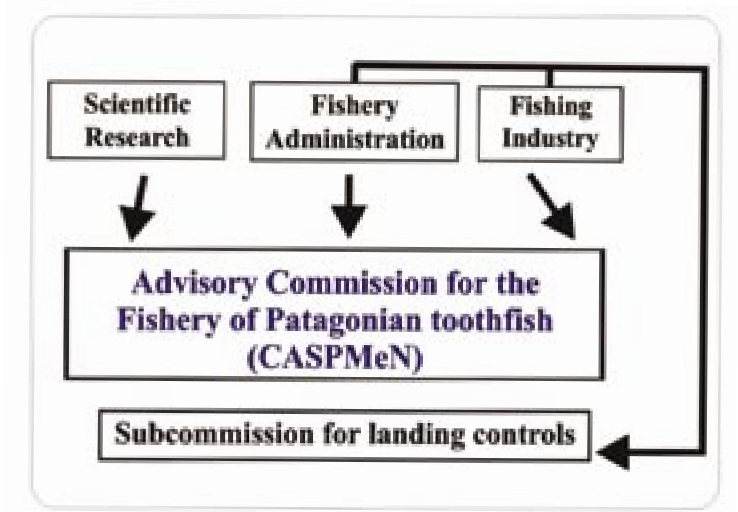
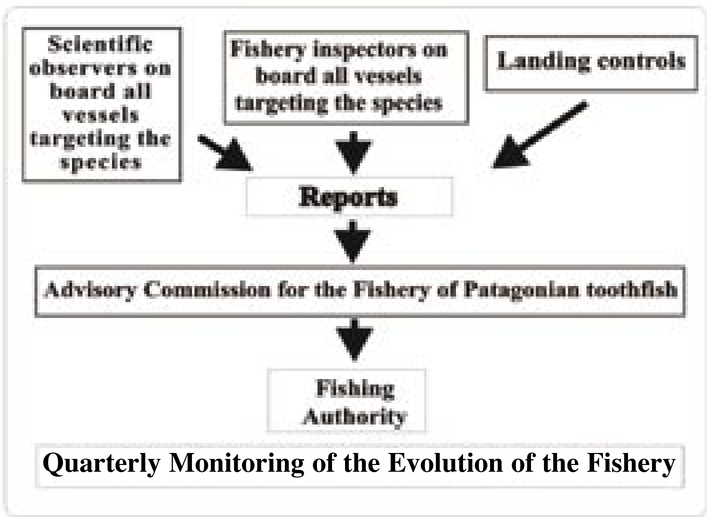


FIGURE 5
Schematic diagram showing information sources used for the adaptive management established for the Argentine fishery of Patagonian toothfish by the Federal Fishing Council
(i.e. main fishing authority)



- Reporting by scientific observers on board all vessels targeting the species. The observer programme is developed on the basis of a sampling protocol previously agreed to by the CASPMeN. The information thus obtained is analyzed by the INIDEP and becomes an integral part of its scientific advice used for recommendations on the opening and closing of juvenile protection areas.
- Reports of the fishery inspectors onboard all the vessels targeting the species, which are legal tools for verifying compliance with the existing regulations and sanctioning infractions.
- Reports of the Sub-Commission for landing controls, where the data on catch and juvenile proportion are verified and compared with skipper's declarations. These reports are also used as legal instruments for enforcement.

4. FINAL CONSIDERATIONS

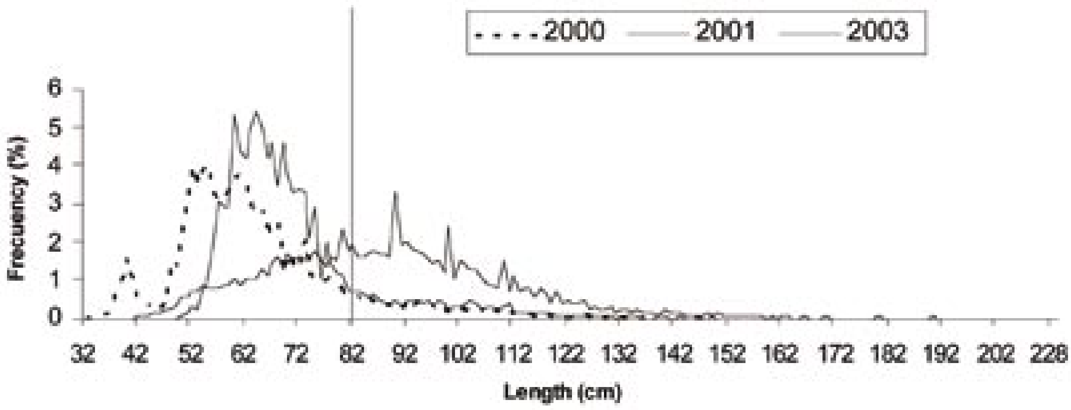
The implementation of the new management scheme produced positive results during 2003. The Argentine Patagonian toothfish fishery has operated under new regulations since the end of 2002 and has developed with a different trend in respect to previous years. This change is reflected in a reduction of total catches (Figure 1) and a change in the fish size-selectivity pattern of the fleet, resulting in fewer juveniles being caught (Figure 6), a fact closely related to the depth restrictions imposed (Wöhler and Martínez 2003a, b, c).

Even in the short period of application of the new regulations, the functioning of the CASPMeN, control of landings at ports and the monitoring and assessment in real time by the Federal Fishery Council, have demonstrated to be effective tools for the management of the Argentine fishery for toothfish.

FIGURE 6

Size frequencies of toothfish caught by Argentine longliners and bottom trawlers during years 2000, 2001 and 2003 (January–September)

Note the reduction in the proportion of juveniles (specimens less than 82 cm TL) in the 2003 catches as a consequence of the new regulatory measures in force since the end of 2002.



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Bycatch in the orange roughy (*Hoplostethus atlanticus*) fishery on the South Tasman Rise[1]

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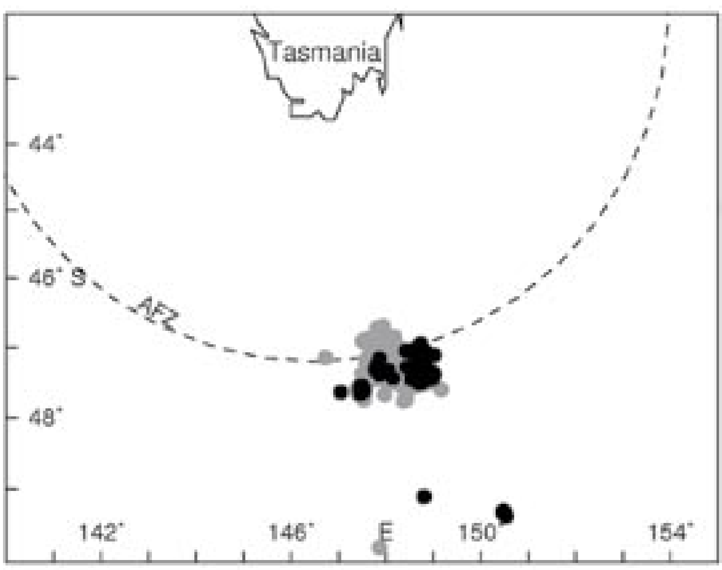
The identification and measurement of the effect of a fishery upon associated species of deepwater fisheries is essential for their conservation. Benthic invertebrate communities are at particular risk in orange roughy fisheries because they tend to be fragile, erectile and slow growing, and because of the heavy nature of the fishing gear used. Estimates of the associated catch of the animals that make up these communities in the initial stages of a fishery are rarely made.

New Zealand Ministry of Fisheries observers have been present on New Zealand vessels in the South Tasman Rise orange roughy fishery, which is prosecuted in international waters south of Tasmania (Figure 1), from the early stages of the development of the fishery. These observers made detailed records of the catch weights of all species caught during 545 trawls between October 1997 and August 2000, covering between 10 percent and 22 percent of the total New Zealand and Australian annual catch.

FIGURE 1
Position of all recorded trawls (New Zealand and Australian) in the South Tasman Rise orange roughy fishery (grey dots) and all observed (New Zealand) trawls (black dots) for the period October 1997 and August 2000
AFZ, Australian Fishing Zone.



Bycatch ratios and the ratio of bycatch weight to tow duration were derived from these data and used to make estimates of total annual bycatch in the fishery for several species groups. Annual bycatch was estimated for three species of oreos (Oreosomatidae), for all coral species combined

[1] The research presented here is based on Anderson, O.F. & M.R. Clark 2003. Analysis of bycatch in the fishery for orange roughy, *Hoplostethus atlanticus*, on the South Tasman Rise. *Marine and Freshwater Research 54*: 643–652.

and for all other bycatch species combined, for the (1 October – 30 September) fishing years from 1997–98 to 1999–2000.

Total oreo bycatch dropped from about 7 400 t to less than 300 t during this time. These estimates agreed well with recorded oreo landings data for three of the four years (Table 1). There was a considerable bycatch of coral, with both the bycatch ratio and the total bycatch declining during the period examined. The total bycatch declined from about 1 760 t to less than 200 t a year. The coral bycatch comprised a large number of species and was dominated by *Solenosmilia variabilis*, a reef-forming stony coral that provides the structural habitat for a wide range of other invertebrate species. The long-term effect of such bycatch on the ecosystem is unknown. However, such bycatch needs to be considered in the management of a developing fishery. Annual bycatch of all other species combined, mainly rattails (Macrouridae) and dogfishes (Squalidae), was low (30–120 t). The bycatch of this group dropped sharply in each year, due a combination of a decreasing bycatch ratio and decreasing fishing effort.

TABLE 1

Annual bycatch ratios and annual bycatch levels (with 95% confidence intervals) in the South Tasman Rise orange roughy fishery, divided into three species groups, and the reported landings of oreo species.

Species	Fishing year	Bycatch ratio (kg/h)	Annual bycatch (t)	95% C.I.	Recorded landings (t)
Oreos	1997–1998	6 877	7 411	(4 336–12 841)	1 205
	1998–1999	2 321	1 683	(1 072–2 471)	1 590
	1999–2000	660	279	(97–548)	245
Corals	1997–1998	1 635	1 762	(480–3 298)	–
	1998–1999	729	529	(249–885)	–
	1999–2000	428	181	(56–362)	–
Others	1997–1998	111	120	(80–161)	–
	1998–1999	106	77	(58–104)	–
	1999–2000	72	30	(25–36)	–

Bycatch and discards in major New Zealand deepwater fisheries

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Some level of non-target catch and subsequent discarding is a feature of almost every commercial fishery and the bottom trawling method is considered to be among the most wasteful in this regard. To reduce the level of non-target (non-commercial) catch and discarding in fisheries we need to have an understanding of the scale of the problem and of the factors that contribute to the level of non-target catch and discards. Identification and measurement of the bycatch species associated with a fishery can also contribute to an improved understanding of fish communities and the possible impact of fishing on the long-term stability of the ecosystem.

NIWA has carried out several studies on behalf of the Ministry of Fisheries in recent years to determine the level of bycatch and discarding in New Zealand's major deepwater fisheries, and to identify factors specific to each fishery that contribute to it. These fisheries have included those for orange roughy (*Hoplostethus atlanticus*), oreos (*Allocyttus niger*, *Pseudocyttus maculatus*, and *Neocyttus rhomboidalis*), southern blue whiting (*Micromesistius australis*), hoki (*Macruronus novaezelandiae*), arrow squid (*Nototodarus* spp.), jack mackerel (*Trachurus* spp.), scampi (*Metanephrops challengeri*), and ling (*Genypterus blacodes*). Estimates were made by scaling up known catch and discard rates from the observed portion of the fishery to the total target fishery and were fine-tuned by stratifying the fishery according to factors identified from observer data as having a significant influence on bycatch and discards.

In most fisheries, and for most species categories, variation in bycatch and discard levels were most strongly associated with differences among the large numbers of vessels operating in each fishery. Other important factors were the target species (for jack mackerel, southern blue whiting, arrow squid, orange roughy and hoki), tow-type (mid-water or bottom trawl), time of year (for jack mackerel and arrow squid), and vessel nationality (for arrow squid and hoki). We found that while there was much variability in annual discard levels during the 1990s, they were tending upwards while catches slowly decreased (Figure 1). Annual bycatch also varied considerably from year to year, but again the overall trend was upwards with most of the higher values occurring in recent years (Figure 2).

These results provide a first step towards creating strat- egies for avoiding unwanted bycatch. Most of the fisheries examined proved to be relatively "clean" compared with published information on fisheries in other parts of the world. On average 0.05 kg of non-target fish were discarded per kilogram of hoki caught, the equivalent values for other species were: southern blue whiting, 0.02 kg; orange roughy, 0.06 kg; jack mackerel, 0.12 kg; arrow squid, 0.14 kg; and scampi, 3.5 kg.

FIGURE 1
Total annual discards in the seven fisheries examined (excluding ling) and the total reported catch for the 1990–91 to 2000–01 (1 October – 30 September) fishing years

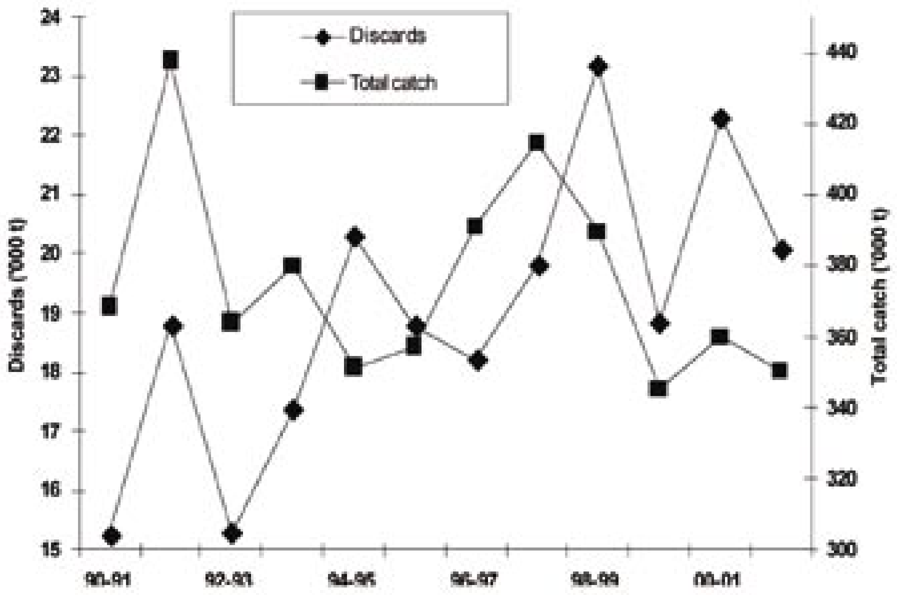
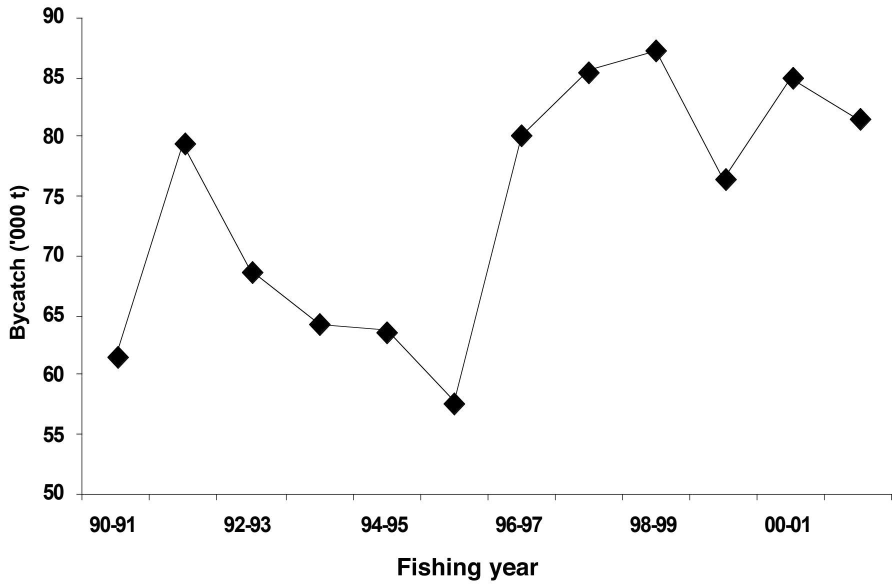


FIGURE 2
Total annual bycatch in the seven fisheries examined (excluding ling) for the 1990–91 to 2000–-01 (1 October–30 September) fishing years



Characterizing natural and reaction behaviour of large mid-slope fish species: consequences for catchability

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Behaviour studies of large commercially-exploited fish species provide information on both their life strategies and their potential vulnerability to capture by fishing gears. Data on the behaviour of slope species are currently sparse because their acquisition requires expensive, technologically-advanced means of observation.

During a study carried out in the bay of Biscay (West of France) at depths ranging from 1 100 to 1 500 m, natural and reaction behaviour of slope fish species were observed by the remotely operated vehicle (ROV) **Victor 6000**. Three areas were surveyed for a total duration of about 210 hours (see Trenkel *et al.* in press, for details). The behaviour of nine large benthopelagic species and families was analysed: roundnose grenadier (*Coryphaenoides rupestris*), orange roughy (*Hoplostethus atlanticus*), black scabbardfish (*Aphanopus carbo*), deepsea scorpionfish (*Trachiscorpia cristulata echinata*), *Alepocephalus* spp., chimaeroids, squalid and scyliorhinid sharks. Natural fish behaviour was classified in terms of (a) body position with respect to the bottom, (b) locomotion and (c) activity.

Individual reactions to the approaching ROV were categorized, providing not only the proportion of individuals reacting for each species but also their detailed reaction behaviour such as avoidance movements or an optomotor reflex leading to swimming in front of the ROV. Environmental conditions (depth, temperature, current speed and direction) and observation conditions (ROV speed and altitude) were recorded simultaneously with the fish observations in order to explain the variability in the observed reaction behaviours.

Multiple Correspondence Analysis (MCA) was used to characterise the behaviour repertoire of the different species and to identify similarities between species. The probability of reaction to the ROV was modelled as a function of environmental and observation conditions using generalised additive models (GAMs).

The species typology obtained from the MCA strongly separated *T.c. echinata* from all other species due it its motionless and generally non-reactive behaviour (Figure 1, Table 1). The other species formed two groups, (a) species actively swimming, distributed higher in the water column and more reactive and (b), species more or less passively drifting, closer to the bottom and less reactive responses. The second group comprised *H. atlanticus* and *C. rupestris,* two commercially important species previously shown as having strongly different life strategies and spatial distributions. *H. atlanticus* is an aggregative species, a good swimmer and a predator of large prey while *C. rupestris* is found dispersed, is a rather poor swimmer and feeds on small prey (Bulman and Koslow 1992, Koslow 1996, Mauchline and Gordon 1984). Despite these differences, their similar reaction patterns may make both highly vulnerable to bottom trawling. Chimaeroids and *Alepocephus* spp. belong to the same group with the exception of *Alepocephalus* spp. A noticeable proportion of individuals of these species were observed to swim slowly in front of the ROV, which may suggest that they are likely to show herding behaviour in front of a trawl.

FIGURE 1
First factorial plane of ACM of natural behaviour and reaction to the ROV

Taxon (■), Position in the water column (+), Locomotion (◆), Activity (◇), reaction to the ROV (●), Avoidance efficiency (○) were active variables and ROV speed (◁) was illustrative (environment and other observation variables not represented).

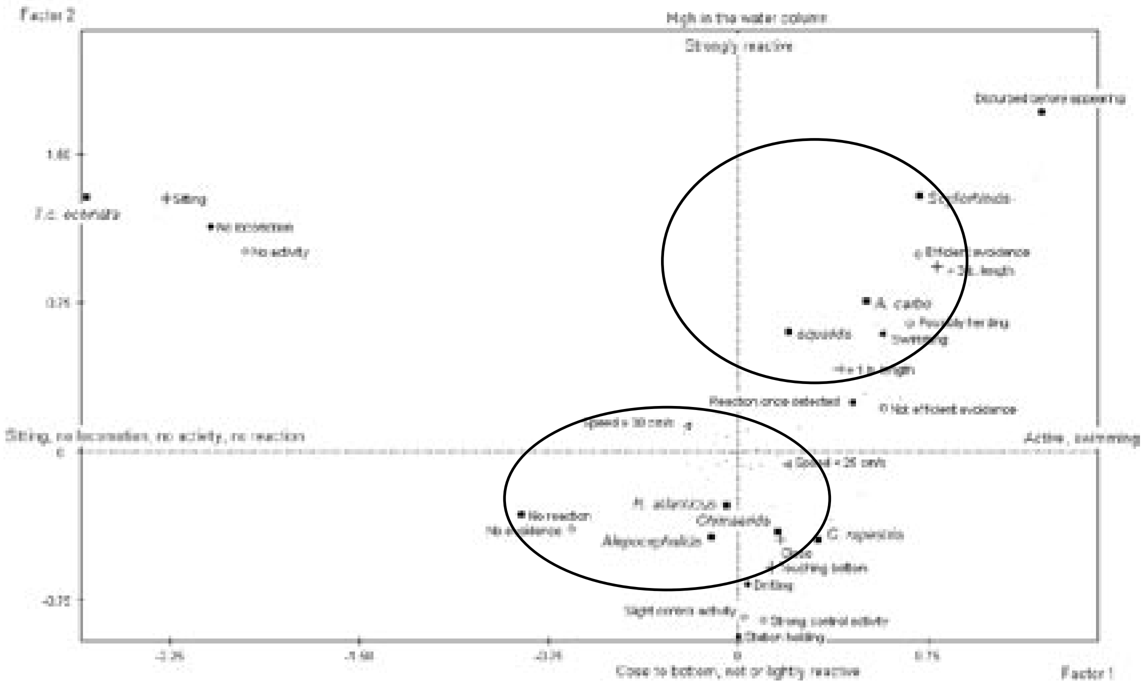

TABLE 1
Species groups and corresponding behaviour according to the MCA

Group	Species	Behaviour
I	*Trachyscorpia cristulata echinata*	Sitting on bottom No locomotion No activity No reaction to the ROV
II	*Hoplostethus atlanticus* *Coryphaenoides rupestris* Chimaeroids Alepocephalids	Close to or touching bottom Station holding or drifting Control activity No or light react to the ROV
III	Scyliorhinids sharks Squalids sharks *Aphanopus carbo*	High up in water Swimming forward Active Strongly reactive to the ROV

Reaction behaviour modelling showed that the overall probability of reaction decreased with surveying speed. The results further suggested that the large benthopelagic predators displayed a range of species-specific behaviours that may change according to environmental conditions. As a consequence of the variability in both natural and reaction behaviour, the catchability by bottom trawls will vary between species and in time and space. Species specific behaviour, in particular the position in the water column, but also reaction behaviour will also affect population density estimates derived from visual transects counts (Trenkel, Lorance and Mahevas 2004).

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Mapping the deepsea: the application of "swath" multibeam data to fisheries

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Multibeam echosounders are becoming increasingly and routinely used for detailed seafloor mapping up to several kilometres either side of the survey vessel. Such multibeam data have typically been used to map seafloor bathymetry and determine substrate composition for geological research. Such systems have powerful applications in benthic ecology and fisheries. They can accurately map submarine topography, such as seamounts or canyons where aggregations of commercial fish species may occur. In addition, the multi-beam seafloor acoustic backscatter data can differentiate between different substrate types, including sediment and exposed bedrock and hence be used to guide successful trawling operations. Multibeam mapping of fishing grounds is markedly more efficient than conventional single-beam echosounders and provides greater resolution and accuracy of both seafloor morphology and composition.

In 2003, during a fish and invertebrate biodiversity survey of the Lord Howe Rise and Norfolk Ridge seamounts (termed NORFANZ) the EM300 multibeam system on NIWA's research vessel **Tangaroa** was used extensively as a basis for sampling operations.

The existing charts of the region proved to be adequate for survey purposes on a large scale and indicated the approximate position of ridges or seamounts. However, on the scale of an individual feature, the depth, size, and shape of a seamount were often poorly charted. The width of seafloor mapped was four times the water depth, and so at 1 000 m depth the bathymetry was determined 2 km on either side of the vessel. This enabled rapid evaluation of the shape of the seabed, which was often very different from the chart.

The seafloor bathy-metry was often rugged and complex (Figure 1) and the multibeam acoustic system proved essential to the success of fishing several sites. The backscatter intensity (Figure 2) gave an indication of substrate composition, which was used to plan trawling operations with less risk of damage to the trawl gear (Figure 3). It also gave data on the type of sediment and habitat, which may be used in later analyses of benthic community structure.

FIGURE 1
Hill shade model of a seamount surveyed during NORFANZ on the Lord Howe Rise

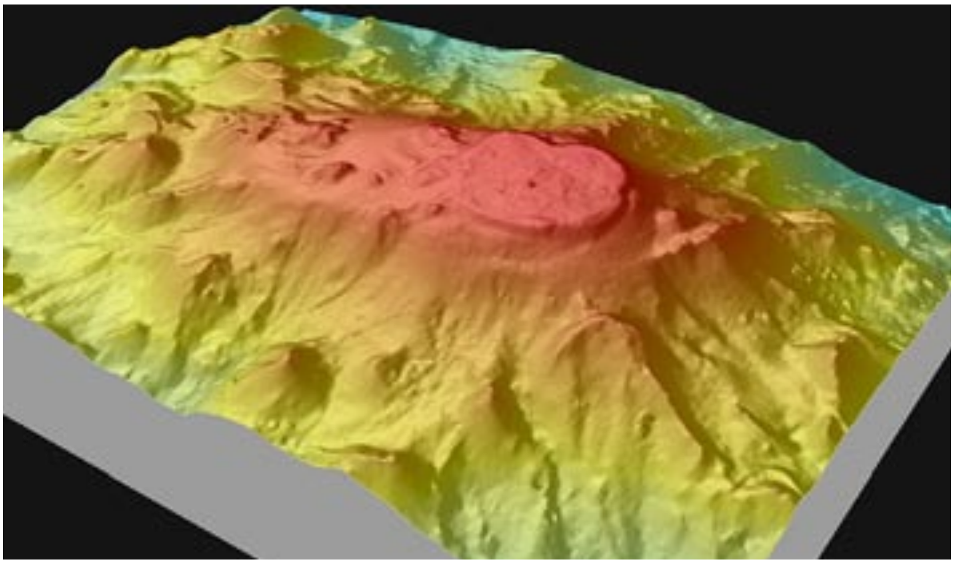


FIGURE 2
Hill shade model of the seamount showing the backscatter distribution
Dark colouration indicates higher reflectivity caused by hard rocky seafloor.

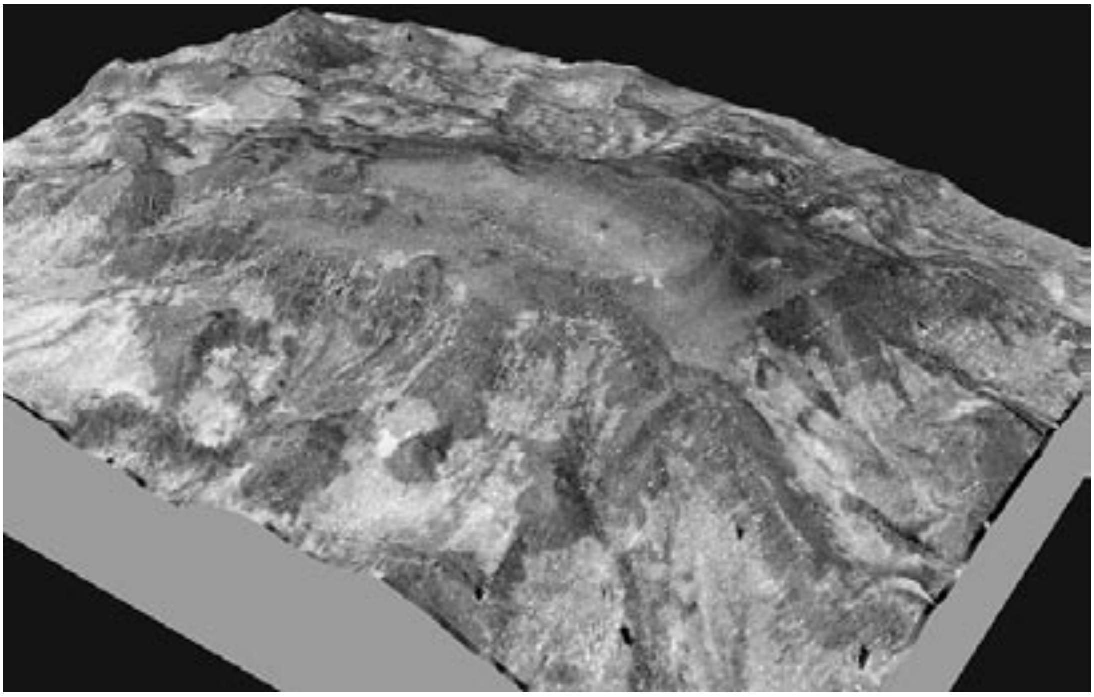
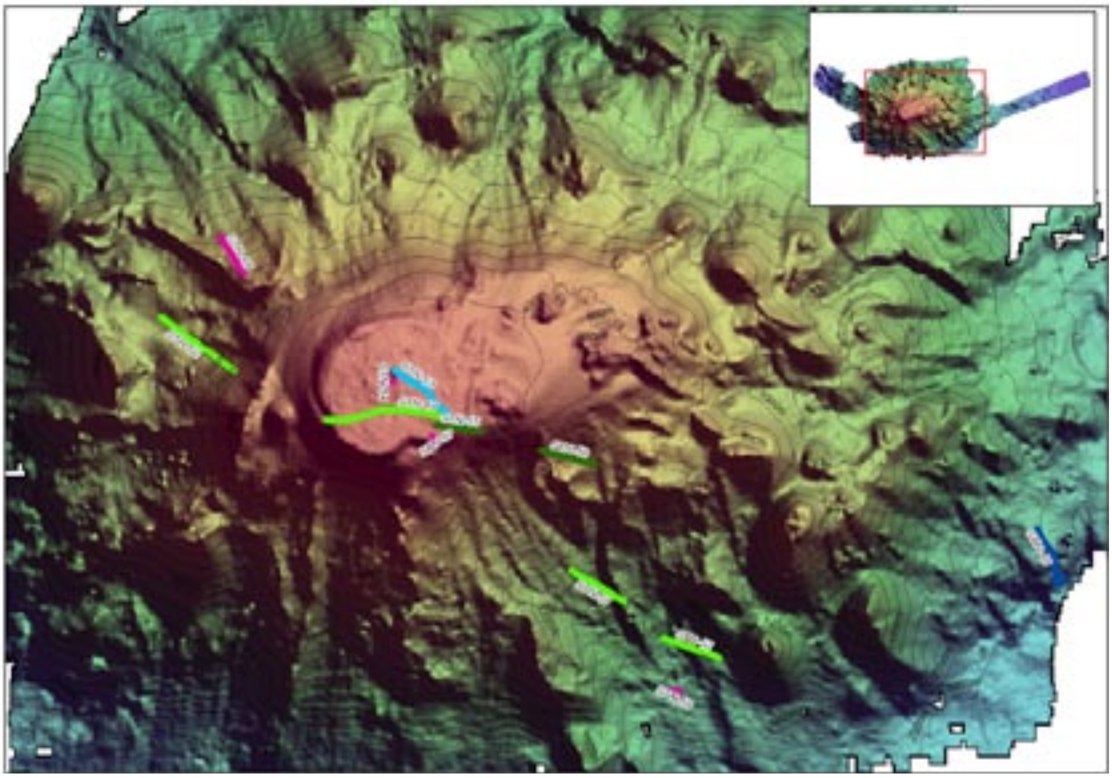


FIGURE 3

View from above of the seamount, showing the location of sampling sites

In this rugged terrain, these were undertaken where the topography and backscatter suggested there was less risk to the gear.



ACKNOWLEDGEMENTS

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Trade-related measures as tools in the management of deep-sea fisheries – opportunities and problems

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Deep-sea fisheries by their nature provide a number of management challenges. Uncertainties in terms of stock assessment are matched by difficulties in compliance and enforcement, particularly when such fisheries are in areas outside national jurisdiction. Recent attention to the problems of unregulated fishing in areas outside national jurisdiction has centred on the efficacy of existing instruments, institutions and practices, and the opportunities provided by new management tools or measures. Providing effective management and combating illegal and, or, unregulated fishing is proving an extremely difficult task, even where deep-sea fisheries are regulated under regional fisheries arrangements or organisations. Several new or improved 'tools' including trade-related measures have been proposed to help increase effective management of deep-sea stocks outside national jurisdiction.

Trade-related measures such as certification and labelling provide means for reducing the financial incentives for catching fish illegally by restricting access to markets and, or, helping to inform consumer choice. Establishing trade-related measures requires regional fisheries organisations to establish a credible system of certification enabling port states and markets to identify with reasonable certainty the fish's provenance. The process of catch certification is distinct from processes to certify and then label fisheries products as derived from sustainably managed fisheries.

The concept of certification and eco-labelling as the basis of market based incentives for the development of sustainable fisheries is of recent origin. Over the last 10 years these approaches have grown in scope and have become increasingly visible to consumers. Certification refers to a focus upon the legal permissibility of the harvest and that the fish has been caught within an agreed regulatory framework. There are a wide variety of labels that could be considered to provide environmental information. These labels range from simple 'appellation controlé' (name/place of origin) approaches to labels issued by external parties after lengthy analysis of the product and production processes.

Certification primarily exists in regional fisheries agreements where cooperation on trade and management is necessary. Eco-labelling tends to move one step further than certification, where a label is granted on the basis of an investigation into the ecological integrity of the harvest, including ecosystem considerations within the fishery.

Labelling schemes and similar approaches centre on consumer interest in food quality and safety and the increasing interest in purchasing products that have been sustainably harvested. The analysis of certification and labelling arrangements and processes highlights opportunities and problems arising from developments in trade-related measures as tools for managing deep-sea fisheries.

Workshop on the Assessment and Management of Deepwater Fisheries

Synopsis

This workshop discussed the assessment and management of deepwater stocks, issues related to trawl, acoustic and egg surveys; the use of catch and effort data; and tag and recapture data. The presentations referred to orange roughy, redfish, smooth oreo dory, Antarctic toothfish and a range of species from the northeast Atlantic. It was noted that many deepwater species have low productivity, aggregate, and often are found associated with underwater features. The reasons for their aggregating behaviour were discussed and it was agreed that more work on fish behaviour is needed. Several noted that the low productivity of deepwater fishes may not be universal as some such species have moderate levels of productivity.

The problems associated with surveys and use of remotely operated vehicles were reviewed as were concerns with understanding stock structure, fish distribution and movement. It was accepted there is no one best way to estimate abundance of deepwater fish and use of a range of methods offers the best way forward. In looking at biology, age and growth it was agreed that biological characteristics vary widely between species, with high longevity, slow growth rates, high age at maturity and low fecundity. For such stocks, sustainable yield levels will be relatively low and recovery from depleted states, slow.

Stock structure is generally poorly known for most deepwater species and their depth of capture means that direct methods to monitor distribution and movements can rarely be used. Biological parameters are often variable and poorly known. Several deepwater species do not spawn each year so that reliance upon gonad data to determine age at maturity may mislead. Transition zones in otoliths may mark onset of spawning and spawning frequency may determine the proportion of the stock available to capture or survey each year. Ecological processes and interactions and links between deepwater demersal fish and energy sources must be better understood as stock-recruitment relationships and recruitment remain poorly known for most deepwater species.

The need for accurate catch and appropriate spatial-scale data, valid indices of abundance and estimating absolute abundance was noted. Although fish age information was considered essential for estimating population productivity, until the development of a validated methodology it was not evident that orange roughy is characterised by unusually low growth rates, low natural mortality, high age at maturity and high longevity. The role of biological reference points, the ecosystem approach to fisheries management and data-poor situations were examined. It was agreed that the most important step towards an ecosystem approach to fisheries management is to get single species fishing mortality to appropriate levels where necessary. This needs better integration of assessment and management of marine resources with appropriate management frameworks that ensure single stock management.

Other presentations covered management arrangements for high-seas orange roughy, deep-sea and deepwater fisheries in New Zealand; development of high-seas fisheries in the western Indian Ocean and frameworks for management advice including setting of management reference points.

The Workshop identified eight actions as priorities for improving assessment and management of deep-sea resources:

i. formulate management objectives more explicitly
ii. incorporate biological reference points and performance measures into management procedures
iii. implement management systems that promote data collection (e.g. adaptive management)
iv. conduct cooperative research with the industry and other stakeholders
v. implement management procedures that do not have high information needs (e.g. design decision "triggers" for opening and closing fisheries)
vi. integrate assessment and management using, e.g. Management Strategies Evaluation techniques
vii. ensure use of collective experience world-wide (using, e.g. "meta-analyses") and
viii. adhere more closely to the precautionary approach.

Biological parameters of deepwater fishes

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This topic may be addressed from the perspective that "deepwater fishes are long lived and slow growing, have a high age and size at first maturity and a low fecundity". This sentence, or a variant of it, is frequently used in the context of deepwater fisheries. An appropriate question to follow is then, "is this statement valid for all deepwater fishes or simply those that are exploited?".

In the Rockall Trough of the northeast Atlantic Ocean there are more than 100 different species of demersal fishes that inhabit depths between about 400 and 2 000 m. Few of these species are marketed, but among those sold are the roundnose grenadier (*Coryphaenoides rupestris*), blue ling (*Molva dypterygia*), black scabbardfish (*Aphanopus carbo*), orange roughy (*Hoplostethus atlanticus*) and two deepwater squalid sharks (*Centrosymnus coelolepis* and *Centrophorus squamosus*). It follows that in the commercial fishery many species are discarded and it is highly probable that none of these discarded fishes will survive. Research trawls that have small mesh usually yield in excess of 40 species at any given depth and many of these would pass through the meshes of a commercial trawl. Deepwater species often have large scales and small amounts of mucus on their bodies. It is a widely held view that many fish will not survive after being damaged while escaping through a trawl. With the growing awareness of the ecosystem effects of fishing it is important to have an understanding of the biology of all the fish species. This presentation reviews the existing knowledge on the biological parameters of several families of deepwater species.

Family Scyliorhinidae

The blackmouth dogfish (*Galeus melastomus*) occurs on the upper slope and is exploited in southern Europe. When spawning it produces up to 30 large eggs per female but despite some research effort determining their age remains uncertain. *Galeus murinus* and several species of the genus *Apristurus* spp. are common on the lower slope but little is known of their biology.

Family Squalidae

There are about 12 species of squalid shark. All produce relatively small numbers of live young. Female *Centroscymnus coelolepis* mature at about 124 cm and ring counts on the spines suggest they attain (unvalidated) maximum ages of about 70 years. The birdbeak dogfish (*Deania calceus*) may attain an age of 35 years. These sharks are seldom found deeper than 2 000 m.

Family Rajidae

Although there are numerous species of rays whose ranges extend to abyssal depths, most occur only in low abundances. Only the relatively small *Raja fyllae* occurs in appreciable numbers. All the rays produce small numbers of large egg cases. The age of the deepwater rays is unknown.

Family Chimaeridae
There are five species of Chimaerids in the Rockall Trough but only two, *Chimaera monstrosa* and *Hydrolagus mirabilis*, are abundant at the depth where the commercial fishery is prosecuted. Sometimes the larger *Chimaera monstrosa* are landed. As with the scyliorhinids and rays, they produce a few large egg cases. Nothing is known about their age and growth.

Family Alepocephalidae
This is a diverse family but in the Rockall Trough only *Alepocephalus bairdii* is abundant and at some depths it comprises a high proportion of the discards. Farther south another species, *Alepocephalus rostratus*, can be dominant in the catches from the mid slope area. Alepocephalids produce large eggs and, in the case of *A. bairdii*, in batches of 2 500 to 8 500. Unvalidated age estimates for this species suggest that it lives for about 35 years.

Family Argentinidae
The argentine, or greater silver smelt (*Argentina silus*), is a semi-pelagic species that is commercially exploited in the Rockall Trough. It grows to a length of about 60 cm and has a maximum age of about 25 years. Female argentines mature at about 35 cm (6–9 yr). The eggs are large and the fecundity is relatively low (16 000–36 000).

Family Synaphobranchidae
The cut-throat eel (*Synaphobranchus kaupi*) has a wide depth range, from about 500 to 2 000 m and exhibits a typical "bigger-deeper" size-distribution characteristic. Although seldom caught in commercial trawls it is the most abundant species at mid-slope depths in the catch of small survey trawls. Its fecundity is between 60 000 and 165 000 and this specices has a pelagic leptocephalus stage. They metamorphose at a length of about 9 to 10 cm. Their age is unknown.

Family Notacanthidae
The two dominant spiny eels, (*Notacanthus bonapartei* and *Polyacanthonotus rissoanus*), have a relatively low fecundity (30 000 and 9 000 respectively) and also have a leptocephalus stage. The age is unknown.

Family Macrouridae
This is a diverse family that occupies all depths on the slopes of the Rockall Trough. The roundnose grenadier is one of the main exploited species. Its age has been validated up to six years and ages of up to 75 years have been reported. In the fishery most of the fish landed are less than 30 years old. The age at maturity is about 10 years and the fecundity is relatively low at about 25 000 eggs. The other species of the upper to mid-slope tend to be smaller in size but a maximum, unvalidated age of 20 to 30 years appears to be the norm.

Family Gadidae
The blue ling attains a length of about 145 cm and a length at first maturity at about 90 cm. It probably has a maximum age of about 30 years. In common with most gadoid fishes it is highly fecund producing millions of eggs.

Family Moridae

The only species of interest to the fishery is *Mora moro*. It attains an age of about 34 years and produces two to three million eggs. The smaller *Lepidion eques*, a significant discard in the fishery, reaches a maximum size of 40 cm and females mature at about 24 cm. Their fecundity ranges up to 100 000 eggs.

Family Trichiuridae

The black scabbardfish (*Aphanopus carbo*) has been fished in deepwater since the 17th century yet many features of its life history remain unknown. Mature fish of length greater than one metre are found around Madeira and off mainland Portugal but the eggs, larvae and early life history stages have not been found. In the Rockall Trough the fish caught in the trawl fishery are all sub-adults and catches of juveniles are rare. Unvalidated age estimates suggest that this is a fast growing species with ages from about 10 to 25 depending on the ageing method that is used.

Family Scorpaenidae

The bluemouth (*Helicolenus dactylopterus*) is an important commercial species in southern Europe. Small bluemouth can be an important component of the discards from the bottom trawl fishery in the Rockall Trough. The maximum size is about 46 cm and ages of up to 46 years have been reported. Females reach maturity at about 13 years and produce live young.

Family Trachichthyidae

The orange roughy (*Hoplostethus atlanticus*) can reach a maximum size of about 60 cm but in the Rockall Trough they generally attain lengths of about 40 cm. Ages of up to 125 years have been estimated and females mature at about 53 cm. The fecundity ranges from about 28 000 to 380 000. The silver roughy (Hoplostethus mediterraneus) attains a maximum size of 42 cm and is a shallower living, more southerly distributed, species. Ages of 10 to 11 years have been reported and the fecundity ranges from 4 000 to 100 000.

In 2001 one of the terms of reference of the ICES Working Group on the biology and assessment of deep-sea resources (WGDEEP) was to rank the commercial species in order of vulnerability to fishing. On a scale of 1–5 (1 being the most vulnerable) the following species were ranked as follows; squalid sharks (1.5), orange roughy (1.6), roundnose grenadier (2.4) black scabbardfish (4.0) and blue ling (4.0). It was acknowledged, in view of the many uncertainties, that these were fairly crude estimates but that the main pattern as indicated was robust.

This review includes a range of the non-target species and reveals a similar pattern of wide variability in life history parameters with a tendency for high age, slow growth, high age at maturity and low fecundity.

The fishery management process for deepwater fisheries in New Zealand: now and in the future

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1. FISHERIES MANAGEMENT IN NEW ZEALAND

Commercial fish stocks in New Zealand are managed under the successful and evolving quota management system (QMS). Individual transferable quotas (ITQs) ensure ownership as well as responsibility for the sustained use of a fishery. Annual catch entitlements (ACE) provide the assurance that ownership rights can be developed under an annual total allowable commercial catch (TACC) determination for a stock. The Minister sets an annual TACC representing the total amount of fish that commercial fishers can remove from a fish stock with reference to the highest yield that can be achieved over time while maintaining maximum productivity (MSY). A process is in place to impose a penalty for exceeding the ACE and a deemed value is paid when the catch exceeds the catch limit. Statutory and voluntary compliance is continually monitored through audits of fish returns and licensed fish receivers inspections. Scientific research and compliance services costs are recovered from the industry in proportion to the investigation of specific fisheries.

The *1996 Fisheries Act* mandates the Ministry of Fisheries to provide for the use of fisheries resources while ensuring sustainability. The Minister is required to maintain stocks at, or above, a level that can produce the MSY. The Ministry of Fisheries provides the Minister with scientific advice on which to base these decisions. Scientific stock assessments identify a safe level of fishing that is not expected to reduce the biomass of the underlying population below 10 percent of the initial biomass 90 percent of the time. A consultative process ensures that stakeholders concerns and interests are addressed. It is this consultative process that facilitates fishery management decisions. A more complete and detailed description of the New Zealand QMS can be found in Sissenwine and Mace (1992), Annala (1996) and Batstone and Sharp (1999).

2. FISHERIES MANAGEMENT PROCESS FOR DEEPWATER STOCKS

Deepwater fisheries

Major deepwater fisheries in New Zealand include: orange roughy (*Hoplostethus atlanticus*), smooth oreo (*Pseudocyttus maculatus*), black oreo (*Allocyttus niger*), cardinal fish (*Epigonus telescopus*), hoki (*Macruronus novazelandiae*), hake (*Merluccius australis*), ling (*Genypterus blacodes*), bluenose (*Hyperoglyphe Antarctica*), warehou (*Seriolella punctata*), southern blue whiting (*Micromesistius australis*), squid (*Notodarus sloanii)*, and scampi (*Metanephrops challengeri*). These species dominate New Zealand seafood production with annual harvests near 525 000 t. This figure is 70 percent of the total annual catch of seafood products in New Zealand. The 2002 Export Value of deepwater species was $NZ 502 million FOB, representing 70 percent of the export value of live, chilled and frozen fish (SeaFIC 2002).

Commercial fishery descriptions

The deepwater fishing fleet is mix of over 150 domestic vessels, 50–60 foreign vessels (chartered by New Zealand companies), and up to 10 foreign licensed vessels. The deepwater fleet consists of (a) New Zealand owned ice "fresher boats" reliant on land-based fish processing and (b), factory trawlers, which can be domestic or foreign-flagged vessels, and spend up to 6 months at sea. Vessel sizes range from 10 to 100 m in length. Owners hold a portfolio of species quota to enable better use of their capital assets, processing and marketing infrastructure and to allow them to align their fishing strategies to market opportunities.

3. GENERAL DEEPWATER FISHERY MANAGEMENT INFORMATION

Sustainability information

Fishery managers use multiple sources of information to enable sound management decisions. Deepwater scientific stock assessments are used as performance indicators for sustainability of commercial fish populations. Deepwater stock assessments rely on acoustic surveys, trawl surveys and species-specific sampling for catch at age and length-frequency information. Accurate stock assessments are needed as technological advances in fishing fleets increase catch efficiency. Fishery managers are dependent on the scientific stock assessment process to ensure that stocks are at a level that can provide maximum sustainable yield. It is critical that all stakeholders in a fishery increase their understanding and trust in the stock assessment procedures, as the stock assessment is the defining scientific process for estimating the biomasses that determine the annual TACCs.

Fishery management welcomes the incorporation of multispecies models to address multispecies fisheries or species complexes. Ecosystem management has a tendency to be based on policy and environmental issues with little scientific application from a fishery basis. In most areas, hoki is the target species of a mixed trawl fishery with as much as 12 percent of the catch composed of bycatch species such as hake, ling and warehou. In non-selective trawl fisheries, addressing the incidental catch of marketable and non-marketable species can challenge achieving sustainability and utilisation objectives. Concerns over the sustainability of a bycatch species can become a constraint to the best use of the target species.

Environmental effects from fishing information

Orange roughy and deepwater oreo fisheries have developed on plateaus, seamounts and underwater topographic features at depths of 700–1 400 m. They have become the largest and most valuable fisheries in New Zealand and Australia landing over 500 000 t (Koslow 1997; Koslow et al., 2000). Smooth and black oreo aggregate at slope depths of 850–1 150 m on rough ground and seamounts. Their longevity and productivity are similar to orange roughy. Annual sustainable yield is estimated at less than 2 percent of virgin biomass. Since the early 1980s the catch has fluctuated between 15–25 000 t. Indications from scientific assessments are inconclusive with respect to whether landings at these levels are sustainable. The International Cooperation for the Exploitation of the Sea (ICES) advise that orange roughy stocks cannot sustain high rates of exploitation and their fisheries should be strictly limited and the populations closely monitored.

Utilisation information

Monitoring and evaluation of effort in a deepwater fishery is necessary to monitor fleet behavior in response to changes in stocks or changes in management measures including the TACC. Aligning stock abundance and variability with fishing effort provides fishery mangers with some of the information regarding behavior with respect to existing and future fisheries. Effort data is important to fishery analysts who study the trends in activity and fleet behavior. In addition, changes in catch per unit effort (CPUE) over a season and between seasons show how the fleet adjusts to abundance and fishery management decisions. Additional monitoring of spatial effort and fleet distribution is necessary as CPUE analysis may not identify changes in fleet behaviour as local aggregations of orange roughy are reduced. Changes in CPUE may better reflect a change in fishing strategy, geographical distribution of effort or in fish accessibility than changes in stock abundance. CPUE series are not informative about the size of the effort reduction necessary to allow stock rebuilding to commence.

A consultative process is used to allow stakeholders to express their operational concerns with respect to specific fisheries. Fishery managers address the costs and benefits of proposed sustainability actions with respect to an individual's right to improve their well being. The consultative process is composed of three parts. First, participation in the stock assessment working group where the scientific information is presented and discussed. Second, a plenary session that incorporates the stock assessment information and any additional sustainability issues. The third opportunity for participation is through response to publicly promoted initial position papers presented by the Ministry of Fisheries. Submissions are summarized and presented to the Minister of Fisheries in a final advice paper. In this process, the Minister can determine the issues and concerns of industry, environmental groups and individuals.

Fishery managers complete additional monitoring and specific evaluation of economic and fishery data that can provide critical information that may not be specifically presented in the working groups or plenary sessions. Stakeholders often provide information or identify inconsistencies or specific trends in fleet behaviour. Fishery managers analyse this and other relevant information in the formation of a position for the Ministry of Fisheries to present to the Minister. In the case where specific skills are required, fishery managers initiate additional research or request specialist review of policies to address contentious issues. Two specific fisheries are presented here to demonstrate specific sustainability and utilisation fishery management interactions in deepwater fisheries: the high-value orange roughy fishery and the high-volume hoki fishery.

4. THE ORANGE ROUGHY MANAGEMENT PROCESS

The orange roughy fishery is one of New Zealand's most important fisheries in terms of export value. In the year ending December 2002, orange roughy exports were worth $NZ14 534 a tonne, with total earnings of $NZ124.4 million, representing 17.2 percent of finfish export earnings[1]. The largest overseas market is the USA followed by Australia. The major exported product form is frozen fillets, although some product is exported in chilled-whole or processed form. New Zealand's orange roughy is a relatively low volume fishery currently constrained within a TACC of 15 221 t.

Biology

Orange roughy inhabit depths between 700 m and at least 1 500 m within the New Zealand Exclusive Economic Zone (EEZ). Orange roughy are thought to be extremely slow growing and long-lived, possibly living to 120–130 years. They reach a maximum size of about 50cm and vary considerably in length from one stock to another.

[1] New Zealand Seafood Export Statistics (volume of live, chilled, frozen fin fish).

History

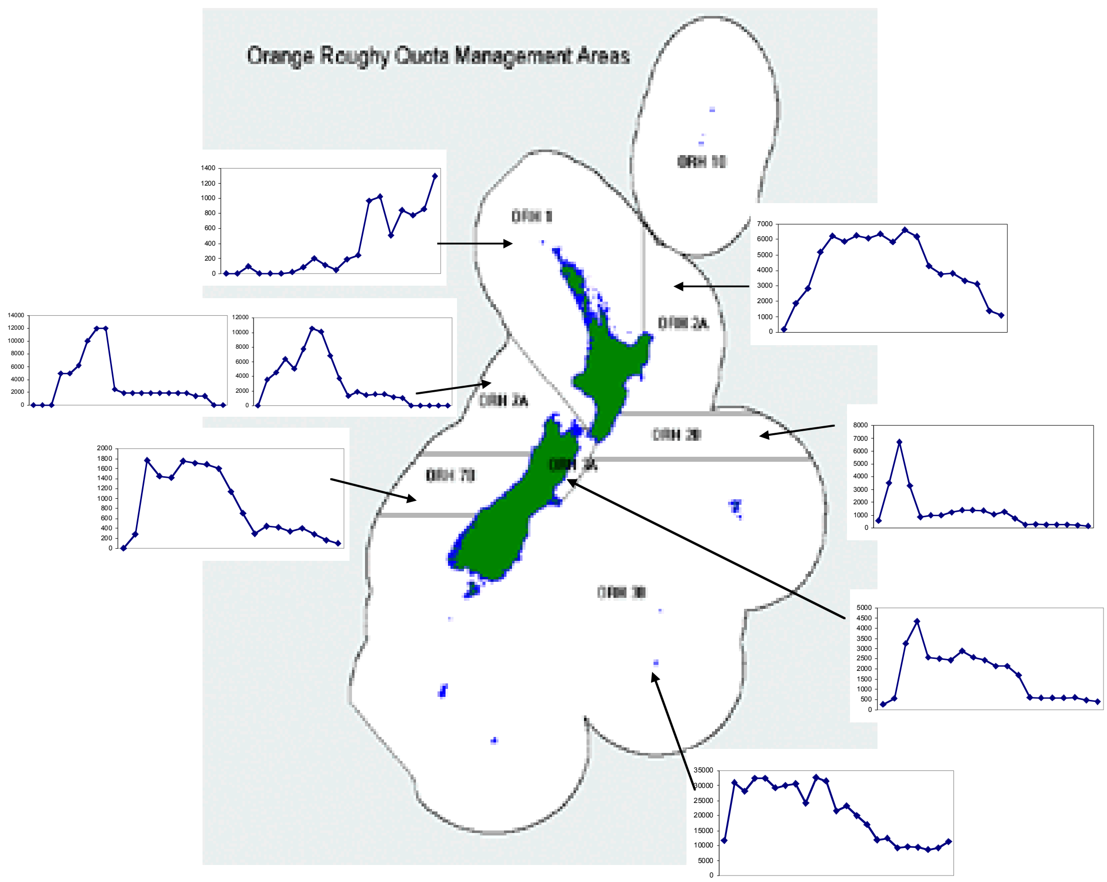
New Zealand's orange roughy fishery developed in the 1970s and although catches have declined since then New Zealand remains one of the world's largest suppliers. Figure 1 illustrates the separate stocks of orange roughy in New Zealand waters and their catches from the late 1970s and early 1980s through 2002. Catches are taken mainly from the Chatham Rise, the southern part of the South Island's west coast and some parts of the Challenger Plateau.

Characteristics and fishery

The orange roughy bottom trawl fishery is prosecuted by highly-skilled operators and has industry-led management regimes. Figure 2 shows the concentration ratios[2] for selected fisheries. They reveal that the six largest quota holders for ORH 3A hold 95 percent of the quota for this QMA. As for the hoki fishery, the orange roughy fishery is dominated by a small number of large quota holders, as indicated by the Herfindahl index[3] (Figure 3). The index for ORH 3B is the highest for any fishery in New Zealand.

FIGURE 1

Orange roughy Quota Management Areas, Fisheries, and catch in tonnage from the late 1970sand early 1980s through 2002



² A Concentration Ratio describes the proportion of total output in an industry that is produced by a given number of the largest firms in the industry. The most commonly used concentration ratios are the relative outputs for the four largest firms and the eight largest firms. Although 'total output' is not necessarily synonymous with quota holding, one might expect the correlation between the two to be high.

³ A Herfindahl index provides a measure of concentration of the production in an industry and is calculated as the sum of the squares of market shares for each firm. Although 'market share' is

FIGURE 2
Deepwater and inshore fishery 4-, 6- and 8-firm concentration ratios

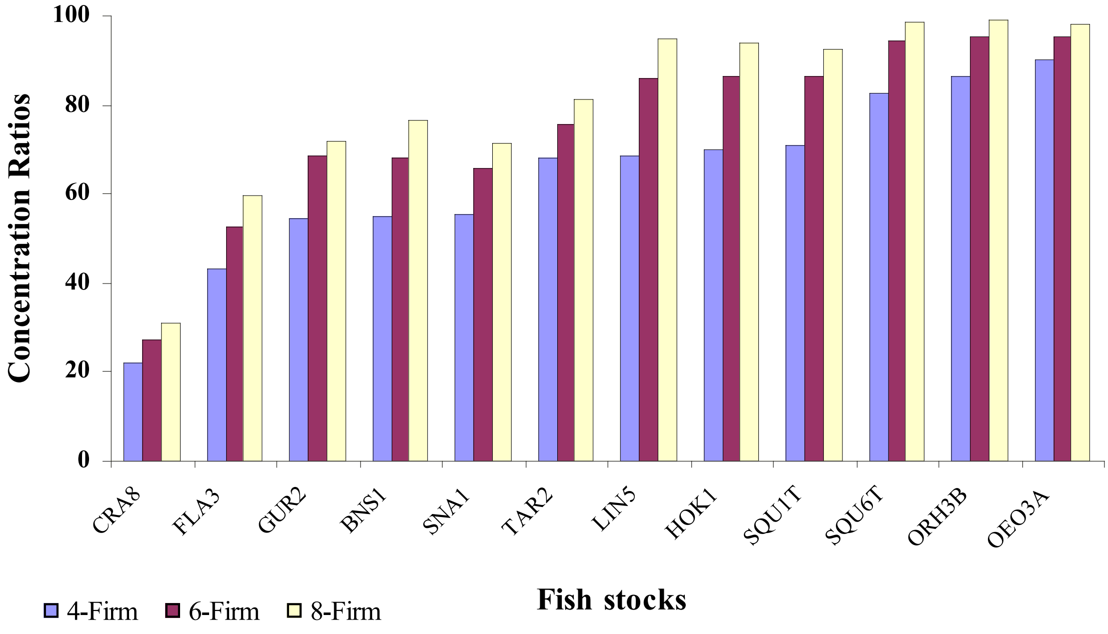
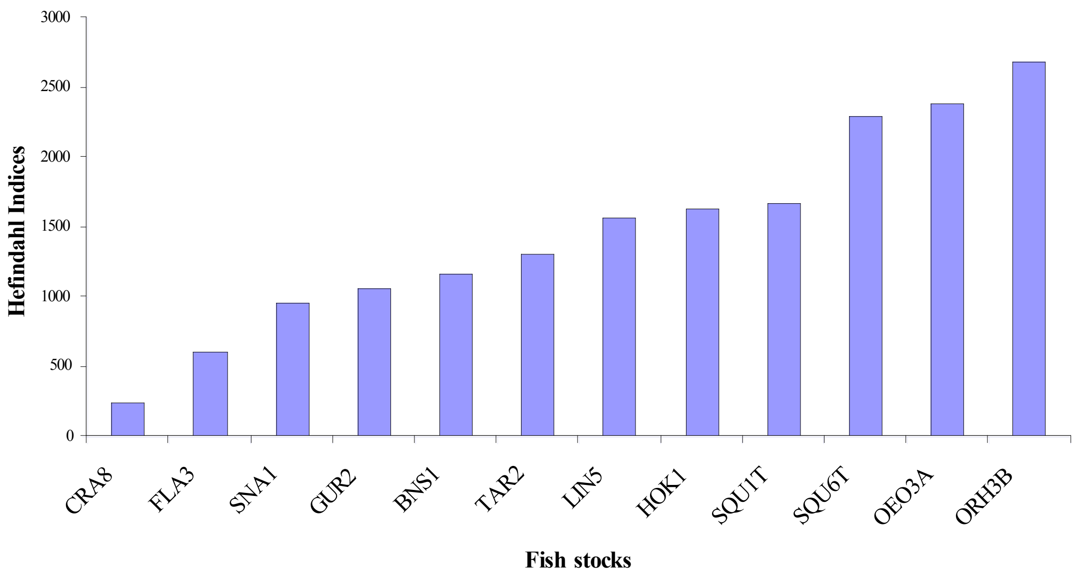


FIGURE 3
Deepwater and inshore fishery Herfindahl indices



Bycatch in this fishery is categorized into two distinct groupings, commercial bycatch (fish that can be sold commercially) and other non-commercial incidental species. Commercial bycatch of cardinal fish, spiky oreo and other oreo species accounts for approximately 30 percent of the total catch, other bycatch of approximately 44 non-

not necessarily synonymous with quota holding, one might expect the correlation to be high. The Herfindahl index is an alternative method of summarising the degree to which an industry is oligopolistic and the relative concentration of market power held by the largest firms in the industry. It is generally believed to give a better indication of the relative market control of the largest firms than can be found with the four-firm and eight-firm concentration ratios.

commercial species accounts for around 0.5 percent by volume of the total catch (Anderson, Gilbert and Clark 2001). There are no known interactions between the orange roughy fishery and protected species.

Current orange roughy management regime

The New Zealand Government and industry take the conservation of orange roughy and other fish stocks extremely seriously. They are managed and harvested under New Zealand's QMS, which provides predetermined catch limits for eight management areas. The QMS allows rapid responses to new information, provides economically rational rules regarding the methods of fishing and also rewards a long-term fishing perspective. Current catches have been set at, or below, sustainable levels, which are estimated to be six percent or less of the standing stock sizes. In cases where sustainability measures have been triggered catch levels and TACCs have been reduced and in some cases closed, often at the request of industry. Industry leadership and participation in the management of these fisheries contributes to the international success achieved by the QMS. Catch limits have been respected because of the onerous penalties that face rule breakers, including confiscation of catch, vessels, equipment and quota, coupled with severe fines. More importantly New Zealand fishers recognize and directly gain from the long-term benefits of managing fisheries at sustainable levels.

The long-term management strategy set under the *Fisheries Act 1996* is to maintain ea ch fishery stock at, or above, the level that can produce the MSY. Regular stock assessments monitor the status of each fishery (Francis, 1992), and there is strong participation from the industry and other stakeholders in the fisheries research and stock assessment process. For orange roughy, the MSY is interpreted as either the Current Annual Yield (CAY) or Maximum Constant Yield (MCY).

Sustainability measures used in the orange roughy fishery are a combination of measures imposed by the *Fisheries Act (1996)* and *Fisheries (Commercial Fishing) Regulations (2001)* and industry management initiatives endorsed by the Minister of Fisheries. Industry initiatives include the management of sub areas within QMAs, restricted areas, fishing gear restrictions and compulsory bycatch reporting.

The future of orange roughy management

The ongoing challenge for fisheries management arises from the great longevity of orange roughy and their relatively low productivity. Orange roughy are susceptible to overfishing and there are concerns over long-term damage to their stocks. The comprehensive stock assessment programme that has been underway for a number of years is to continue. Stock assessments and other research are funded by government levies and contracted to external science providers as well as directly purchased by industry. Examples of proposed future research projects that are initiated by the Ministry include:

- ORH2003/01 "Estimation of the abundance of orange roughy in selected areas"
- ORH2003/02 "Orange roughy stock assessment" and
- ORH2003/03 "Stock assessment of orange roughy fisheries outside the New Zealand EEZ".

The orange roughy quota holders collective, the Orange Roughy Management Company (ORMC) and the Tasman Pacific Fishing Company have initiated limited management responsibilities for orange roughy fisheries. Future opportunities for full-scale management through the development of fish plans may be developed.

5. FISHERY EXAMPLE: HOKI

The hoki fishery is New Zealand's most important fishery in terms of weight and had a total allowable commercial catch (TACC) of 200 000 tonnes in the 2002–2003 season and an estimated value of $NZ 1.1 billion[4].

Hoki is also New Zealand's single biggest fish export earner; in the year to April 2003, 13 200 t of Hoki products worth $NZ47.1 million FOB were exported representing 25 percent of all fish exports by weight. The largest overseas markets are the USA, Australia, Germany, Japan, and the People's Republic of China. Major exported product types include frozen fillets, fillet blocks, loins and portions and minced blocks.

Biology
Hoki is a member of the Merlucciidae family, which grows to an average length of 60–100 cm and an average weight of 1.5 kg. Hoki are widely distributed throughout New Zealand waters from 34° S to 54° S from shallow water to around 900 m. Juveniles are generally found in shallower waters and adults in waters deeper than 400 m. Hoki normally live to around 12 years of age but may live to 25 years old.

History
New Zealand's hoki fishery was developed in the early 1970s by Japanese and Soviet vessels, and to a lesser extent by South Korean vessels in the late 1970s. Prior to 1978 domestic vessels caught less than 1 000 tonnes a year. Until the 1987-88 fishing year domestic vessels were still catching less than 10 000 tonnes a year with the majority of the hoki quota being caught by foreign vessels chartered to New Zealand firms.

Characteristics of the hoki fishery
The hoki fishery, in common with other deepwater fisheries in New Zealand, is dominated by larger quota holders relative to inshore fisheries, although less so than in the case of oreo and orange roughy fisheries. Figure 2 shows that the 4–, 6–, and 8–firm concentration ratios are much higher than for the inshore fisheries; Figure 3 indicates that the Herfindahl indices for the deepwater fisheries are an order of magnitude higher than for inshore fisheries, reflecting the need for larger vessels to harvest these deepwater stocks.

The hoki season runs year-round but the major portion of the catch is taken from late June to late August–September when hoki aggregate to spawn around Hokitika Canyon off the South Island's West Coast and in Cook Strait. Minor spawning grounds also occur off the Pegasus Bay on the South Island's east coast and also off Puysegur Bank in the south-western-most part of the South Island. Non-spawning hoki are predominantly targeted in Cook Strait and on the Chatham Rise. In each case harvesting is by midwater or bottom trawling with most of the commercial catch taken between 200 and 800 m. Bycatch of several species is considered problematic and includes ling, silver warehou and in particular hake. The HAK7 (Challenger FMA) quota has been overfished in nine of the last 12 years.

Quota management areas
Hoki is managed as a single stock, denoted as the quota management area (QMA) HOK1 with a nominal fishery, HOK10, in the Kermadecs. An informal subdivision within HOK1 into an eastern and western stock enables fine-tuning of catch effort to reduce pressure on the two juvenile stocks as required.

Management of the hoki fishery
Management methods of the hoki fishery are well developed and it is administered by a combination of statutory fishing rules as established under the *Fisheries Act 1996* ('the Act') and the *Fisheries (Commercial Fishing) Regulations (2001)*, both

[4] Based on an interim value of $NZ580/tonne and 195 713 tonnes landed in the 2001–2002 fishing year.

administered by the Crown through the Ministry of Fisheries and a voluntary Code of Practice (CoP) established by the Hoki Fishery Management Company (HFMC). The Ministry of Fisheries perceive that generally, statutory and non-statutory rules work well in tandem and that agreement with industry is often sufficient to achieve the Government's sustainability objectives, rather than regulating for changes in catch, effort, for example.

The HFMC is a private company comprised of 40 or so shareholders who hold around 99 percent of the hoki quota. The objectives of the HFMC are to improve the management and economics of the hoki fishery by representing the interests of quota holders with the government responsible for fisheries research and stock assessment programmes, assisting with the balancing of catch against annual catch entitlements and implementing and monitoring fisheries management programmes.

The Hoki Fishery Management Company obtained certification in 2001 from the Marine Stewardship Council (MSC) for the New Zealand hoki fishery. This process involves independent, third party scientific certification of sustainability measures employed in a fishery. Achieving certification is a means of assuring consumers of the environmental sustainability of the fishery and offers potential for improved market access and value-adding opportunities. New Zealand hoki was awarded this certification subject to undertaking certain corrective actions identified in the independent assessment process. The corrective actions planned by the HFMC address environmental risks and ecological impacts associated with the fishery, including seabird and marine mammal interactions and marine habitat issues cited in the Ministry's sustainability review.

The sustainability measures used in the hoki fishing industry are a combination of measures imposed by the *Fisheries Act 1996*, e.g. the TAC/TACC setting (s13), requirement to hold a fishing permit (s89); statutory regulation of the *Fisheries (Commercial Fishing) Regulations (2001)*, which, *inter alia*, prohibit the use of nets with a mesh size less than 100mm mesh size (s 71), vessel length restrictions; requirements to furnish returns, *Fisheries (Reporting) Regulations 2001* and voluntary measures imposed by the HFMC code of practice (CoP). Voluntary measures include the requirement to redirect fishing effort to another area at least 3 nautical miles away for at least three days should more than 10 percent of the hoki catch be less than 60 cm total length; towing at depths more than 450 m and avoiding areas where small hoki are known to aggregate.

The future of hoki management

The comprehensive stock assessment programme that has been underway for several years is to continue. Stock assessments and other research are funded by government levies and contracted out by MFish to external science providers and are also directly purchased by the industry. Examples of proposed future research projects initiated by MFish include the following.

- HOK2002/04 "Determination of catch at age data in hoki fisheries". This project will determine the catch at age from hoki fisheries as input to the stock assessment.
- HOK2003/01 "Hoki population modelling and stock assessment". This project will update the stock assessment of hoki in the year 2004 including estimates of biomass.
- HOK2003/02 "Estimation of hoki and middle depth fish abundance on the Chatham Rise using trawl surveys".
- OK2003/03 "Estimation of spawning hoki biomass using acoustic surveys". A further acoustic survey of the west coast of the South Island is proposed for winter 2004.

The HFMC has stated[5] that they intend to develop a fishery plan to better manage the hoki fishery. Under s11A of the *Fisheries Act* there is provision for each fishery to develop an alternative management regime to the necessarily broad plan administered by MFish.

According to the HFMC, “The new management plan …will build on the current model and should manage the fishery in a long-term sustainable way as well as monitoring the commercial viability of the fishery. The new plan will undoubtedly provide more detail on procedures for such things as mitigating bycatch, trawling methods, ecological risk assessments and processing stock assessments in a timelier manner. However, developing the plan will involve scrutiny of changes to process, outcomes and information flows, through a process of consultation and with the agreement of relevant government bodies.” This ambitious goal is consistent with government policy, namely to devolve responsibilities to the industry who, with the right frameworks in place, are better able to manage the fisheries resources at a micro-level than government can hope to achieve.

6. FUTURE DIRECTIONS IN FISHERY MANAGEMENT

The Strategic Plan of the Ministry of Fisheries describes the goal of fishery management as to maximize the value New Zealanders’ obtain through the sustainable use of fisheries resources and to protect the aquatic environment. Pearce (1991) suggested that the Ministry transfer the responsibility for managing the resource users’ operations to those who hold the resource rights and charge government with the responsibility for protecting the broader public interest in resource conservation and environmental protection.

The future governmental role will be to act in the public’s interest by setting the ground rules to ensure sustainability of marine species based on scientific and environmental standards. The Government can provide an enabling framework to stimulate innovative opportunities for fishery utilisation as well as environmental protection. The Ministry of Fisheries can identify the public interest affected by fishing and protect the public interest by defining enforceable ground rules upon which those who have the rights to fish can organise themselves and exercise their rights. Public interests include stock conservation, protection of seabed habitat, seabirds, marine mammals, biodiversity and biosecurity. The Ministry must design specifications that set out the constraints on how resources are to be used. Performance standards will be developed to facilitate decisions about harvesting, stock management and allocation to those who hold the property rights.

Government objectives for fishery management are outlined in the *1996 Fisheries Act* to provide for the utilisation of fisheries resources while ensuring sustainability. Three strategies are designed to achieve the government objectives: (a) protect the health of the aquatic environment, (b) enable people to get the best value from sustainable and efficient use of fisheries and (c), ensure the Crown delivers on its obligations to Maori with respect to fisheries.

Operational objectives

The Ministry of Fisheries is initiating an evaluation of its present fishery management system with the expectation of identifying and changing policies that do not meet the objectives for the governments’ future vision for fishery management. Specifically, deepwater fisheries policies will be assessed with respect to how they achieve the objectives of sustainability, environmental effects and utilisation. This evaluation will encompass the services that fishery mangers rely on for specific stock management. Services such as research, scientific observation, compliance, enforcement, monitoring,

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[5] See their website <*www.hokinz.com/fishery_plan*>.

education, cost recovery and deemed values are to be reviewed with respect to the roles government, industry and other stakeholders play.

A stock strategy will provide an outline of the Government's ground rules and statutory requirements with respect to specific stocks under the *1996 Fisheries Act*. It will provide the Ministry's direction for the future of specific fisheries. It will demonstrate the extent to which the Government will participate in the prosecution of a fishery and outline where further opportunities exist for stakeholders to maximize the value of their wellbeing in fisheries. It is the intent of the Ministry of Fisheries to provide the operational framework that can facilitate the long-term development of such stakeholder fish plans.

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Hyperdepletion in orange roughy fisheries

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Catch per unit effort (CPUE) is commonly used as an index of abundance in stock assessments. However, it is possible that CPUE declines more slowly than abundance (hyperstability), or more rapidly than abundance (hyperdepletion). Harley, Myers and Dunn (2001) compiled CPUE and independent abundance data from the International Council for the Exploration of the Sea (ICES) and found evidence supporting hyperstability. However, hyperdepletion could not be completely ruled out and was most evident in hake fisheries.

In this study, the linearity between abundance (N) and CPUE (U) was tested using a log-transformed power function within a measurement model assuming independent errors, i.e.,

$$\log(U) = \log(q) + \beta \log(N)$$

and

$$Y = \log(U) + u \quad u \sim N(0, \sigma_u^2)$$
$$X = \log(N) + w \quad w \sim N(0, \sigma_w^2)$$

Estimates were found using maximum likelihood and confidence intervals for β were found with likelihood profiles.

Data from six orange roughy stocks were used to obtain CPUE and fishery independent abundance estimates: three from New Zealand, one from Australia and two from Namibia. Fishery independent abundances were either the results from stock assessments, which did not use CPUE as the dependent variable, research trawl surveys or research acoustic surveys. Within some stocks, there were alternative estimates of fishery independent abundance (i.e. different assumptions in a stock assessment were available), resulting in multiple analyses for that stock. Inconsistencies with the Namibian CPUE data precluded that stock from being analysed; thus only the New Zealand and Australian stocks were analyzed with the measurement error model.

The CPUE from three of the four analyzed stocks showed significant hyperdepletion when compared to the biomass outputs from the stock assessments. However, results from direct comparison of CPUE to survey data were not as significant, which may be attributed to fewer paired CPUE/abundance observations. The observation of hyperdepletion instead of hyperstability may be surprising, but it is consistent with orange roughy fisheries experience that in some cases stocks disappear as soon as fishing starts, but in places like Namibia, when fishing stops the fish come back. Further, hyperdepletion can occur in fisheries that are characterized by localized high density aggregations and a large low density abundance (Hilborn & Walters 1992), similar to hill fisheries typified by three of the four stocks analyzed. In contrast, the stock that showed a linear trend between CPUE and abundance consisted of a fishery targeting a single large spawning aggregation over flat ground. It appears that hyperdepletion is common in orange roughy fisheries and is related to the nature of the fishery. Understanding and accounting for hyperdepletion will have important consequences in the management of these fish.

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Issues in the management of high seas orange roughy fisheries in the New Zealand region

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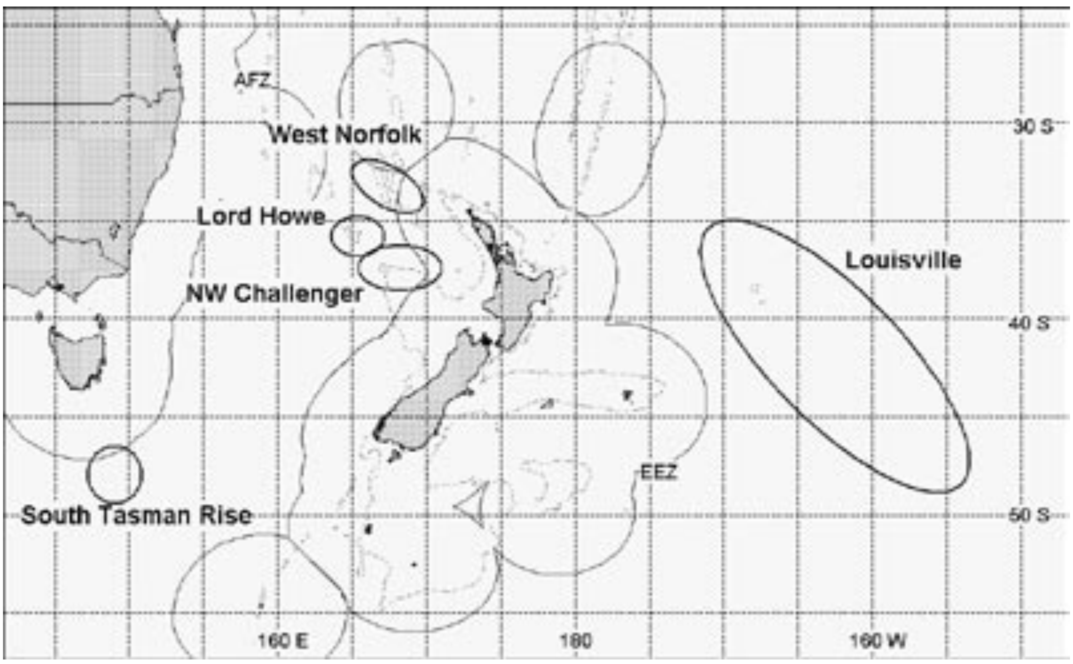
1. INTRODUCTION

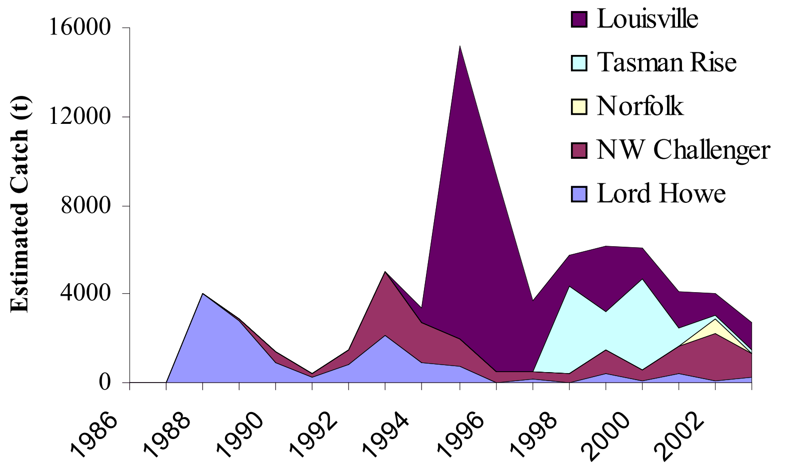
Orange roughy are a common deepwater species in the southwest Pacific and fisheries for this species developed in New Zealand and Australian waters in the 1980s and 1990s (Clark 2001, Koslow *et al.* 1997). In addition to the major fisheries inside the 200 mile EEZs of these countries, a number of fisheries occur on the high seas in the region, on the Lord Howe Rise, Northwest Challenger Plateau, West Norfolk Ridge, South Tasman Rise and Louisville Ridge (Figure 1).

FIGURE 1
The New Zealand region, showing location of major fisheries for orange roughy outside New Zealand and Australian EEZs
(1 000 m depth contour shown around New Zealand)



These fisheries have at times been substantial with total catches reaching over 15 000 t and regularly being around 4 000–5 000 t (Figure 2). The fisheries have been largely unregulated. In this paper we briefly describe these fisheries, trends in catch and effort, and discuss how the fisheries have fared in the absence of management and consider some issues for their future sustainability and management.

FIGURE 2
Estimated catches of orange roughy from the high seas fisheries in the New Zealand region
Data are primarily from the New Zealand Ministry of Fisheries and Australian Fisheries Management Authority. 1988 on the x-axis, e.g. is the 1987–88 fishing year.

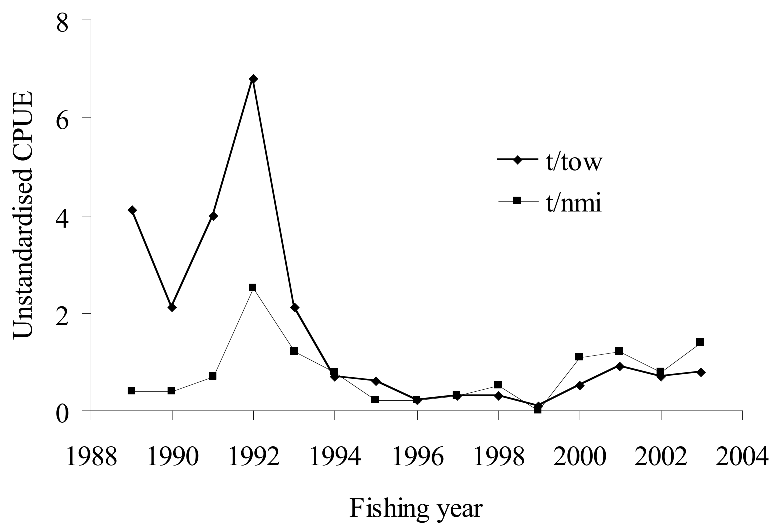


2. THE REGIONAL FISHERIES

2.1 Lord Howe Rise

The Lord Howe Rise extends from the northwestern margin of the Challenger Plateau, off the west coast of New Zealand, out to Lord Howe Island in the western Tasman Sea. The ridge is mostly in international waters, although it does extend into both the Australian and New Zealand EEZs. A major fishery for orange roughy developed on the Lord Howe Rise in 1988. A number of countries fished the area in the late 1980s, but during the 1990s it was fished mainly by New Zealand and Australian vessels. Annual catches were initially as high as 4 000 t, but in recent years the fishery has become small with catches between 100 and 300 t.

FIGURE 3
Unstandardised CPUE indices from the Lord Howe Rise orange roughy fishery1988–1989 to 2002–2003
1990 on x axis is the 1989–90 fishing year (from Clark 2004)



Catch-per-unit-effort (CPUE) has also decreased over time. Unstandardized and standardized CPUE analyses have been carried out on New Zealand data (Clark and O'Driscoll 2002, O'Driscoll 2003) and show a peak in the early 1990s, declining rapidly to low levels and remaining relatively consistent at less than 1 t/tow to the present (Figure 3). The number of vessels in the fishery has fluctuated between 4 and over 20 and effort has also varied with time of year. It has made CPUE hard to use confidently as an index of abundance, but this mesure still indicates a strong decrease in the stock size.

There has been no management of the fishery, although New Zealand and Australia have been discussing management options since the early 1990s. The low catch rates in the fishery have led to a sporadic distribution, and level, of effort, and many of the New Zealand vessels involved in the fishery in the last ten years have been small boats, which often hold little deepwater quota inside the New Zealand EEZ.

2.2 Northwestern Challenger Plateau

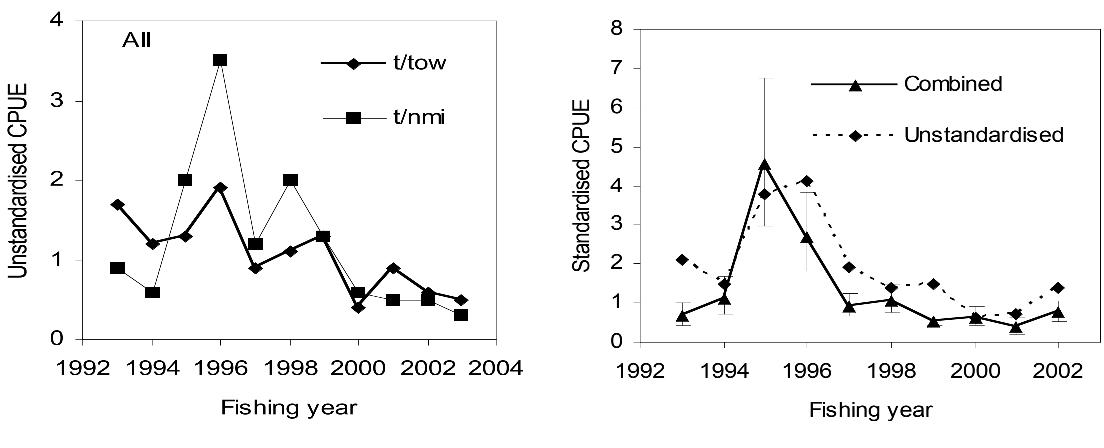
The northwestern corner of the Challenger Plateau has a large number of small seamount-like features arising from the continental slope, and these and flat ground in between have been the focus of this fishery since the early 1990s. As catch rates on the Lord Howe Rise started to decline, effort shifted to this region and it has seen more effort and larger catches than Lord Howe. Over 60 different vessels have fished the area since 1991 making over 11 000 trawls. There have been some marked changes in the distribution of fishing over time. In the first two years, most trawling was carried out on flat ground, but tows then became progressively shorter as the vessels increased their targeting on the small seamounts. Over the last three years effort has shifted back to the flat area and average tow duration has increased from one hour/tow to over four hours/tow.

The maximum annual catch was 2 900 t in 1992–93 and although catch levels of 1 000–2 000 t have occurred in recent years, this has been with almost double the number of tows undertaken in the early-mid 1990s. Catch-per-unit-effort has decreased over time. Unstandardized and standardized CPUE analyses have been carried out on New Zealand data (Clark and O'Driscoll 2002, O'Driscoll 2003), and show mixed results. Unstandardized CPUE over the entire year peaked in the mid-1990s, then declined to the present (Figure 4). Standardized CPUE showed an increasing trend over time (O'Driscoll 2003), but when core vessels (those consistently involved in the fishery) in the June period (when effort had been most constant on the small seamounts) were excluded the pattern was similar to the unstandardized result.

FIGURE 4

CPUE indices from the Northwest Challenger orange roughy fishery 1992–1993 to 2002–2003

Left panel: Unstandardized for all vessels and full year (Clark 2004). Right panel: Standardized and un-standardized indices for selected core vessels in June (O'Driscoll 2003). 1992 on x axis is the 1991–1992 fishing year.



Stock size appears to have decreased over time, especially the component that resides on the small seamounts where orange roughy spawn or feed. Catch rates have declined less than on Lord Howe, although this appears partly to be a result of the fleet's spreading effort over a wider area. There has been no management, although New Zealand and Australia have discussed management options for this fishery as well as for the Lord Howe Rise region.

2.3 West Norfolk Ridge

New fishing grounds have recently developed on the West Norfolk Ridge, which runs northwest from the North Island towards New Caledonia. This comprises a chain of ridge peaks and seamount features both within and beyond the New Zealand EEZ.

Up to 15 Australian and New Zealand vessels have been involved in this fishery, which yielded almost 700 t in 2001–2002. Most of this came from three small seamount features. However, it appears to have declined almost as rapidly as it developed, with a decrease in catch to 40 t in 2002–2003. The average catch per tow has decreased from 3 t/tow in 2001–2002 to 0.8 t/tow in 2002–2003.

2.4 South Tasman Rise

The South Tasman Rise is a prominent ridge extending south from Tasmania into the Southern Ocean. It has a series of small peaks near its main summit at about 900 m in depth just outside the Australian 200 mile Fishing Zone.

The orange roughy fishery started in September 1997 and expanded rapidly as more Australian and New Zealand boats entered the fishery. An estimated 3 900 t was caught in the 1997–1998 fishing year. Reported catches increased to over 4 000 t in 1999–2000. One Belize and three South African flagged vessels fished for a period during the 1999 winter, but no other non-Australasian vessels are known to have fished the region. Oreos were previously taken as bycatch in the fishery with over 1 000 t caught in both 1997–1998 and 1998–1999. Catches have dropped markedly since then, to around 100–200 t a year, but were greater than the orange roughy catch in 2003–2004.

CPUE analyses have been difficult because the fishery has varied greatly between years in levels of effort and the times of the year when fishing occurred. Average unstandardized catch rates have decreased from over 3 t/tow in 1999–2000, to less than 1 t/tow. Standardized CPUE indices have also decreased substantially (CSIRO, unpublished data).

In contrast to the other fisheries covered here, attempts were made early on to apply a management regime. The fishery has been regulated by a Memorandum of Understanding (MOU) between Australia and New Zealand since early 1998 (Tilzey 2000). A precautionary TAC of 2 100 t was agreed on for the period 1 March 1998 to 28 February 1999, but the MOU was not renewed for the 1999–2000 fishing season. The TAC was subsequently increased to 2 400 t for the 2000–2001 fishing season, before being reduced in 2002–2003 to 1 800 t, and subsequently to 800 t and 600 t for 2003–2004 and 2004–2005 respectively (Table 1).

2.5 Louisville Ridge

The Louisville Ridge is a chain of seamount and guyot features extending southeast for over 4 000 km from the Kermadec Ridge. It is a "hotspot" chain of more than 60 volcanoes, most of which rise to peaks of 200–500 m from the surrounding seafloor at depths around 4 000 m. The Ridge is outside the New Zealand EEZ and thus in international waters.

TABLE 1
Quota levels (under the MOU) and orange roughy catch (t) in the South Tasman Rise fishery

Fishing year	Quota (t)	Combined Australian and New Zealand catch
1997–1998	None	3 930
1998–1999	2 100	1 940
1999–2000	None	3 620
2000–2001	2 400	830
2001–2002	2 400	170
2002–2003	1 800	110
2003–2004	800	

The fishery started in the 1993–1994 fishing year. Reported catches by New Zealand and Australian vessels rose from about 700 t in that year to over 13 000 t the following year. Since then annual catches have fluctuated between 1 000 and 3 000 t. Vessels from other countries have fished at times, but catches are not thought to have ever been substantial. There have been strong seasonal trends between years in catch and effort. Initially effort in the fishery was spread over much of the year, but from 1998–1999 onwards effort has been heavily concentrated in June, July and August. The distribution of catches has also varied between years. The fishery initially developed in the central region in 1994–1995, with other grounds quickly developing in the northern region of the Ridge. Southern seamounts also yielded good catch rates from 1995–1996. Over the last three years effort has decreased in the central region and good catch rates have occurred on fewer seamounts. Fishing success on the northern-most seamounts has also been reduced, but fishing has expanded to more features in the southern area (Clark 2004).

Unstandardized CPUE has been examined, based on mean catch per trawl for the total Louisville Ridge area, and the three main regions separately (Clark 1999, Clark and Anderson 2001). Most fishing grounds showed reductions in CPUE from peak values in the first two to three years, but the pattern has differed between the three broad divisions of the Ridge (Figure 5). CPUE on individual seamounts has also been examined and again shows highly variable levels between years.

The Louisville fishery has not been subject to any management measures. Catches, and presumably stock size, have, in general, decreased over time and there are indications that some seamounts have been overfished while other new ones have been found to maintain catches. However, overall the fishery appears more stable than those in the Tasman Sea.

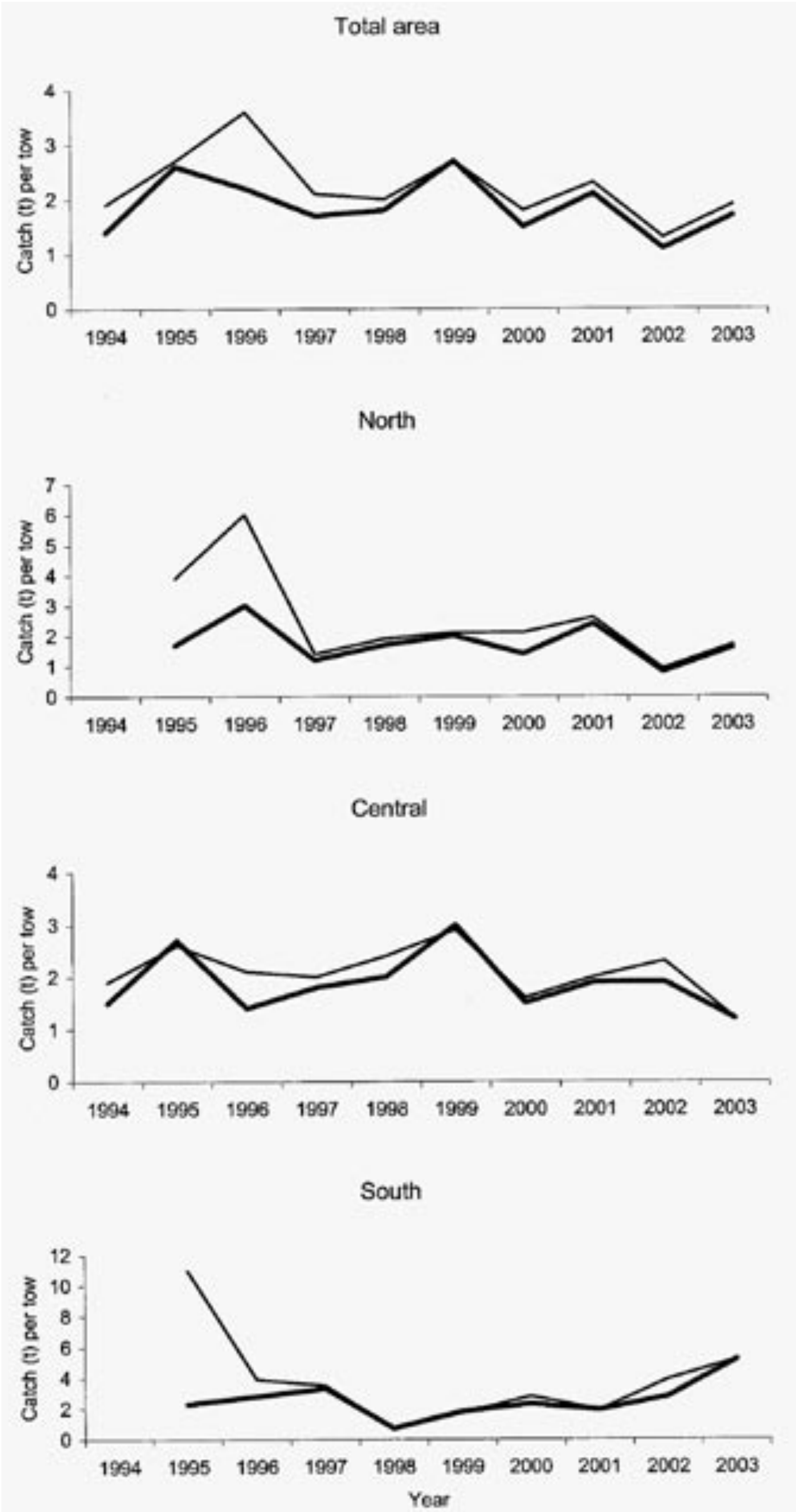
3. DISCUSSION

Most fisheries on the high seas around New Zealand have a history of rapid development and then rapid decrease after several years of high catches. With the exception of the South Tasman Rise, none have had any management measures applied. However, despite this lack of management, fisheries on the Lord Howe Rise, northwestern Challenger Plateau and Louisville Ridge have persisted, and average catch rates in recent years have been relatively stable. Catch levels in the West Norfolk Ridge fishery have decreased dramatically in just two years and this may have been because it was based on a small and localized stock.

Stock assessment has been problematic with all these fisheries. There have been no fishery-independent surveys undertaken, as research on stocks within the New Zealand EEZ have taken priority for limited institutional resources. Our knowledge and assessment of changes in the stocks have been based on catches and CPUE. These in turn are affected by the consistency of both the fishing fleet characteristics and fishing practices in the fisheries. Both have typically been highly variable. Fishing outside the EEZ has tended to be undertaken by small New Zealand vessels that had insufficient quota inside the EEZ to fully utilize vessel capacity. This has varied considerably between years and between fishing grounds. A clear example of this is with theLord Howe Rise, where the total datset examined for CPUE analyses by O'Driscoll (2003) comprised about 3 400 tows from 53 individual vessels. However, the distribution across years, seasons, vessels and smaller fishing areas, was patchy, and only seven vessels met inclusion criteria (based on number of tows and number of years in the fishery); none of these were in the fishery during its early years and, although these vessels accounted for almost 60 percent of all tows in the fishery, combined they carried out fewer than 100 tows in 11 of the 14 years of the fishery. This restricts the usefulness of detailed catch–effort analyses and for the Lord Howe Rise CPUE has not been accepted as a measure of abundance. Data from the Northwest Challenger Plateau

FIGURE 5

Unstandardized CPUE (t/tow) by area by year for all months (heavy line) and for the winter period (thin line)



and Louisville Ridge are more stable although, even with these fisheries changes in the vessel composition over time and the areas fished between years, they pose difficulties. The lack of reliable abundance estimates or indices for any of the fisheries has restricted any planning for appropriate management.

Orange roughy can form dense aggregations for spawning or feeding, which enables high commercial catch rates even as stock size is declining. This makes the species vulnerable to overexploitation. In addition, roughy are slow-growing and long-lived and sustainable exploitation rates are low. Hence recovery from overfishing should take a long time. These characteristics make it important that management occurs from an early stage of any fishery to avoid overfishing. The examples of some orange roughy fisheries in New Zealand, Australia, Namibia and the Indian Ocean that have developed rapidly and then declined to low levels with serial depletion of some fishing grounds (e.g. Branch 2001, Clark *et al.* 2000) highlight the need for immediate management. In a meta-analysis of New Zealand seamount fisheries, Clark, Bull and Tracy (2001) examined the likely stock sizes of individual seamount-like features and concluded that almost all around New Zealand were of the order of several hundred to 3 000 t, with only a few over 10 000 t. Stocks of this size can be quickly depleted, and long-term sustainable catch levels are only 50–150 t/year.

The Louisville Ridge fishery has continued to sustain a catch of several thousand tonnes, despite concerns when a large amount of effort was being applied to the fishery in the mid-1990s. However, the distance from the nearest country (New Zealand) may have played an important role, as a three to four day steam is a major commitment by a fishing vessel. If catch rates are low, or catches small, such trips can be uneconomic. Catch rates of orange roughy may be affected by heavy trawling breaking up aggregations and often a fishery is more successful when fewer vessels are involved. Although unregulated, the Louisville fishery may have reached such a balance, where the stock's size, distribution, number of vessels and effort and catch levels have reached an equilibrium.

Several of these factors were considered when the South Tasman Rise fishery developed in 1997. A memorandum of understanding was agreed upon in a short space of time between New Zealand and Australian governments. Issues of catch history, in the first regulation of deepwater fishing activity on the high seas for Australasian vessels, were used to determine a mutually agreed catch division. Compliance and other countries fishing were all problems in the first years and in 1999–2000 the quota was substantially exceeded. There were discussions on research between New Zealand and Australia, and an exploratory research programme was implemented to establish stock structure, and the distribution of the fishery to allow planning for an acoustic abundance survey. However, the survey never happened as catches started to drop and it became clear that the fishery may be relatively small. Quota levels have now been considerably reduced (although they have lagged behind catches) and there is a trigger mechanism that will increase the available catch if aggregations re-appear. The management of this fishery was less than optimal as the initial TAC was too high to be precautionary. However, a lot has been learnt about what is required for effective orange roughy management (Francis and Clark 2005). Central to these factors on the high seas are cooperation between governments, fishers, scientists and managers to limit catches early on until more is known of the stock distribution and until fishery-independent estimates of biomass are made.

4. ACKNOWLEDGEMENTS

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Description of the age-structured production model (ASPM) assessment methodology used for the Namibian orange roughy (*Hoplostethus atlanticus*) and the South African Prince Edward Islands Patagonian toothfish (*Dissostichus liginoides*)

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1. INTRODUCTION

Butterworth and Brandão (2005) describe the historical development and assessments of the present status of the Namibian orange roughy (*Hoplostethus atlanticus*) and the Patagonian toothfish (*Dissostichus eliginoides*) off South Africa's sub-Antarctic Prince Edward Islands. This paper sets out the methodologies, based on the age-structured production model (ASPM) approach, which have been used to assess these resources. Common methodology is set out under general headings, within which the differences in the methodology applied for the two stocks are detailed under sub-headings for each.

While the methodology applied for the toothfish is relatively standard, that for the orange roughy incorporates novel features to deal with the "intermittent aggregation" hypothesis that is considered for this resource.

2. THE BASIC POPULATION DYNAMICS

Both the orange roughy and toothfish dynamics are described by the equations.

$$N_{y+1,0} = R(B^{sp}_{y+1}) \tag{1}$$

$$N_{y+1,a+1} = (N_{y,a} - C_{y,a})e^{-M} \qquad 0 \leq a \leq m\text{-}2 \tag{2}$$

$$N_{y+1,m} = (N_{y,m} - C_{y,m})e^{-M} + (N_{y,m-1} - C_{y,m-1})e^{-M} \tag{3}$$

where:

$N_{y,a}$ is the number of fish of age a at the start of year y

$C_{y,a}$ is the number of fish of age *a* taken by the fishery in year *y*

$R(B_y^{sp})$ is the Beverton-Holt stock-recruitment relationship described by equation (15) below

B_y^{sp} is the spawning biomass at the start of year *y*
M is the natural mortality rate of fish (assumed to be independent of age) and
m is the maximum age considered (i.e. the "plus group").

In the interests of simplicity, this approximates the fishery as a pulse fishery at the start of the year. Given that both orange roughy and toothfish are relatively long-lived with low natural mortality, such an approximation would seem justifiable.
The number of fish of age *a* caught in year *y* is given by:

$$C_{y,a} = N_{y,a} S_a F_y \tag{4}$$

where:

F_y is the proportion of the resource above age *a* harvested in year *y* and
S_a is the commercial selectivity at age *a*.

The mass-at-age is given by the combination of a von Bertalanffy growth equation for length-at-age l(*a*) defined by constants l_∞,$_\infty$ κ and and a relationship relating length to mass. Note that here l refers to standard length:

$$\ell(a) = \ell_\infty [1 - e^{-\kappa(a-t_0)}] \tag{5}$$

$$w_a = c\ell(a)^d \tag{6}$$

where:
w_a is the mass of a fish at age *a*.
The total catch by mass in year *y* is given by:

$$C_y = \sum_{a=0}^{m} w_a C_{y,a} = \sum_{a=0}^{m} w_a S_a F_y N_{y,a} \tag{7}$$

which can be re-written as:

$$F_y = \frac{C_y}{\sum_{a=0}^{m} w_a S_a N_{y,a}} \tag{8}$$

3. FISHING SELECTIVITY

Orange roughy
The commercial fishing selectivity, S_a, for orange roughy is assumed to be knife-edge and given by:

$$S_a = \begin{cases} 0 & a < a_r \\ 1 & a \geq a_r \end{cases} \tag{9}$$

where:
a_r is the age at recruitment to the fishery, assumed equal to the age at maturity (a_m) for the Namibian orange roughy populations.

Toothfish

The commercial fishing selectivity (assumed to vary from year to year), $S_{y,a}$, for toothfish is assumed to be described by a logistic curve, modified by a decreasing selectivity for fish older than age a_c. This is given by:

$$S_{y,a} = \begin{cases} \left[1+e^{-(a-a_{50,y})/\delta}\right]^{-1} & \text{for } a \le a_c \\ \left[1+e^{-(a-a_{50,y})/\delta}\right]^{-1} e^{-\omega_y (a-a_c)} & \text{for } a > a_c \end{cases} \tag{10}$$

where

$a_{50,y}$ is the age-at-50% selectivity (in years) in year y, where $a_{50,y} = \bar{a}_{50} e^{\varepsilon_y^{\bar{a}_{50}}}$.

The $\varepsilon_y^{\bar{a}_{50}}$ are assumed to be normally distributed with mean zero and standard deviation $\sigma_{\bar{a}_{50}}$

δ defines the steepness of the ascending section of the selectivity curve (in years^{-1})

ω_y defines the steepness of the descending section of the selectivity curve for fish older than age a_c in year y, where $\omega_y = \bar{\omega} e^{\varepsilon_y^{\bar{\omega}}}$ and $\varepsilon_y^{\bar{\omega}}$ are assumed to be normally distributed with mean zero and standard deviation $\sigma_{\bar{\omega}}$.

In cases where equation (8) yields a value of $F_y > 1$ for a future year, i.e. the available biomass is less than the proposed catch for that year, F_y is restricted to 0.9, and the actual catch considered to be taken will be less than the proposed catch. This procedure makes no adjustment to the exploitation rate ($S_{y,a}F_y$) of other ages. To avoid the unnecessary reduction of catches from ages where the TAC could have been taken if the selectivity for those ages had been increased, the following procedure is adopted for the toothfish fishery (CCSBT 2003):

- The fishing mortality, F_y, is computed as usual using equation (8).
- If $F_y \le 0.9$ no change is made to the computation of the total catch, C_y, given by equation (7).
- If $F_y > 0.9$, the total catch is computed by:

$$C_y = \sum_{a=0}^{m} w_a g(S_{y,a}F_y) N_{y,a} \tag{11}$$

The modified selectivity is denoted by $S^*_{y,a}$,
where:

$$S^*_{y,a} = \frac{g(S_{y,a}F_y)}{F_y} \tag{12}$$

so that

$$C_y = \sum_{a=0}^{m} w_a S^*_{y,a} F_y N_{y,a}$$

where:

$$g(x) = \begin{cases} x & x \le 0.9 \\ 0.9 + 0.1\left[1 - e^{(-10(x-0.9))}\right] & 0.9 < x \le \infty \end{cases} \tag{13}$$

Now F_y is not bounded at one, but $g(S_{y,a}F_y) \leq 1$ hence $C_{y,a} = g(S_{y,a}F_y)\,N_{y,a} \leq N_{y,a}$ as required.

4. STOCK-RECRUITMENT RELATIONSHIP

The spawning biomass in year y is given by:

$$B_y^{sp} = \sum_{a=1}^{m} w_a f_a N_{y,a} = \sum_{a=a_m}^{m} w_a N_{y,a} \tag{14}$$

where:

f_a is the proportion of fish of age a that are mature (assumed here to be knife-edge at age a_m).

The number of recruits at the start of year y is assumed to relate to the spawning biomass B_y^{sp} at the start of year y by the Beverton-Holt stock-recruitment relationship (assuming deterministic recruitment):

$$R(B_y^{sp}) = \frac{\alpha B_y^{sp}}{\beta + B_y^{sp}} \tag{15}$$

The values of the parameters α and β can be calculated given the initial spawning biomass K^{sp} and the steepness of the curve h, using equations (16) – (20) below. If the initial (and pristine) recruitment is $R_0 = R(K^{sp})$, then steepness is the recruitment (as a fraction of R_0) that results when spawning biomass is 20% of its pristine level, i.e.:

$$hR_0 = R(0.2K^{sp}) \tag{16}$$

from which it can be shown that:

$$h = \frac{0.2(\beta + K^{sp})}{\beta + 0.2K^{sp}} \tag{17}$$

Rearranging equation (17) gives:

$$\beta = \frac{0.2K^{sp}(1-h)}{h-0.2} \tag{18}$$

and solving equation (15) for α gives:

$$\alpha = \frac{0.8hR_0}{h-0.2}$$

In the absence of exploitation, the population is assumed to be in equilibrium. Therefore R_0 is equal to the loss in numbers due to natural mortality when $B^{sp} = K^{sp}$, and hence:

$$\gamma K^{sp} = R_0 = \frac{\alpha K^{sp}}{\beta + K^{sp}} \tag{19}$$

where:

$$\gamma = \left\{ \sum_{a=1}^{m-1} w_a f_a e^{-Ma} + \frac{w_m f_m e^{-Mm}}{1 - e^{-M}} \right\}^{-1} \tag{20}$$

5. PAST STOCK TRAJECTORY AND FUTURE PROJECTIONS

Given a value for the pre-exploitation spawning biomass (K^{sp}) of a fish stock and the assumption that the initial age structure is at equilibrium, it follows that:

$$K^{sp} = R_0 \left(\sum_{a=1}^{m-1} w_a f_a e^{-Ma} + \frac{w_m f_m e^{-Mm}}{1 - e^{-M}} \right) \tag{21}$$

which can be solved for R_0.

The initial numbers at each age a for the trajectory calculations corresponding to the deterministic equilibrium, are given by:

$$N_{0,a} = \begin{cases} R_0 e^{-Ma} & 0 \le a \le m-1 \\ \dfrac{R_0 e^{-Ma}}{1 - e^{-M}} & a = m \end{cases} \tag{22}$$

Numbers-at-age for subsequent years are then computed by means of equations (1) – (4) and (7) – (15) under the series of annual catches given.

The model estimate of the exploitable component of the biomass for orange roughy is given by:

$$B_y^{\exp} = \sum_{a=0}^{m} w_a S_a N_{y,a} \tag{23}$$

In the case of the toothfish assessment, the model estimate of the exploitable component of the biomass is adjusted for the fact that some estimated selectivities never reach one. This adjustment is given by:

$$B_y^{\exp} = \frac{\sum_{a=0}^{m} w_a S_a N_{y,a}}{\frac{1}{n'} \sum_{a'=5}^{15} S_{a',y}} \tag{24}$$

where n' is the number of the summed terms (15-5+1).

6. THE LIKELIHOOD FUNCTION

The age-structured production model is fitted to all available indices of abundance to estimate model parameters. The likelihood function is calculated assuming that each observed abundance index is lognormally distributed about its expected value:

$$I_y^i = \hat{I}_y^i e^{\varepsilon_y} \text{ or } \varepsilon_y = \ln\left(I_y^i\right) - \ln\left(\hat{I}_y^i\right) \tag{25}$$

where

I_y^i is the ith abundance index for year y (for orange roughy these consist of the GLM standardized CPUE, the acoustic and the research swept-area abundance indices whereas for toothfish only CPUE are available)

$\hat{I}_y^i = \hat{q}^i \hat{B}_y^{exp}$ is the corresponding model estimate

where

$\hat{B}_y^{exp}$ is the model estimate of exploitable biomass of the resource for year *y* and
q^i is the catchability coefficient for the *i*th abundance index and
ε_y is normally distributed with mean zero and standard deviation σ_y^i.

Orange roughy

Under the "catch-induced" hypothesis for the decline in indices of abundance described in Butterworth and Brandão (2005), the negative of the penalized log-likelihood (ignoring constants), which is minimized in the fitting procedure (results given in Figure 6 of Butterworth and Brandão (2005) consists of the combination of the contribution of each abundance index plus the contribution of the penalty placed on the natural mortality parameter as well as the contribution of the penalty applied to the multiplicative bias of the acoustic abundance series (both these penalties are frequentist analogs of Bayesian priors for these quantities). The (penalized) negative log-likelihood function minimized for each aggregation is thus given by:

$$
\begin{aligned}
-\ln L = & \frac{1}{2(\sigma_q^{AC})^2}\left(\ln q^{AC} - \ln q^{est}\right)^2 + \ln q^{AC} + \frac{1}{2\sigma_M^2}\left(\ln M - \ln M^{est}\right)^2 + \ln M \\
& + \sum_y^{AC} \frac{1}{2(\sigma_y^{AC})^2}\left(\ln I_y^{AC} - \ln\left(q^{AC} B_y^{exp}\right)\right)^2 + \sum_y^{SA} \frac{1}{2(\sigma_y^{SA})^2}\left(\ln I_y^{SA} - \ln\left(q^{SA} B_y^{exp}\right)\right)^2 \\
& + \sum_y^{CPUE} \frac{1}{2(\sigma^{CPUE})^2}\left(\ln I_y^{CPUE} - \ln\left(q^{CPUE} B_y^{exp}\right)\right)^2 + n_{CPUE}\left(\ln \sigma^{CPUE}\right)
\end{aligned}
\tag{26}
$$

where

q^{AC} is the remaining multiplicative bias of the acoustic abundance series whose maximum likelihood estimate is given by:

$$
\ln \hat{q}^{AC} = \frac{\left(\sum_y^{AC} \frac{1}{\left(\sigma_y^{AC}\right)^2}\left(\ln I_y^{AC} - \ln \hat{B}_y^{exp}\right)\right) - 1}{\left(\sum_y^{AC} \frac{1}{\left(\sigma_y^{AC}\right)^2}\right) + \frac{1}{\left(\sigma_q^{AC}\right)^2}}
$$

q^{SA} is the 'catchability coefficient' for the research swept-area abundance indices, whose maximum likelihood estimate is given by:

$$
\ln \hat{q}^{SA} = \frac{\left(\sum_y^{SA} \frac{1}{\left(\sigma_y^{SA}\right)^2}\left(\ln I_y^{SA} - \ln \hat{B}_y^{exp}\right)\right)}{\left(\sum_y^{SA} \frac{1}{\left(\sigma_y^{SA}\right)^2}\right)}
$$

q^{CPUE} is the catchability coefficient for the standardized commercial CPUE abundance indices, whose maximum likelihood estimate is given by:

$$\ln \hat{q}^{CPUE} = \frac{1}{n_{CPUE}} \sum_{y}^{CPUE} \left(\ln I_y^{CPUE} - \ln \hat{B}_y^{\exp} \right) \tag{27}$$

σ_q^{AC} is the standard deviation of the penalty function applied to q^{AC}, which is input; its value is the CV of the distribution of the product of the systematic bias factor distributions applied to the acoustic abundance indices

q^{est} is the mean of the penalty function applied to q^{AC}, whose value is taken to be equal to one as the distribution of the bias factors for the acoustic estimate have been defined in such a way that the corrected acoustic estimate is intended to be an unbiased estimate of abundance

M is the natural mortality rate

M^{es} is the mean of the penalty function applied to M (i.e. the prior distribution mean), which is input

σ_y^{AC} is the standard deviation of the log acoustic abundance estimate for year y, which is input and is given by

$$\sigma_y^{AC} = \sqrt{\left(CV_y^S\right)^2 + \left(CV_y^R\right)^2}$$

where

CV_y^S is the CV of the sampling error distribution and

CV_y^R is the CV of the distribution of the product of the random bias factor distributions taken to apply to the acoustic abundance indices,

σ_y^{SA} is the standard deviation of the log research swept-area abundance index for year y, which is input and is given by the sampling CV of the research swept-area index of relative abundance,

σ^{CPUE} is the standard deviation of the standardized CPUE series (assuming homoscedasticity of residuals), whose maximum likelihood estimate is given by

$$\hat{\sigma}^{CPUE} = \sqrt{\frac{1}{n_{CPUE}} \sum_{y}^{CPUE} \left(\ln I_y^{CPUE} - \ln \hat{q}^{CPUE} \hat{B}_y^{\exp} \right)^2} \tag{28}$$

I_y^{AC} is the acoustic series estimate for year y

I_y^{SA} is the research swept-area series index for year y

I_y^{CPUE} is the standardized CPUE series index for year y and

n_{CPUE} is the number of data points in the standardized CPUE abundance series.

The estimable parameters of this model are q^{AC}, q^{SA}, q^{CPUE}, K^{sp}, σ^{CPUE} and M.

Under the "intermittent aggregation" hypothesis (Butterworth and Brandão 2005) estimable multiplicative bias factor x_y is included in the model so that the various terms in equation (26) become

$$- la\ L = \left(\ln I_y^i - \ln\left(x_y\ q^i\ B_y^{\exp}\right)\right)^2 \quad (29)$$

where i represents the type of abundance index in the likelihood; for example, $i = AC$, when dealing with the acoustic abundance index and so on. This x factor allows for the possibility that not all the orange roughy belonging to an aggregation are present at that site each year.

The results of the acoustic survey carried out in 2002 for the Frankies ground (closed to commercial fishing since 1999) show an index of abundance for 2002 that is in the region of the 1997 estimate (Brandão and Butterworth 2003) indicating that the low indices of abundance observed in years subsequent to 1997 cannot be interpreted as purely a consequence of fishing down of the population, but instead reflect that the extent of aggregation of the stock that occurs from year to year is variable. A penalty function is applied for the proportion of stock present (x_y) to reflect an assumption that these proportions follow a beta distribution, which is restricted to the pertinent [0,1] range by construction. Thus the following term is added to the negative of the log-likelihood function given in equation (26) (in which the terms corresponding the the abundance indices are modified to reflect equation (29)):

$$-\left[N\{\ln\Gamma(\eta+\varphi)-[\ln\Gamma(\eta)+\ln\Gamma(\varphi)]\}+\sum_{y=1994}^{2002}\{(\eta-1)\ln(x_y)+(\varphi-1)\ln(1-x_y)\}\right]$$

where

N is the total number of years considered in the assessment

η is a parameter of the beta distribution, with $\eta > 0$

ϕ is a parameter of the beta distribution, with $\phi > 0$.

Clearly the data cannot uniquely determine both η and ϕ, as this model would then not preclude an interpretation of the data that reflects an enormous resource little of which aggregates each year. Thus for precautionary management purposes, these two parameters were constrained to yield a proportion present in 1997 of at least 80% for the Frankies aggregation, and the remaining degree of freedom is used to match the spread of the distribution of annual proportional aggregation evident from the abundance indices. Only Frankies provides sufficient data contrast to be able to effect such estimation, so that the values of η and ϕ obtained there were taken to apply to the other aggregations.

Toothfish

The age-structured production model is fitted to the GLM standardized CPUE of toothfish to estimate model parameters. The likelihood is calculated assuming that the observed CPUE abundance index is lognormally distributed about its expected value as indicated by equation (25).

The negative log-likelihood function (ignoring constants), which is minimized in the fitting procedure (results given in Figure 10 of Butterworth and Brandão (2005)), consists of the combination of the contribution of the CPUE abundance index plus the contribution of the penalty placed on the parameters $a_{50,y}$ and ω_y of the selectivity function given by equation (10). The negative log-likelihood function is thus given by:

$$-\ln L = \sum_{y}^{CPUE}\left[\frac{1}{2(\sigma^{CPUE})^2}\left(\ln I_y^{CPUE} - \ln\left(q^{CPUE} B_y^{\exp}\right)\right)^2 + \left(\varepsilon_y^{\bar{a}_{50}}\right)^2 \Big/ 2\left(\sigma_{\bar{a}_{50}}\right)^2 + \left(\varepsilon_y^{\bar{\omega}}\right)^2 \Big/ 2\left(\sigma_{\bar{\omega}}\right)^2\right] + n_{CPUE}\left(\ln\sigma^{CPUE}\right) \tag{31}$$

The estimable parameters of this model are $\bar{a}_{50}$, $\bar{\omega}$, δ, $\varepsilon_y^{\bar{a}_{50}}$, $\varepsilon_y^{\bar{\omega}}$, q^{CPUE}, K^{sp} and σ_{CPUE}. The values of $\sigma_{\bar{a}_{50}}$ and $\sigma_{\bar{\omega}}$ were fixed at 1.0 and 0.3 respectively. Closed form estimates for q^{CPUE} and σ_{CPUE} are given by equations (27) and (28) respectively.

7. EXTENSION TO INCORPORATE CATCH-AT-LENGTH INFORMATION

The model above provides estimates of the catch-at-age ($C_{y,a}$) by number taken by the fishery each year from equation (4). These in turn can be converted into proportions of the catch of age a:

$$p_{y,a} = C_{y,a} \Big/ \sum_{a'} C_{y,a'} \tag{32}$$

Using the von Bertalanffy growth equation (5), these proportions-at-age can then be converted to proportions-at-length – here under the assumption that the distribution of length-at-age remains constant over time:

$$p_{y,\ell} = \sum_{a} p_{y,a} A_{a,\ell} \tag{33}$$

where

$A_{a,\ell}$ is the proportion of fish of age a that fall in length group ℓ. Note that therefore:

$$\sum_{\ell} A_{a,\ell} = 1 \text{ for all ages } a \tag{34}$$

The A matrix has been calculated here under the assumption that length-at-age is normally distributed about a mean given by the von Bertalanffy equation, i.e.:

$$\ell(a) \sim N^*\left[\ell_\infty\left\{1 - e^{-\kappa(a-t_0)}\right\}; \theta(a)^2\right] \tag{35}$$

where

N* is a normal distribution truncated at ± 3 standard deviations (to avoid negative values) and

$\theta(a)$ is the standard deviation of length-at-age a, which is modelled here to be proportional to the expected length at age a, i.e.:

$$\theta(a) = \tau\ell_\infty\left\{1 - e^{-\kappa(a-t_0)}\right\} \tag{36}$$

with τ a parameter estimated in the model fitting process.

Note that since the model of the population's dynamics is based upon a one-year time step, the value of τ and hence the $\theta(a)$'s estimate will reflect not only the real variability of length-at-age, but also the "spread" that arises from the fact that fish in the same annual cohort are not all spawned at exactly the same time and that catching takes place throughout the year so that there are differences in the age (in terms of fractions of a year) of fish allocated to the same cohort.

The model is fitted by adding the following term to the negative log-likelihood of equation (31):

$$-\ln L_{len} = w_{len} \sum_{y,\ell} \left\{ \ln\left[\sigma_{len} / \sqrt{p_{y,\ell}}\right] + \left(p_{y,\ell} / \left(2\sigma_{len}^2\right)\right)\left[\ln p_{y,\ell}^{obs} - \ln p_{y,\ell}\right]^2 \right\} \quad (37)$$

where

$p_{y,\ell}^{obs}$ is the proportion by number of the catch in year y in length group ℓ, and

σ_{len} has a closed form maximum likelihood estimate given by:

$$\hat{\sigma}_{len}^2 = \sum_{y,\ell} p_{y,\ell}\left[\ln p_{y,\ell}^{obs} - \ln p_{y,\ell}\right]^2 \Big/ \sum_{y,\ell} 1 \quad (38)$$

Equation (37) makes the assumption that proportions-at-length data are log-normally distributed about their model-predicted values. The associated variance is taken to be inversely proportional to $p_{y,\ell}$ to reduce the contributions from expected small proportions, which will correspond to small observed sample sizes. This adjustment (originally suggested to us by A.E. Punt) is of the form to be expected if a Poisson-like sampling variability component makes a major contribution to the overall variance. Given that overall sample sizes for length distribution data differ quite appreciably from year-to-year, subsequent refinements of this approach may need to adjust the variance assumed for equation (37) to take this into account.

The w_{len} weighting factor may be set at a value less than 1 to reduce the contribution of the catch-at-length data to the overall negative log-likelihood compared to that of the CPUE data in equation (31). The reason that this factor is introduced is that the $p_{y,\ell}^{obs}$ data for a given year frequently show evidence of strong positive correlation, and so are not as informative as the independence assumption underlying the form of equation (37) would otherwise suggest.

In the practical application of equation (37), length observations were grouped by 2 cm intervals, with minus- and plus-groups specified below 54 and above 138 cm respectively, to ensure $p_{y,\ell}^{obs}$ values in excess of about 2% for these cells.

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High seas resource management: some discussion of the Madagascar ridge, Western Indian Ocean

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> *"Conscious that the problems of ocean space are closely inter-related and need to be considered as a whole"*, Preamble to the 1982 Convention of the Law of the Sea.

1. INTRODUCTION

The negotiation of the 1982 United Nations Convention on the Law of the Sea (LOSC) is a triumph of perseverance. The fact that this convention exists, that it has spawned so many crucial legal instruments and that the Convention itself has been signed by more than 150 states is evidence that the majority of states acknowledges that the oceans must be managed globally. Fundamental to the LOSC is the freedom of the high seas and an obligation to cooperate in the management of high seas. The need to cooperate on the high seas has resulted in the establishment of several Regional Fisheries Organizations.

2. DEVELOPMENT OF SOUTH AFRICAN HIGH SEAS FISHERIES

South Africa has developed fisheries in recreational, artisanal, subsistence, small-scale commercial and heavy-industrialized fisheries. The National Department of Environmental Affairs & Tourism advises the Minister on the allocation of some 683 000 tonnes and 166 500 tonnes of total allowable catch (TAC) in the small pelagic and demersal hake trawl fisheries. In 2003 these two fisheries were the two largest industrialized fisheries in South Africa with 112 rights holders in the small pelagic fishery and 53 rights holders in the demersal hake trawl fishery. With capacity such as this it was inevitable that the industry would begin to explore resources outside the national EEZ, as is their right. In 1996 the Minister issued South African companies with permits to fish the EEZs of the Prince Edward Islands and South Africa's Antarctic Territories. Within a year these companies progressed to fishing other CCAMLR areas. Expeditions to explore South East Atlantic and Western Indian oceans for catches of orange roughy (*Hoplostethus atlanticus*), alfonsino (*Beryx spendens*) and oreo dory and large pelagics like tuna began to increase. Of course South Africa's history of highs-seas fishing does predate the 1990s as rock lobster fisheries off Tristan and Gough Islands and tuna fishing off Vema Seamount were established in the early 1980s.

Currently South Africa does not exploit South East Atlantic high-seas stocks of orange roughy, alfonsino and oreo dory. The industry, like those of other nations, is more successful in the Western Indian Ocean on the Madagascar Ridge (Figure 1). This harvesting is undertaken in the absence of management by a regional fisheries organization.

In attempting to find new and more economically efficient reserves of orange roughy, a South African company, Irvin and Johnson, undertook exploratory trawls on a number of seamounts on the Madagascar Ridge, during January and February 2000. The trawls were undertaken between the Ndomed and Gallieni Facture Zones (Figure 2). Material from a total of 42 trawls was sampled. Additional material was supplied from other trips to the Melville Bank area. The following results describe the work of Leslie, Compagno and Hulley (2001). Figures 3-12 show some of the unusual fishes taken from this area.

FIGURE 1
Position of Melville Bank area in relation to South Africa

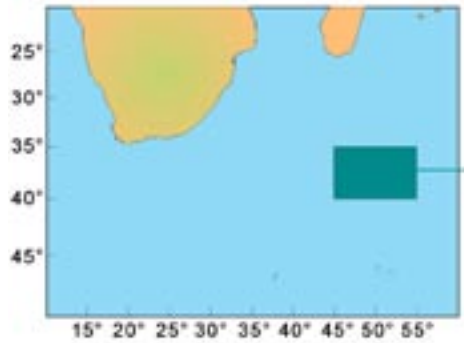


FIGURE 2
Location of exploratory trawls

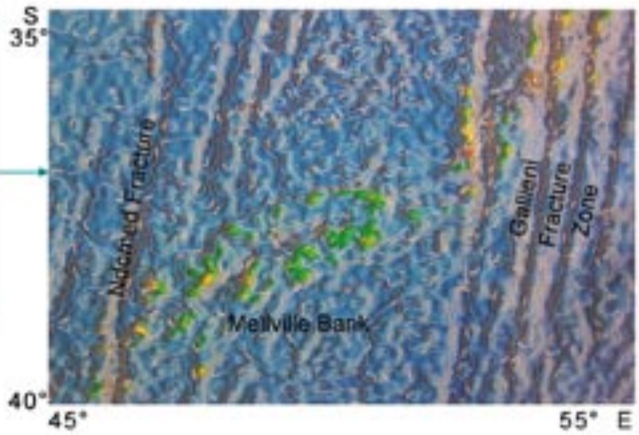


FIGURE 3
Specimens of *Etmopterus cf priceps* (Etmopteridae) collected on the Madagascar Ridge closely resemble *E. princeps*, which is known only from the North Atlantic

FIGURE 4
Specimens from the Madagascar Ridge of *Etmopterus brachyurus* (Etmopteridae) and South Africa resemble *E. brachyurus*, which is known from Japan, the Philippines and Australia

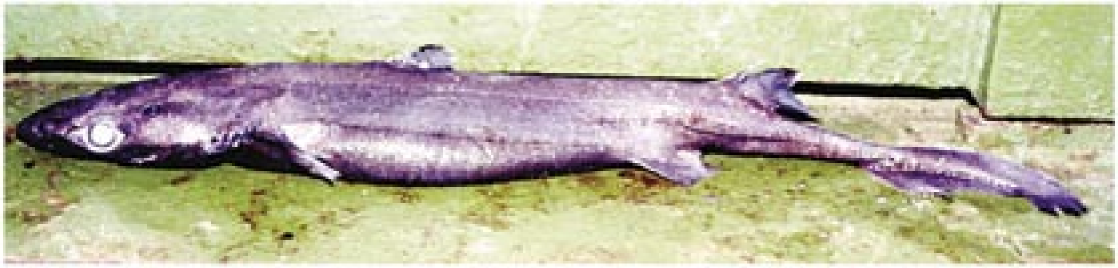


FIGURE 5
***Proscymnodon plunketi* (Somniosidae). Catches of this species show a significant range extension for this species, which was known only from New Zealand and Australia.**

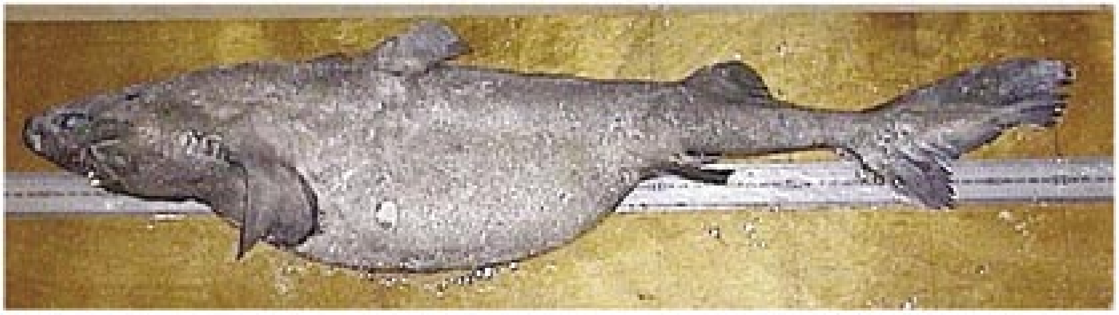


FIGURE 6
***Somniosus antarcticus* (Somniosidae), widely distributed in the Southern oceans but not previously recorded from the Melville Banks region.**

FIGURE 7
***Parmaturus macmillani* (Scyliorhinidae). This species was regarded as endemic to New Zealand. These records constitute a significant range extension.**

FIGURE 8
Sladenia sp. **(Lophiidae), an undescribed anglerfish fish species. The first record of this genus in the Indian Ocean.**

FIGURE 9
Apisturus cf investigatoris **(Scyliorhinidae). Close to or perhaps identical to** *A. investigatoris***, known only from the type locality in the Andaman sea**

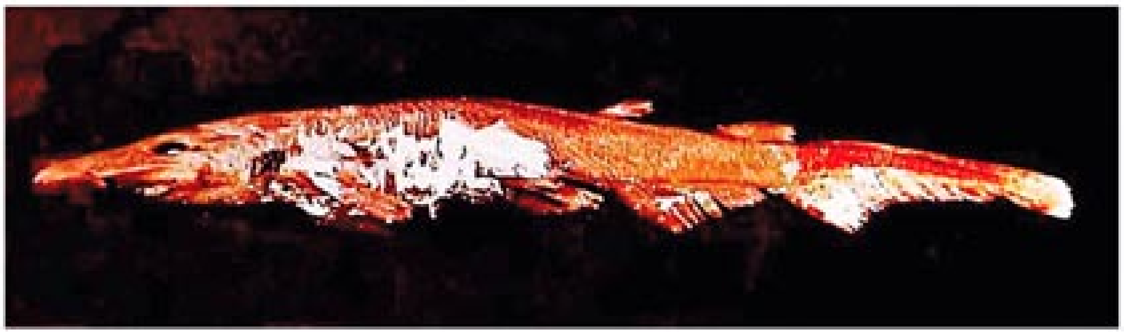
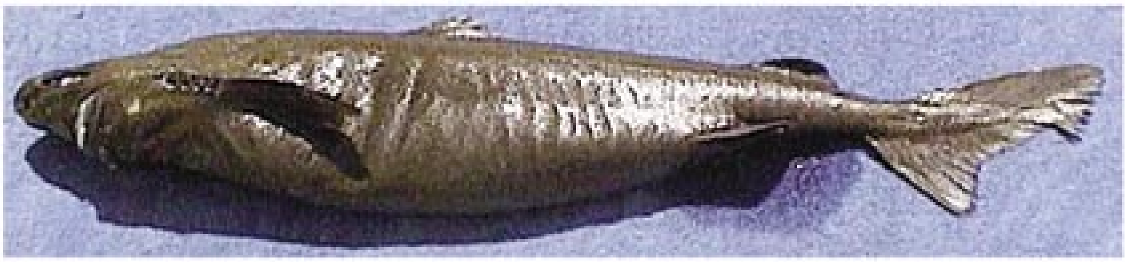


FIGURE 10
Centrosymnus coelolepis **(Somniosidae). Widely distributed in deep waters of the Mediterranean Sea and the Atlantic (Grand Banks to South Africa) and Pacific (Japan to New Zealand and Australia) Oceans**



FIGURES 11–12
An undescribed catshark, Apristurus sp. (Scyliorhinidae) and chimaera, Chimaera sp. (Chimaeridae)

3. BYCATCH OF DEEPWATER FISHING OPERATIONS

The results of this analysis show that the chondrichthyan bycatch from the Melville Banks area had unexpected strong links to deep-water fauna from the orange roughy grounds off Australia and New Zealand rather than to the geographically-closer shelf off Africa. This could be a reflection of the relatively poor knowledge of the deep fauna off the shelf of the east coast of Africa. Alternatively it could suggest that there is an ancient common fauna on the Indo-Pacific sea mounts. The results of this analysis, although restricted to the chondrichthyan and teleost fauna, make it clear that there is a vast reserve of knowledge on high seas biodiversity that must be tapped.

4. MANAGEMENT CHALLENGES

These results present fascinating research challenges and open up novel avenues for biodiversity research. Such topics for research have not as yet been explored and it will be unfortunate to lose possible clues before these opportunities are explored.

All nations will agree that the protection of high seas biodiversity is necessary; the question that must be answered is where that responsibility lies. Can Regional and International Fisheries Organisations function in this role? In the Atlantic Ocean, fisheries for tuna and tuna-like species are managed by ICCAT. The newly established South East Atlantic Fisheries Organisation will assume control of fisheries for other resources in the South East Atlantic on the high seas, like the Tristan Bluefish (*Hyperoglyphe antarctica*). The picture in the Indian Ocean is rather different. Although management of tuna and tuna-like species falls under the gambit of the Indian Ocean Tuna Commission (IOTC), this body has yet to develop into an authoritative body, and there is no organisation responsible for other species. It is in this managerial void that the demersal longline and trawl fisheries on Walters Shoal and the Madagascar Ridge have developed in the western Indian Ocean. Evidence of the increase in high seas fishing in the southern African region can be observed though the number of international longline vessels that have requested permits to make port calls to South African ports (see Table 1).

TABLE 1
Increase in high seas fishing

Year	No. of countries	No. of vessels	No. of calls
2001	25	117	174
2002	25	296	744
2003	18	169	301

Note the more than 100 percent increase from 2001 to 2002. The apparent drop in 2003 is because the data are only for the first five months of that year. The figures for these first five months are already over 50 percent of the 2002 figures and will probably exceed the 2002 figures.

Regional and international fisheries organizations are attractive means to consider as custodians of high seas management because there currently exists a host of RFOs and similar commissions. Regional (RFOs) and international Fisheries Organizations generally face a number of challenges. There exists inadequate scientific knowledge for decision making, often due to data constraints. This affects their ability to make informed management decisions and to adopt appropriate measures for conservation and management. Even if only management measures are adopted, members can opt out from measures decided by the RFO, which results in voluntary compliance. This is compounded by a general inability to adequately enforce or monitor compliance. Further, non-members may undermine efforts by RFOs as they are not bound in any manner to abide by RFO measures. Finally, the management and allocation of fishing rights for migratory and straddling stocks generally underscore the agenda of RFOs. Ecosystem conservation and high-seas biodiversity is not a priority.

All of these limitations can be addressed through the funding of practical solutions. However the solutions and their funding must be a result of the political will and the adopting of appropriate National and International Laws. Political will remains fundamental to success (Pearce 2002).

We must seize the opportunity that the Final Plan of Implementation of the World Summit on Sustainable Development (WSSD) offers us in providing a statement of will to conserve high-seas biodiversity: The WSSD Plan of Implementation calls upon states to "maintain the productivity and biodiversity of important and vulnerable marine and coastal areas, including in areas within and beyond national jurisdiction" (para 31a). Paragraph 31 must be acknowledged as a commitment from heads of states not only to coastal, but also marine, ecosystem conservation.

Ideally we would want scientifically sound and rigorously tested scenarios on which to develop management plans for high seas biodiversity. However, while developing these and encouraging the international political will to fund such research there must be a parallel process of beginning to identify unique and vulnerable habitat types for conservation and protection. Marine protected areas offer a management solution for protection and conservation that is less dependent of detailed assessments.

Sumaila *et al.* (2000) make a convincing argument for the use of marine protected areas (MPAs) as a management tool for marine and coastal ecosystems. The effects on fishing on the ecosystems are largely not factored into current management measures. Total allowable catches and total allowable effort measures are dependent on accurate stock assessments and assessments of fishing capacity, which are difficult to achieve even when both scientific and legal infrastructure and capacity exist. Most management measures tend to focus on the species being exploited and are therefore not sensitive to symptoms like fishing down the foodweb as described by the landmark paper of Pauly *et al.* (1998). Myers and Worm (2003) claim that fishing pressure has reduced predatory fish levels of the world's oceans by 90 percent. This must surely impact ecosystem functioning and hence there is a need to rebuild entire community structure.

In addition, we are increasingly beginning to appreciate the destruction caused by trawling gear. One may argue that the gear has a relatively spatially confined footprint, however this footprint may cover a significant portion of a unique habitat. The trawlable fishing areas of sea mounts (top and moderately steep sides) may in fact be different ecotones from the steeper slopes and gullies and deeper regions between sea mounts.

5. MARINE PROTECTED AREAS

If the slow changes to predator-prey relationships and to the structure of the interactions within high seas areas that become increasingly significant with time are to be avoided, then marine protected areas on the highs seas must become a reality.

The size and number of MPAs required is a complex question. The success of an MPA is a function of its size related to the life history and mobility of the species which are being protected (Attwood and Bennet 1995). It is commonly accepted that 20 percent of the unfished amount of spawner biomass is required for sustainable fisheries. This percentage is also suggested as the minimum of a total habitat type that should be protected to ensure conservation of that ecosystem type (Plan Development Team 1990). However, it is unlikely that one reserve will serve the needs of a region and a system of a network of MPAs will be required (NRC 2001, ATEGH 2003).

The more protection offered to a habitat type, the greater insurance against any system failure or localised disaster. More protection can be offered through a combination of increasing the scope of a single MPA or increasing the number of MPAs. The balance between increased conservation or protection and the perceived limiting of economic gain from high seas stocks will be severely debated. Agardy (2000) makes the argument that protected areas often translate into better economic returns to the fishery through improved fish yields. In addition protected areas allow for a control site to test management options that ultimately serve the needs of the fishery.

The Committee on the Evaluation, Design and Monitoring of Marine Reserves and Protected Areas, of the United Sates list the possible benefits of marine protected areas in seven categories (NRC 2001):

i. conservation of biodiversity and habitat
ii. fishery management
iii. scientific knowledge
iv. educational opportunities
v. enhancement of recreational activities and tourism
vi. sustainable environmental benefits and
vii. protection of cultural heritage

If high seas MPAs are to be a reality and supported by sufficient political will, then meetings such as Deep Sea 2003 must begin to identify mechanisms to unlock benefits from these seven categories.

Finally, if we accept that legally defined MPAs on the high seas are necessary then the most challenging question remains, who has the authority to declare these MPAs or how do we mandate any authority to declare MPAs? Are the RFOs and other commissions on migratory and straddling stocks suitable to be mandated bodies, should research collaborations like ICES take the lead or is there a need to begin thinking about an International World Oceans Commission? As for where this will be negotiated, the success of United Nations with regards to the LOSC and the ensuing instruments, makes such an organization an ideal candidate for these tasks.

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Workshop on the Management of Deepwater Artisanal and Small Scale Fisheries

Synopsis

Small-scale deepwater fisheries usually occur along the continental shelf break and shelf slope where such fishing grounds are accessible to fishermen using smaller boats. Fishermen characteristically use drop lines that are retrieved using hand-powered, electric or hydraulic reels. These fisheries are particularly important to small-island states and because of the limited size of slope fish habitats, the associated fisheries resources are inevitably modest in size and of relatively low productivity. Fish that are targeted by these fisheries tend to have longevities of 30 to 50 years, and grow to sizes of 50–100 cm with slow growth rates. These species tend to be found in aggregations, which make them vulnerable to rapid depletion.

Many countries possessing slope-fishery resources have inadequate institutional and technical capacity to effectively manage them and the 'boutique' nature of the resources requires the same management capacity and costs as that associated with large-scale fisheries. Small countries are less able to deal with IUU fishing because they lack surveillance capacity and learn of resource depletion long after the IUU vessels have moved elsewhere.

Among issues the workshop addressed were the need: to disaggregate data to show the geographical scale of fisheries; for data confidentiality; and for provision of generic log books and other data recording and collection logistics. Because many small-scale deepwater fisheries involve few vessels, providing appropriate log books is expensive and often beyond the capacity of small-country management authorities.

In addressing resource assessment, information on stock structure indicates that such resources may be highly restricted if not almost territorial. Thus fisheries, even in small areas, will exploit more than one stock. Management must account for this though resolving this problem will require taxonomic studies to investigate sub-population structures. Analysis of the population parameters shows that estimates for the 'same' species from different areas may, in fact, differ widely, and that fish believed to be the same species, but found in different areas, may be different species.

The suitability of CPUE as an aid in such data-poor situations was recognized but examples were noted of fisheries prosecuted by only a few vessels where the arrival or departure of a single high-liner radically changed conclusions about resource abundance as implied by trends in the CPUE. This emphasized the need for care in undertaking trend analyses based on CPUE.

Experiences indicated that most slope-water fisheries caught several species of which two would be commercially abundant. Thus, single-species approaches would sub-optimize management of at least one species while multi-species approaches would be impractical. Further, the sustainability of less abundant species in catches must be monitored and investigated when harvesting decisions were based on one, or a few, more abundant indicator species. Risk adverse management approaches included that of basing harvesting decisions on the sustainability requirements of the slower growing and less productive species.

Scarcity of management funds means that harvest strategies must be simple, easily implemental, robust and understood by stakeholders. Given the speed at which these fisheries can develop and the difficulty of small and under-funded departments to rapidly implement management plans, the utility of developing "off-the-shelf and over-the-counter" management plans that could be rapidly implemented was noted. Such plans should cover data collection, resource assessment, control of harvesting and fishing down virgin fish resources. Such plans should include "move-on" criterion for when a resource has reached a limit level of depletion and effort must be relocated or stopped.

Current management paradigms need to consider the priorities of governance needs and it was agreed that the multiplicity of management and conservation requirements complicates efforts at governance and could be counterproductive to achieving less ambitious, but obtainable, objectives.

Research and management systems for tropical deepwater demersal fish resources – a case study from northwestern Australia

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1. INTRODUCTION

The demersal fish resources off the northwest coast of Western Australia were first explored and fished by the Japanese in the late 1950s and were intensively fished by Taiwanese pair trawlers in the 1970s. The ratification of Australia's Exclusive Economic Zone (EEZ) in November 1979 allowed further foreign fishing in these waters but under a licence agreement with the Commonwealth of Australia. The northwest coast of Western Australia is at present split into two regional management zones along the continental shelf, the Pilbara region (114 °E to 120 °E longitude) and the Kimberley region (ca. 120 °E to 129 °E longitude) that extends to the border with the Northern Territory.

Fishing by Taiwanese and Chinese pair trawlers continued in the Kimberley region until 1990. The trawling effort by these foreign vessels in the Kimberley region was low compared to the adjacent Pilbara region (Nowara and Newman 2001). Following the departure of the foreign fishing fleets from the Kimberley region in 1990, a domestic trap and line-fishery has developed operating out of Broome and Darwin. The demersal trap and line-fishery in the Kimberley region of Western Australia is now known as the Northern Demersal Scalefish Fishery (NDSF).

The NDSF targets a multispecies group of fishes consisting primarily of snappers (Lutjanidae), emperors (Lethrinidae) and groupers (Serranidae). Snappers are the most important species group in the fishery (Newman 2002). Most of these species are considered to be only capable of sustaining low rates of exploitation because they are generally likely to be long-lived, have slow growth rates, a late onset of maturity and low rates of natural mortality.

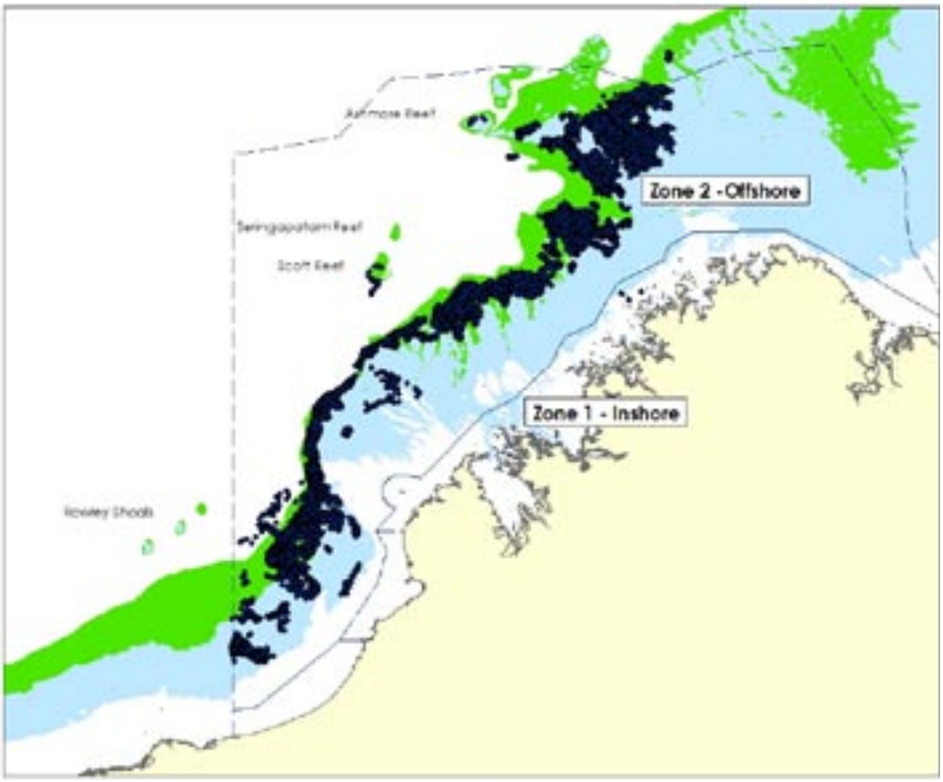
This paper will use the NDSF as a case study to outline the research and management systems currently in use for all the tropical deepwater demersal fish resources of north-western Australia. A summary of available information is provided, detailing the species targeted and their distribution, knowledge of their stock structure and hence the appropriate spatial scales of management, their biology, a synopsis of the fishery including gear and equipment, the status of the demersal fish resources and the management and regulatory system including the innovative effort–quota allocation system developed for the NDSF and now applied elsewhere.

2. SPECIES TAKEN BY THE FISHERY AND THEIR DISTRIBUTION

The commercially important demersal fishes of the NDSF comprise three main families of reef fish; snappers (Lutjanidae), cods and groupers (Serranidae) and the emperors (Lethrinidae). The main target group is the snappers with the goldband snapper complex (consisting of 3 species, principally *Pristipomoides multidens*, and also *P. typus* and *P. filamentosus*) and red emperor (*Lutjanus sebae*) comprising over 50 percent of the total demersal finfish catch from the NDSF. The next largest component of the landed catch is the cods that consist of many species that are endemic to the Indian Ocean region, such as *Epinephelus multinotatus* and *E. bleekeri*, followed by the emperors, such as the spangled emperor (*Lethrinus nebulosus*).

These commercially important species are widely distributed across the continental shelf. The fishery principally operates in depths of 60–150 metres with effort concentrated along the old continental shelf coastline in approximately 100 metres of water (Figure 1). The target species inhabit hard bottom areas and areas of vertical relief and large epibenthos. The distribution of fishes tends to be concentrated in these specific habitat areas.

FIGURE 1
Spatial distribution of fishing effort in the NDSF showing the concentration of fishing effort along the old continental shelf coastline



The deeper continental slope waters of the NDSF, ranging from 150 m to 400 m depth, are only beginning to be explored. The fish fauna at these depths is diverse with variation in species composition between the continental shelf habitats and those of the offshore atoll reefs. To date many species of commercial fishing interest have been identified. These species include the deepwater snappers (*Etelis carbunculus*, *E. coruscans*, *E. radiosus*, *Lipocheilus carnolabrum*, *Paracaesio kusakarii*, *Paracaesio stonei*, *Pristipomoides argyrogrammicus*, *P. zonatus*, *P. auricilla* and *Aphareus rutilans*), the deepwater sparid (*Dentex tumifrons*), the deepwater emperor (*Wattsia mossambica*) and the deepwater cods (*Epinephelus morrhua*, *Epinephelus radiatus* and *Epinephelus octofasciatus*). Many of these species are already being landed in small quantities by the fishery.

3. STOCK STRUCTURE

Stock identity studies that examined populations of *L. sebae* and *P. multidens* in north-western Australia have revealed the presence of multiple functionally distinct assemblages of post settlement fish, indicating that adult populations are separate and therefore independent for most purposes of fisheries management (Newman *et al.* 2000, Stephenson *et al.* 2001). Thus, adult populations of both these species in the Pilbara region to the west and in the waters of the Northern Territory to the east are separate to those in the NDSF. There may also be low to very low rates of mixing between populations within the NDSF. The larvae of these species may move greater distances and thus mix among populations providing a conduit for gene flow. Therefore, while the NDSF region is likely to form part of one spawning stock (Ovenden *et al.* 2002), it is considered that management can be applied separately to each of the stocks at a regional (or location) level along the north-western Australian coast.

The presence of separate and distinct stocks of adult fish implies that the size of the total adult spawning stock (i.e. the combined sum of each of the separate functionally distinct assemblages of adults) could affect recruitment. Thus, fishing on any one stock could potentially indirectly affect yields from any other stock by affecting subsequent levels of recruitment should severe depletion of the total spawner biomass occur. However, impacts of fishing on one stock should not directly affect adjacent stocks (or any fishing effect should be negligible).

Knowledge of the stock structure of populations of *L. sebae* and *P. multidens* in the NDSF has provided fishery managers with a sound basis for the formulation of regional management plans that seek to ensure that adequate levels of the total adult spawning biomass of each species are maintained in each region.

4. BIOLOGY OF THE KEY SPECIES

Pristipomoides multidens, collected from commercial trap and line-fishers in the NDSF, were successfully aged by examination of thin sections of sagittal otoliths (Newman and Dunk 2003). The oldest fish examined was estimated to be at least 30 years of age. Age estimates were validated using marginal increment analysis with opaque and translucent zones each formed once per year. No significant differences were found in the growth curves between sexes. The von Bertalanffy growth parameters were L_∞ = 598 mm, K = 0.187 yr^{-1} and t_0 = -0.173, indicating moderately slow growth. Estimates of natural mortality were in the range 0.104–0.139. These instantaneous rates indicate that in the absence of fishing 9.9–13.0 percent of the population would die each year due to natural causes. The early life history of *P. multidens* is poorly understood. However, Newman (unpublished data) obtained juveniles from fish trawls over uniform sedimentary habitat with no relief in depths of 95–119 m off the Pilbara coast.

Newman and Dunk (2002) examined the age, growth and mortality of *L. sebae* from the commercial catches of fishers in the NDSF. Specimens ranged from 183 to 728 mm fork length (FL); males had a mean FL of 509 mm and were significantly larger than females, which had a mean FL of 451 mm. Ages were estimated from thin sections of sagittal otoliths. Marginal increment analysis of sagittal otoliths showed a single annual minimum during September and October and indicated that one annulus is formed each year. Male *L. sebae* (211–728 mm FL) ranged from age 2 to 30 years and females (183–584 mm FL) ranged from age 1 to 34 years. There was significant differential growth between sexes. Growth parameters for males were; L_∞ = 628 mm, K = 0.151 yr^{-1} and t_0 = -0.595 and for females; L_∞ = 483 mm, K = 0.271 yr^{-1} and t_0 = 0.065. The estimated instantaneous rate of natural mortality (M) ranged from 0.104 to 0.122.

The length at maturity of *P. multidens* was estimated to be 552 mm TL for females and 549 mm TL for males, corresponding to a mean age at maturity of approximately 8 years for females and males. The length at maturity for *L. sebae* was 461 mm TL for females and 491 mm TL for males, corresponding to a mean age at maturity of approximately eight years for females and males (Newman, Moranton and Lenanton 2001).

The protracted longevity, moderately slow growth, large size and age at maturity and low natural mortality rates of the key target species indicate that these species have a low production potential and are particularly vulnerable to overfishing.

The spawning characteristics of each of the key target species are different (Newman *et al.* 2001). The spawning period of *P. multidens* is during the mid-summer to mid-autumn months of January to April inclusive, with a peak during March. The co-occurrence of post-ovulatory follicles, hydrated oocytes and yolk-granule oocytes in some ovaries during the spawning period indicates that *P. multidens* is a multiple spawner (females spawn more than once during the spawning season) and also suggests that annual fecundity is indeterminate (i.e. unyolked oocytes continue to be matured and spawned during the spawning season). The overall sex ratio in catches collected from commercial fishing vessels was close to parity. The relatively large size of the ripe testes indicates that group spawning is likely to occur in *P. multidens*.

The spawning period for *L. sebae* was principally in mid-spring during the month of October with opportunistic spawning periods in January and March. Male *L. sebae* have small testes in relation to the female ovaries. Thus *L. sebae* are considered likely to be gonochoristic pair spawners.

The biology of the deeper slope species off north-western Australia is largely unknown, however, we have investigated the longevity of some of the larger species collected to date. At present, longevities of at least 56 years have been estimated for *Epinephelus octofasciatus* and at least 30 years for *Etelis carbunculus* using the bomb radiocarbon chronometer method of validating fish age (Kalish, Newman and Johnston 2002).

5. FISHERY SYNOPSIS

The demersal fish resources of the NDSF have been exploited at varying levels for more than 20 years and have been reviewed by Nowara and Newman (2001). A foreign Taiwanese pair trawl fishery began in 1980 and lasted until 1990. The total annual catch of the Taiwanese vessels reached a peak in 1985 of 4 394 tonnes, corresponding to a peak in trawl effort of 14 896 hours (Nowara and Newman 2001). The total catch per unit effort of the Taiwanese pair-trawl fishery showed a significant decline over the duration of the fishery from 1980 to 1990 (Nowara and Newman 2001). Following the departure of the Taiwanese fleet, a domestic fishery developed primarily using fish-traps. The catch of the Taiwanese pair-trawl vessels includes many species that are not caught by the methods used in the current fishery. Therefore, the catch in the current fishery is much lower than that reported by the Taiwanese vessels.

During the period 1989 to 1992, the NDSF recorded a rapid increase in the level of exploitation with catches growing from approximately 50 tonnes in 1989 to approximately 730 tonnes in 1992. Managers introduced a control on the number of trap boats fishing in the fishery in 1993 because they had a limited knowledge of the capacity of the resource to sustain this increasing fishing mortality. The number of trap boats permitted to fish the NDSF was limited to nine boats in 1993. This stabilized the annual catches from 1992 to 1997 at an average level of approximately 817 tonnes. However, a limited number of line vessels were also operating in the fishery at this time that were not subject to the trap fishery management controls. The NDSF came under formal management on 1 January 1998 and included the line vessels. Annual catches in the period from 1998 to 2002 have been lower at approximately 508 tonnes on average. The number of licences to fish in the offshore waters of the NDSF was limited to 11 in 1998. The NDSF forms a major component of Western Australia's commercial production of high-quality finfish, contributing over 434 tonnes in 2002 for a catch value of approximately $A 2.41 million. Further expansion and development of fishing activities in deeper outer-shelf waters using trap and lines is likely to occur in the future.

The fishery is now managed by setting a notional total allowable catch in combination with a total allowable effort allocation to individual vessels as individual transferable effort (ITEs) to target that catch (see Section 7 for details). In 2002, five vessels fished the effort quota allocated to the 11 licences. The notional TAC in the NDSF is presently 800 tonnes.

At present there is little recreational or charter boat fishing effort directed towards the deeper-water fish species in the offshore zone of the NDSF that are the key species targeted by commercial fishers. Most of the recreational fishing effort targeting demersal finfish in the Kimberley region is concentrated in the Broome sector of the inshore zone of the NDSF that is closed to commercial fishing.

The main fishing method in the NDSF is the more efficient fish traps, although line-fishing methods such as handlines and, or, droplines are permitted under the ITE system. The use of longline, trotline and fish trawl gears in the NDSF is currently prohibited. The size of fish traps is controlled, with a maximum internal volume permitted equal to, or less than, 2.25 m^3 to ensure the ITEs are equitably applied. The fish-trap design used in the NDSF has been modified from the initial O or cylindrical shaped trap that had been historically used in Western Australia. The shapes of fish traps are now roughly square in shape with a length of approximately 1.6 m, a width of approximately 1.5 m and a height of approximately 0.9 m. The entrance to the fish trap has incurving walls that taper to the vertical slit entrance that extends deep into the trap. The entrance is approximately 10-15 cm wide and extends from the top to the bottom of the trap. Trap frames are composed of steel rods and are covered with 50 mm square weld mesh. The whole trap is often zinc-dipped. Traps are baited with 1–2 kg of pilchards (Sardinops sagax). The soak time of traps varies with each operator, but in general ranges from 2–4 hrs during the day. Traps are also set overnight. There is no restriction on the number of traps that can be fished per vessel. However, as each licencee is allocated an annual effort quota in standard fishing days that is based on the use of 20 traps or less, when the number of traps being fished increases, the number of allowable standard fishing days declines. Fishers are allowed to leave traps on the fishing grounds for extended periods, but they must be unbaited and have open doors.

The line gear consists of either hand-hauled or hydraulic reels. The main line of each reel has a terminal weight of 2–4 kg with 6–30 hooks attached at approximately 1 m intervals above the weight. The preferred hook size is a 13/0 tuna circle hook. Line-fishers use a combination of squid and pilchards as bait.

Commercial fishers in the NDSF utilize vessels varying from 15–23 m in length. Vessels are equipped with colour depth echo sounders, radar systems, satellite navigation systems and plotters. Some vessels also have sonar. The electronic equipment now available to fishers allows operators to gather detailed plots of all trap and line sets. These data allow operators to determine the most productive areas available in the fishery. In addition, the size of vessels and the associated electronic navigation and plotting gear provides the fleet with an extensive and flexible capacity to fish throughout the area of the fishery.

Fishing in the NDSF is carried out in all months of the year with most fishers trying to provide a consistent year-round supply of fresh fish to the markets. The landed catch from the NDSF is highly valued and is marketed whole, usually fresh on ice, via road transport from the regional ports of Broome and, or, Darwin for on-shipping to markets in most state capital cities and is occasionally exported.

6. STOCK STATUS AND REPORTING

An integrated age-structured model has been developed for two of the important species in the NDSF, *Lutjanus sebae* and *Pristipomoides multidens*, which includes the estimation of spawning biomass. The model estimates are calculated from (a) known catches by all sectors (commercial, recreational and charter), (b) catch rates from the trap fishing vessels and (c), age composition data from samples collected throughout the NDSF. The specific relationship between stock size and recruitment is not known for either of these two target species. Evidence from other fisheries on similar species suggests that a biomass limit of 30 percent, with a target of 40 percent, of the virgin biomass is appropriate to ensure sustainability of this fishery (Mace 1994, Mace and Sissenwine 1993, Die and Caddy 1997, Gabriel and Mace 1999). The spawning biomass of *L. sebae* and *P. multidens* in 1980 are assumed to represent the virgin stock levels. Spawning biomass levels of less than 40 percent are considered to be exposed to a significant risk of recruitment overfishing. The current stock assessment analyses indicate that the optimum yield of the two target species can be obtained at current effort levels.

The two major target species, *L. sebae* and *P. multidens*, are considered to be representative of other long-lived species (i.e. *Pristipomoides typus*, *Lethrinus nebulosus* and *Lutjanus malabaricus*) present in the landed catch of the NDSF that are similarly vulnerable to overexploitation. In addition, they comprise greater than 50 percent of the total landed catch, consequently they are used as indicator species for this entire group of long-lived species. Thus, management action is focused on ensuring catch levels for these two indicator species are sustainable given that they are assumed to be the most vulnerable of the main species landed. Therefore, if adequate levels of the spawning biomass of the two indicator species are maintained, it is considered likely that the management arrangements will be affording similar protection to other long-lived species, and conservative yields from any shorter-lived species.

In 2002, the total spawning biomass of the two indicator species, red emperor and goldband snapper, in the NDSF were estimated to be at 54 percent and 41 percent of the estimated virgin levels. These levels were both above the recommended target level of 40 percent of the virgin spawning biomass and their breeding stocks were considered adequate at the current levels of catch. The level of harvest of the demersal fish resources in the NDSF is in the general range of maximum yields and thus the assessment of the current status of the NDSF stocks is that they are fully exploited.

Catch levels and catch rates in the NDSF are likely to be good indicators of changes in fishing practices that affect the key target species. However, catch rates of trap and line vessels in the fishery are considered to be only moderate indicators of stock size due to the likelihood of 'hyperstability' in the catch rate data. Hyperstability may occur due to the (a) targeting of aggregating fish species, (b) high mobility of the fishing fleet and (c), the relative ease with which fish can be located (they are strongly associated with hard bottom habitats). Under these conditions, the catch rate may remain relatively constant while stock biomass is declining and mask a decline in the true abundance of the stock.

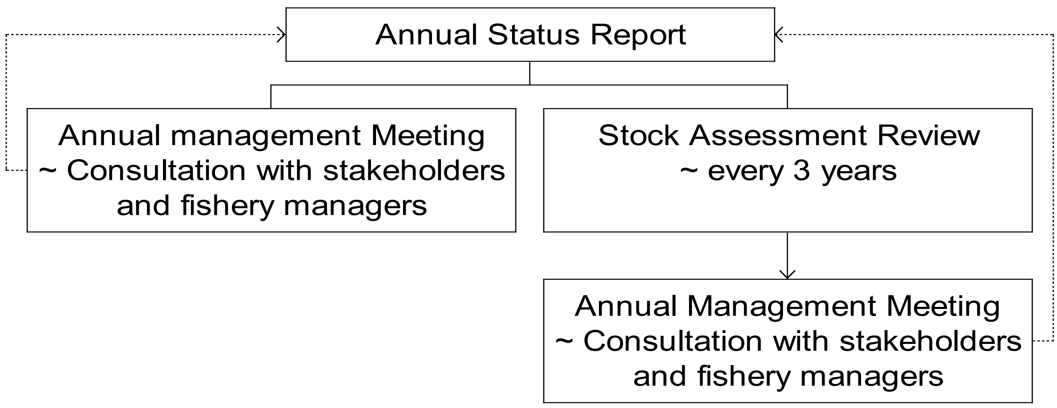
Catch rate data are also likely to be affected by the small number of vessels fishing (5 vessels in 2002 fishing 11 licences). A small number of vessels operating in the fishery (i.e. a small sample size) results in a high level of variability in the catch and effort data.

In particular, catch rate is critically dependent on the number of skilled operators in the fishery, which may vary from year to year.

A time-series of age structure data for each of the key species provides a more robust indictor of stock status than is provided by catch data alone. Age structure data, used in combination with catch and catch rate data, will provide highly robust indicators of stock status for future stock assessments. Nevertheless, the level of robustness of current indicators is considered adequate to manage stocks of *L. sebae* and *P. multidens* in the NDSF at a sustainable level, given the effort controls that are in place take into account effort creep and the fact that no other fishing sector catches significant quantities of these species in the Kimberley region.

The status of the NDSF is assessed each year and forms the basis of a report to parliament (Newman 2002). This is part of the annual reporting cycle for all fisheries in Western Australia. However, undertaking annual stock assessments of key target species are not logistically feasible, and as such, detailed stock assessments of the key target species are undertaken every three years. This reporting cycle is illustrated in Figure 2. The NDSF is also currently in the process of undergoing an Ecologically Sustainable Development (ESD) assessment by the Department of Environment and Heritage (DEH). DEH is a Commonwealth of Australia Agency that has jurisdiction on issuing export permits for Australian fisheries. All export fisheries in Australia must now comply with an ESD assessment.

FIGURE 2
Flow diagram showing the annual reporting cycle and timing of stock assessment reviews for the NDSF



The ESD assessment includes a detailed report on the status of target species and byproduct species, and measures used to assess the fishery against management objectives, such as performance indicators, performance measures and the associated management responses (see Fletcher *et al.* 2002 for details). The report also includes an examination of non-retained species (discards) and more general impacts on the environment. The ESD assessment requires the formulation of a set of performance indicators for the fishery that allow it to be assessed on a 5–year basis to allow fishers to continue to export fish products.

7. THE INDIVIDUALLY TRANSFERABLE EFFORT MANAGEMENT SYSTEM

The area of the NDSF is divided into an inshore zone (Zone 1) and an offshore zone (Zone 2) that operate under two different management regimes (Figure 1). The inshore zone is regulated by a limit to a total of 4 on the number of licences authorizing fishing in this zone in conjunction with a limit on the type and quantity of handlines that may be fished. Zone 1 licence holders may use up to five handlines with no more than six hooks per line. There is a prohibition on the use of automated line hauling gear in Zone 1 of the NDSF. In addition, there is an area closure around the town of Broome to reduce the potential for conflict between commercial operators, recreational fishers and charter boat fishers.

The offshore zone of the NDSF is regulated by means of individually transferable effort allocations. The only fishing methods allowed in this zone are demersal fish trapping and demersal line-fishing. The numbers of licences available to fish in the NDSF is also restricted in this zone. Additional management arrangements pertaining to Zone 2 licencees include a restriction on the maximum number of hooks (30) that can be fished per handline or dropline; a restriction on the maximum internal volume of a fish trap (equal to, or less than, 2.25 m^3) and a restriction on the size of the mesh used in the trap (not less than 50 mm square mesh with the diagonal corners of each square being not less than 70 mm). Furthermore, the management plan for the fishery allows for the Executive Director of the Department of Fisheries, Western Australia to close the fishery if the notional TAC is exceeded and catches are considered to threaten the sustainability of the resource. In data-limited situations a notional TAC can also be tested within an adaptive management framework in the ITE system.

Requirements for the ITE allocation system include

- a recommended notional total allowable catch – the TAC is a recommended level of catch for the entire demersal species complex and is derived from the estimated sustainable catch of the key target species (determined through detailed stock assessments) and their historical proportions in the catch
- maximum number of boats with access to the fishery
- knowledge of the catch rate (kg/boat-day) and
- calibration of fishing effort.

The notional target TAC was initially set based on historical levels of total catch and more recently from specific stock assessment advice. The notional TAC in the NDSF is presently set at 800 tonnes of demersal scalefish.

From 1993 to 1997 the numbers of fish traps that fishers were allowed to fish was limited to 20 fish traps a vessel a day. Following the formal implementation of the effort quota system in the NDSF in 1998, a number of fishers have chosen to fish more than 20 fish traps a vessel a day through the purchase of additional effort quota with the number of fish traps used a vessel a day having varied between 20 and 40. To use these data fishing effort needs to be calibrated so that it is comparable to the fishing effort used in previous years. The calibrated fishing effort is referred to as a standard fishing day.

Fishing effort is transformed to the equivalent number of vessels that operated 20 fish traps a vessel a day. This calibrated effort may be calculated by multiplying the number of days fished by the average number of traps used a day by that vessel, then dividing by 20. For example, if a fish trap boat uses on average 30 fish traps a day and fishes for 14 days in any one month, then the calibrated fishing effort for that month is obtained by multiplying the nominal effort (14 days) by 30 and then dividing by 20, therefore the resultant calibrated fishing effort is 21 standard fishing days.

A similar effort calibration procedure is used to calibrate line-fishing effort, with line-fishing effort transformed to the equivalent number of vessels that operated five lines a vessel a day. For example, if a line boat fishes for 14 days but uses on average 10 lines a day, then the calibrated fishing effort for that month is obtained by multiplying the nominal effort (14 days) by 10 and then dividing by 5, therefore the resultant calibrated fishing effort is 28 standard fishing days.

The setting of the annual ITE in the NDSF is based on the catch rate of trap vessels, as this measure of effort has been more consistent and less variable throughout the history of the fishery. Fishers then have a choice to use either traps or lines depending on their fishing operation.

The ITE allocation process is determined by the following relationship:

$$\text{ITE} = a \div (b \times c)$$

where,

ITE = number of standard fishing days (SFDs) to be allocated a boat
a = recommended notional TAC
b = catch rate (kg a boat day) in recent years
c = number of licences with access in the fishery

i.e.

ITE [No. SFDs/boat] = TAC ÷ (No. licences × catch rate)

(Note: This allocation mechanism provides for an equitable effort allocation among all licences in the fishery).

The industry members are consulted each year prior to the allocation of fishing days for the following year. In the calculation procedure defined above the number of licences that allow vessels to operate in the fishery is fixed, along with the recommended notional TAC. The TAC can be changed on an annual basis if required, but is generally left fixed from one detailed stock assessment to the next. Therefore, by varying the projected future catch rate, the allocation of standard fishing days can vary. Usually a number of catch rate scenarios (see below) are presented to industry and fishery mangers for their consideration. The projected catch rate (kg/boat/day) is determined from the catch and effort statistics from the previous year, based on the information supplied by all licence holders in the NDSF that is submitted on a monthly basis. Effectively, the allowable effort in terms of the total number of days fishing in the fishery can vary on an annual basis.

Catch rate scenarios generally include the following:

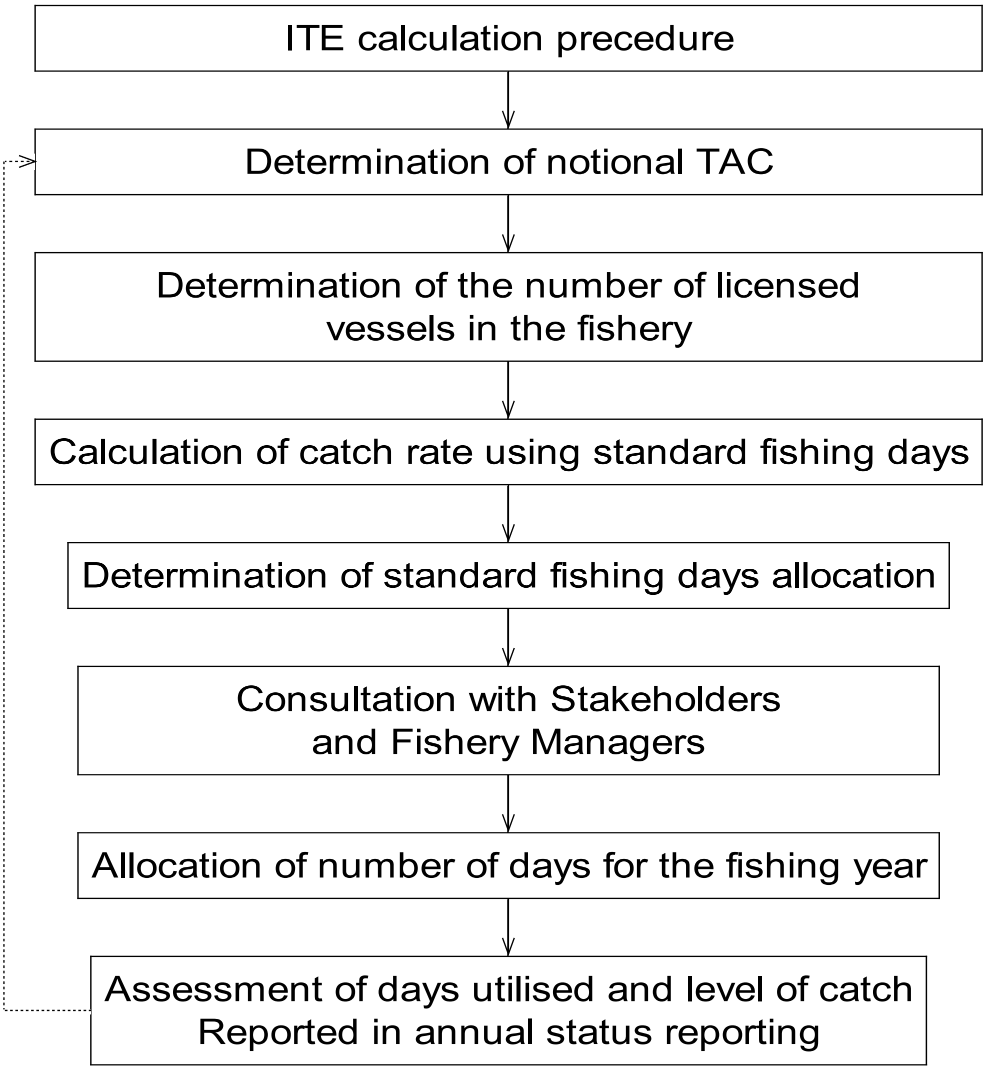
i. the average catch rate of all vessels in the fleet over all months for the past three consecutive years
ii. the average catch rates in the next allocation year are predicted from the historical catch rate trend and
iii. the average catch rate for all vessels achieved in the preceding year.

All catch rate scenarios assume that each boat with an effort allocation will achieve the specified catch rate. The catch rates and the corresponding fishing days access are provided to industry and managers along with an assessment of the probability of exceeding the notional TAC. The standard fishing day is calibrated to a number of gear units, for example 20 traps a day. This allows flexibility for fishers (vessels) who may then choose to fish more gear units, for example say 40 traps and thus the amount of time they have in the fishery is then halved. That is, the effort allocation is in standard fishing days. Using more gear units reduces the number of days a vessel can fish in the fishery. The ITE allocation process is illustrated in Figure 3.

Licensed vessels may choose to fish using either traps or lines in the fishery. This provides flexibility for the fishing operation and the ability to target species or species groups of interest to the market. At present, both gear types cannot be used simultaneously in the fishery, although this option is to be further investigated.

The number of licence holders within the fishery is fixed. However, licencees have the capacity to either temporarily or permanently transfer ITE units and thus adjust their unit holding to suit their fishing operations. This option allows fishers to increase their economic efficiency without affecting the sustainability of the resource. In addition, this mechanism also allows internal restructuring of the fishery with operators able to sell and buy ITE units to maximize their economic viability. This has

FIGURE 3
Flow diagram of the management process illustrating the ITE allocation procedure for the NDSF



resulted in fewer boats fishing in the fishery, but with each boat having a larger ITE unit holding.

A vessel's time in the fishery is monitored through a satellite-based vessel monitoring system (VMS). Each vessel is required to install a VMS in order to operate in the fishery. The VMS tracks a vessels movement within the fishery via satellite to a remote base station. The amount of time within the fishery is then calculated from this data record. The operators of each vessel are required to nominate the quantity of gear they are fishing with. The VMS allows the amount of effort and gear used in the fishery to be calculated on a trip-by-trip basis. The amount of effort used in each trip is then deducted from the total allowable effort for each operator in a given year. When an operators ITE allocation has been exhausted, fishing must cease or additional unused units acquired from other operators.

8. DISCUSSION

The life history of deep-slope reef fish species are characterized by slow growth, long life spans, low rates of natural mortality and large size and age at maturity. These life-history characteristics imply that deep-slope reef fish have a low production potential and may be vulnerable to over-exploitation. In addition, the apparent low survival rate for released fish that have been caught in depths greater than 40 m of water indicates that the traditional use of legal minimum sizes to increase survival to spawning sizes and hence increase overall yields is not a practical option (Newman and Dunk 2003).

Conservation of deep-slope reef fish species requires low frequency or low intensity harvest strategies. In addition, harvest strategies that include appropriately targeted spatial or temporal fishery closure systems may provide a useful additional means of controlling effort and hence of the exploitation rate, thus preserving the spawning stock biomass of these fish to protect against recruitment overfishing (Newman *et al.* 2003). The use of indicator species in the assessment of the NDSF is a cost effective method of monitoring the status of the demersal fish resources.

The primary benefit of the ITE management system is that it encourages vessels to maximize their return for each day fished in the fishery. Thus, there is no dumping or high grading of the catch such as that experienced in output control fisheries under individual transferable quota systems. In the NDSF, the notional TAC has not been exceeded since the introduction of the ITE system. In all years a large proportion of the allocated effort has remained unutilized, due to the operators choosing to maximize their economic performance by operating below the estimated MSY.

The underlying concern for resource managers in any multispecies fishery is how to minimize exploitation of long-lived vulnerable and less productive species and maximize the exploitation of the more productive species. The use of the ITE system and regulation of the fishery through using a VMS allows flexibility in future management arrangements. More specifically, the adoption of VMS technology has facilitated opportunities to regulate the spatial distribution of fishing effort and thus direct fishing away from vulnerable areas and, or, species of concern.

The NDSF is located in a remote area of north-western Australia where the resources available for direct compliance checks are limited. The use of the VMS-based ITE management system allows for the sustainable development of these fisheries by reducing the costs associated with enforcement. The transferability of ITE units among licence holders allows for free market trading of effort units and provides operators with the market system to adjust their level of entitlements to suit their fishing operation.

The notional TAC-based ITE system is similar to a TAC-based individually transferable quota system but directly controls fishing capacity while keeping fishing effort relatively constant for research purposes. The ITE system removes latent effort and automatically adjusts for changes in technology and efficiency increase. The ITE system allows for a constant exploitation rate harvest strategy as opposed to the hard TAC found in ITQ systems. The primary benefit of the constant exploitation rate harvest strategy is that in years of increased availability of the demersal fish resources, more fish can be removed and hence landings increase, while in those years of reduced availability of the demersal fish resources, less fish are removed and landings decrease. Thus the ITE system allows exploitation rates to remain stable while the size of the standing stocks of demersal fish resources in the region may change due to natural cycles.

For example, managers set ITQs as an absolute harvest quantity, often resulting in a total catch that does not respond dynamically to changing catchability and stock availability from year to year. It is sometimes politically harmful for elected officials to lower ITQs until the stock is reduced to such a low level that serious economic consequences are evident. The ITE system does not have the same economic and financial consequences to fishers, as the notional TAC often remains the same and the effort quota is all that is adjusted. Monitoring of effort days is straight forward using the satellite vessel monitoring system.

Illegal under reporting of the catch in ITQ systems is common and difficult to detect or quantify, as fishers are reluctant to risk reporting illegal activities even to researchers who do not have any compliance or enforcement role. In terms of overcapitalisation of the fleet, a common problem with effort controls, the fully tradeable ITE system has many of the attributes of ITQs and in this fishery has resulted in a significant reduction in fleet size (i.e. approximately two–thirds) and capitalisation. The allocation of the ITQs at implementation is often highly divisive among licence holders whereas under the ITE system described above there is an equitable allocation of the effort quota and this allows good fishermen to continue to perform well relative to less efficient operators. Most importantly, the ITE system has desirable features for achieving the objectives of ecosystem-based management.

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Timor Reef trap and line fishery

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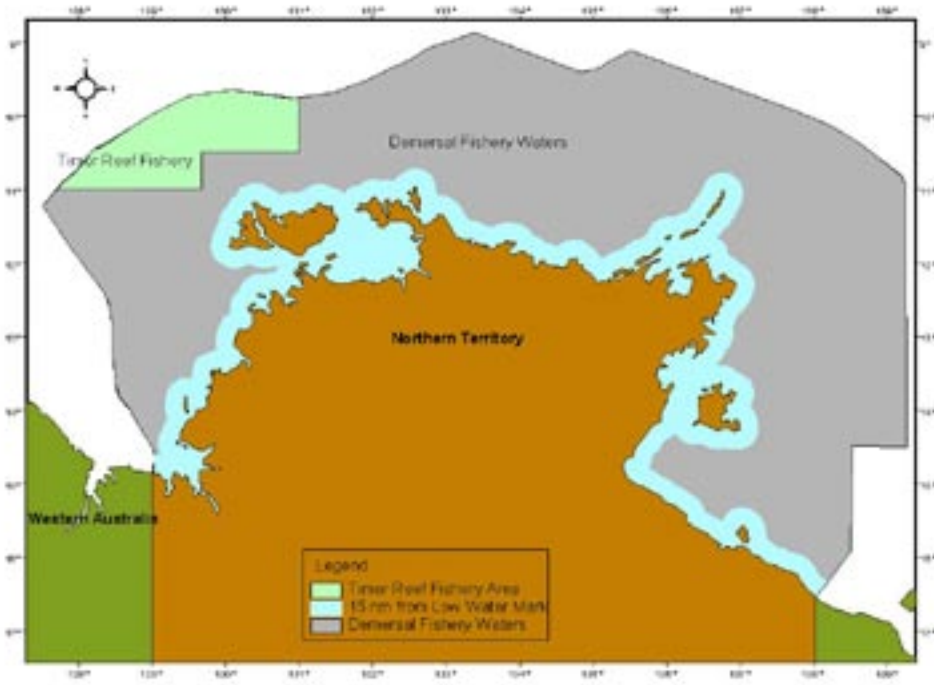
1. INTRODUCTION

The Timor Reef fishery is a multi-species trap and dropline fishery operating in an area between 128° 10′ and 131° E longitude and extending from 11° S latitude northwards to the boundary of the Australian Fishing Zone (AFZ) (Figure 1). Fishing occurs primarily in the 100–200 m depth range. The target species is goldband snapper (*Pristipomoides spp.*), which is a high-value fish, primarily aimed at the interstate restaurant markets. Other important target species in this fishery are red emperor (*Lutjanus sebae*), saddletail snapper (*L. malabaricus*), red snapper (*L. erythropterus*) and various 'cods' (Family *Serranidae*).

FIGURE 1
Area of the Timor Reef fishery



Although fishing occurs during the entire year, there is less activity during the dry season months of June-August when strong northerly winds often prevent fishermen going to sea. The boats range in size from 15 to 24 m and carry sophisticated electronic fish-finding and bottom-sounding equipment. Many operators also have onboard computers. Therefore participation in this fishery requires considerable capital outlay in both the size of the vessel required for operating in exposed offshore conditions and electronic equipment for finding fish schools.

There are currently 12 licence holders who are required to fill out detailed daily logbooks on a shot-by-shot basis. As goldband snapper have a patchy distribution, good spatial data is regarded as essential for monitoring this fishery.

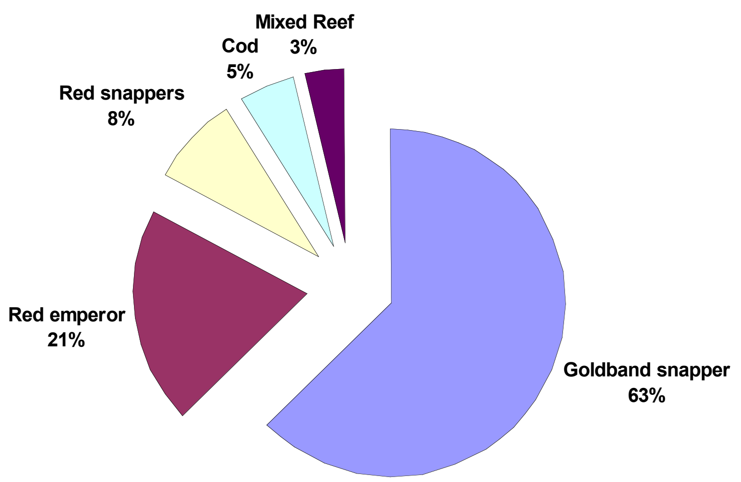
In addition to Australian fishers, Indonesian fishermen also target these resources on the adjacent side of the AFZ. In an effort to more effectively manage this straddling stock fishery, Indonesian and East Timor fisheries managers have been included in the northern Australian fisheries managers' workshops that are conducted on an annual basis in Darwin.

2. THE FISHERY

2.1 Target species

The target species of this fishery is goldband snapper, however there are three species which are grouped together for marketing purposes under this name. These are *Pristipomoides multidens, P. typus* and *P. filamentosus.* Onboard monitoring has revealed that of the three *Pristipomoides* species, *P. multidens* is the most commonly caught, comprising around 73 percent of the *Pristipomoides* catch, while *P. typus* accounts for 21 percent and *P. filamentosus*, 6 percent. Together these three species account for 63 percent of the total catch. Other key species in this fishery are red snappers (*Lutjanus malabaricus, L. erythropterus*), red emperor (*L. sebae*) and 'cods' (Family Serranidae) (Figure 2). There are minimal byproduct and bycatch species and in total they contribute less than 5 percent of total catch. The total catch for 2002 was 340 t of which the goldband snapper catch component was 213 t. Both goldband snapper and total catch have remained relatively constant over the past three years. For 2002 the Timor Reef fishery catch was valued at A$2.3 million.

FIGURE 2
Composition of the catch from the Timor Reef fishery for 2002



2.2 Fishing method

2.2.1 Fishing practices

Although legislation has permitted the use of both traps and droplines, until 1999 droplines were almost exclusively used as the preferred fishing method. However, in 1999, a trap boat originally from Western Australia, began fishing in the Timor Reef fishery with great success. This instigated a rapid change in both fishing gear and fishing methods, from targeting schools of fish with droplines to targeting specific bottom types with traps. Within 12 months nearly all Timor Reef operators had changed from droplines to traps.

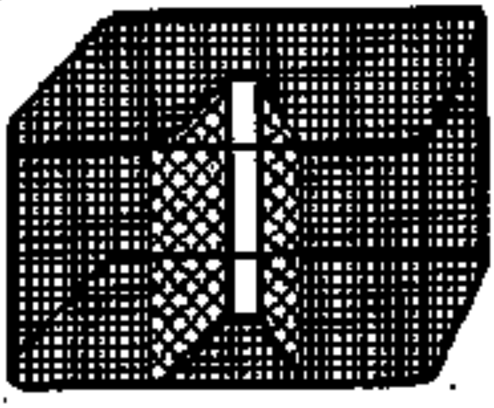
Operators have found that there are a number of advantages in using traps compared with droplines. These include:

- Fewer crew are required as most trap boats operate with 3 crew compared with 5 or more for dropline boats.
- Traps do not have to be set on schools of fish to work effectively, whereas considerable time is spent in searching for fish when droplining
- When droplining schools of fish, operators sometimes find that fish are not in feeding mode and a decision must be made whether to sit on the school in the hope that feeding will commence soon or begin searching for another school.
- Traps are more efficient at catching the highly-priced red emperor.

2.2.2 Trap design

The majority of operators use "WA style traps". These weigh around 85 kg, are constructed of steel mesh (75 mm x 50 mm) and have one funnel (Figure 3). A trap door is located opposite the funnel entrance to allow easy removal of fish and for refilling the bait box. The bait box is located near the funnel entrance and is secured to the bottom of the trap. Pilchards are the most commonly used bait, although tuna, mackerel heads and trevally are also used.

FIGURE 3
WA style fish trap used by the majority of operators in the Timor Reef fishery



The fishing grounds are approximately 150 nm from Darwin, and the average boat takes between 18–24 hours to reach the area. Traps are generally set in the 90–120 m depth range, but can be set as deep as 200 m. Fishing commences where traps were left from the previous trip, usually five days earlier. No dead fish have been observed in unattended traps during monitoring trips. However legislation is currently being implemented to avoid "ghost fishing" by lost traps. It is proposed that an anode be attached to the trap door, which will corrode and release the door should the trap be lost.

Traps are deployed in lines and are set in such a way that the funnel entrance is facing in the lee of the current, which makes it easier for fish to enter the trap. Traps are normally set at least 400 m apart, and have a soak time of 3–4 hours (Figure 4a). Operators aim to setting at least 90 traps a day, with fishing commencing at 4 a.m. and finishing at 11 p.m. Operators normally experience best catch rates during the spring tides, as these tides are more effective in dispersing the odour of the bait further and more rapidly owing to the strong tidal movement.

FIGURE 4 (A)
Trap ready to be deployed

Once fish are landed (Figure 4b), they are bled and held in an ice-slurry for a short period to reduce body temperature quickly. The catch is then packed in insulated storage containers with ice. Upon arrival in Darwin the catch is sent to east coast interstate markets, mainly Brisbane and Sydney, usually by road. Little product is sold in Darwin as the market is small.

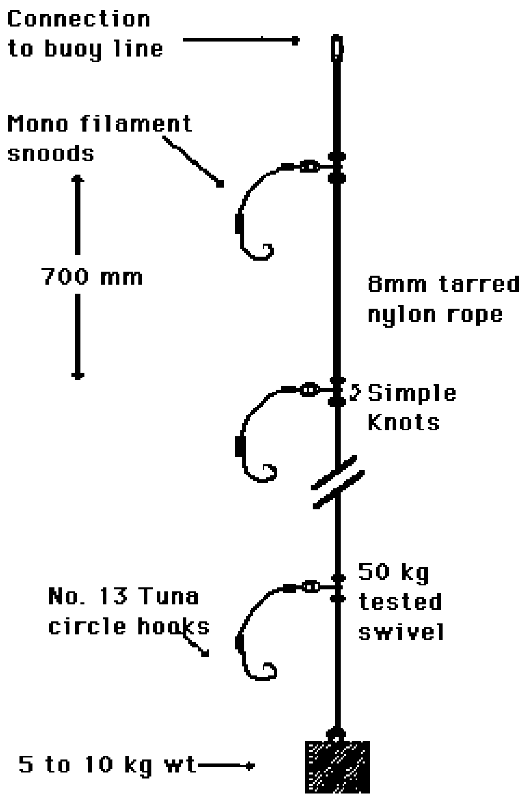
FIGURE 4 (B)
Fish being retrieved from the trap

2.2.3 Droplines

Droplines consist of a single line with a 5 kg weight attached. The lower section of the line has 30–40 tuna circle hooks (size 11/0 to 13/0) each attached to the mainline with a short line (Figure 5). Squid is the preferred bait for dropline fishers.

Fishing occurs in depths of 80-200 metres. Fishers use echo sounders to search for schools of fish that have a distinctive pattern indicative of goldband snapper. Once a school of fish is located, a signal is given to set the lines. Generally 2–6 lines are deployed at a time and the soak time can vary from 2 to 10 minutes. Landed fish are handled in the same manner as described above for trap-caught fish.

FIGURE 5
Lower section of dropline rig



3. ROLE OF THE NORTHERN TERRITORY FISHERIES DIVISION

3.1 Developing the Timor Reef Fishery

During the 1970s and 1980s Australia's northern offshore resources were heavily fished by foreign vessels, mainly Thai and Tawainese trawlers. By the late 1980s the Northern Territory government was looking for ways to encourage Australian fishers to develop these resources. This led to the implementation of a number of development initiatives such as the fishing gear loan scheme, where the Division loaned fishing gear to local operators for a period of several months so they could "try their hand" in a new fishery, without the high cost of purchasing equipment.

The NT Fisheries Division also implemented a number of marketing initiatives as goldband snapper was not well known in Australia at the time. Marketing played a key role in the development of the Timor Reef fishery as Darwin is several thousand kilometres from Australia's main population centres and premium prices were essential to make this fishery profitable. Market research showed that there was a niche market for fresh fish, which led the Division to initiate a study to determine the optimal methods for handling, processing and storing reef fish in order to achieve a high quality product. One of the key findings from this work was that with correct handling techniques, reef fish could be stored for more than three weeks (Poole, Roberts and Knight 1990, Poole *et al.* 1991). Promotional work in interstate capitals was also undertaken in conjunction with this initiative and by the early 1990s Territory reef fish were well accepted in the Sydney and Brisbane markets.

3.2 Early development phase of the fishery

i. Development encouraged

The government encouraged development of this fishery through initiatives such as the fishing gear loan scheme and marketing initiatives. During this early phase all boat owners were based locally.

ii. Unrestricted licences

During the early phase of the fishery there was no restriction on the number of vessels in the fishery. However licences were not transferable and therefore had no investment value. In 1993 it became a managed fishery with only 22 licences issued. As a result these licences became a valuable commodity that attracted investment. In the Northern Territory, a boat is not required to own a fishing licence and therefore fishing licences may be often owned purely as an investment, not attached to a boat.

iii. Fishing area limited

During this early development phase, fishing primarily occurred around a small number of shoals in the north-west section of the fishery.

iv. Processing at sea

Most demand during this time was for gilled and gutted fish. Therefore processing took place at sea. This slowed fishing operations, as fishers would often have to stop fishing to process fish due to the limited room in ice slurry holding bins. Today fish are sent to market whole and as a result fishing operations are more efficient than during the early development phase.

v. Logbooks

Originally logbooks were filled out on a monthly basis using 60-by-60 mile grids, a standard grid size for all Northern Territory fisheries. Unfortunately this spatial scale was too broad for management of this fishery, which was concentrated in a small area. Hence obtaining better logbook information was a priority, but for this to be successful industry cooperation and support was needed. This was begun through extensive wharf visits where the reasons for requiring better information were explained. Then a voluntary daily logbook was tested by operators who asked for information on each fishing shot. This logbook design was regularly modified to make the logbooks as "user friendly" as possible. Compulsory daily logbooks were introduced in 1995.

3.3 Present situation 2003

i. Expansion of fishing areas

Fishing now takes place in all areas of the reef area within the 80–200 m depth range and fishers have now extended their operations into the adjacent demersal fishery area.

ii. Increase in Indonesian fishing vessels

Indonesian bottom-set longline vessels also target goldband and other snappers in the area immediately adjacent to the Timor Reef fishery and across the entire Sahul Banks. This is a relatively recent occurrence as prior to 1996 few Indonesian vessels were seen.

iii. Experienced operators

Today all operators are experienced and have a good knowledge of the fishing grounds. This trend started to occur in 1993 when the Timor Reef fishery became a limited entry fishery and more serious fishers became involved.

iv. Increased use of technology

There have been significant technological advances since the fishery started e.g. global positioning systems linked to detailed bathymetric charts, on-board computers, one operator even has real-time video equipment to observe fish behaviour in, and around, traps.

v. Licence reduction scheme

In recent years, the number of licences in this fishery has been reduced from 22 to 12 by a two-for-one licence transfer policy, which was introduced in 1995. Under this arrangement a new entrant to the fishery must purchase two licences to be able enter the fishery. However once a licence has under gone a two for one reduction it can subsequently be sold as a single licence to new licensees.

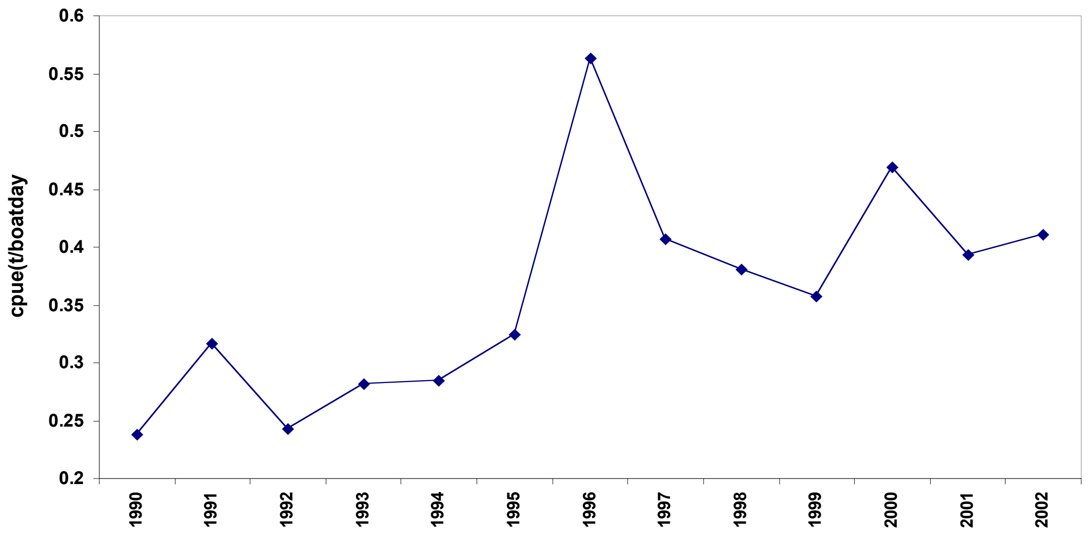
vi. Development of gas fields in the Timor Sea

In recent years there has been considerable exploration of the Timor Sea by petroleum companies as this area has been identified as an area of significant natural gas reserves. A gas-to-methanol conversion plant is soon to be constructed at Tassie Shoal, one of the prime fishing spots in this fishery. The plant will consist of a concrete structure 165 m long by 85 m wide and weighing 174 000 t. This plant is due to begin production in 2006. What effect this will have upon the fishery is not known, however careful monitoring of this area will continue to determine whether the fishery is being effected by this production plant.

4. STATUS OF THE TIMOR REEF FISHERY

While catch per unit effort for the Timor Reef fishery has remained relatively stable in recent years (Figure 6), one of the main concerns has been the possibility of serial depletion. When this occurs falling catch rates at valued fishing sites are masked by fishers moving into new areas where catch rates are higher, or fish from surrounding areas recolonize depleted areas.

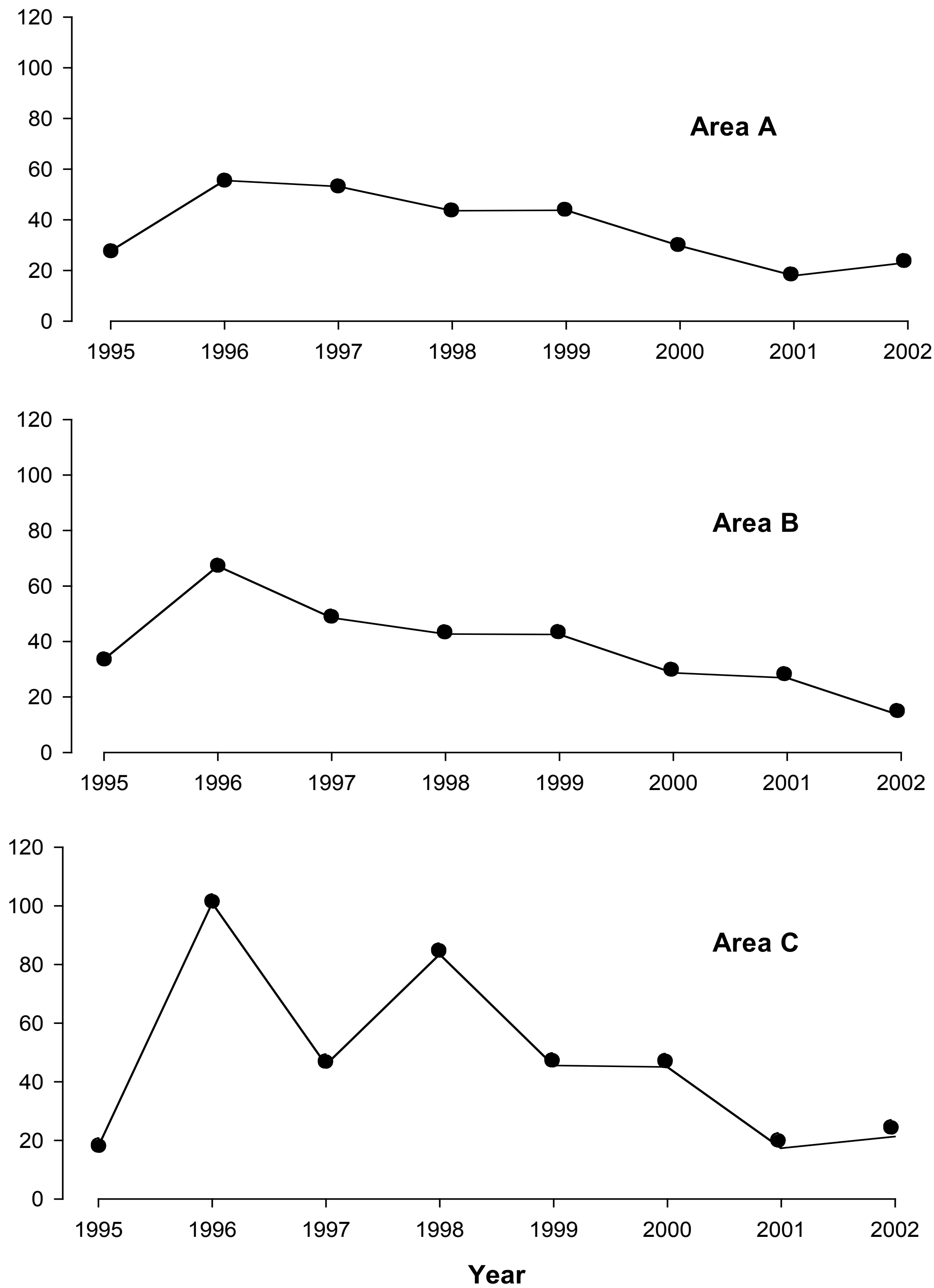
FIGURE 6
Catch per unit effort for the Timor Reef fishery



Three well-known fishing areas were examined to determine whether catch rates had declined over time on a finer spatial scale. In this analysis, no allowance was made for improvements in fishing power due to improved fish finding equipment, introduction of fine-scale bathymetric charts, or increased knowledge and skill over time. Likewise, no allowance was made for variations in catch rate from year to year due to environmental conditions. During 1995 many operators were still getting used to the new daily logbooks and consequently not all the spatial data was recorded for that year.

All three areas showed an overall decline in catch rates over the period 1996-2002, although there were some fluctuations in catch rates for one area. Due to confidentiality constraints (less than five operators per site in some years), areas cannot be identified on graphs (Figure 7).

FIGURE 7
Declining catch rates have occurred at three well-known areas in the Timor Reef fishery



These areas combined account for 15–30 percent of the effort in the Timor Reef fishery, therefore a decline in catch rates in these areas is of concern. While the argument may be put forward that there is always a fishing down of biomass at the start of a new fishery before it stabilises to a sustainable level, this usually happens during the first few years. Therefore we would have expected catches to have stabilized prior to 1996, at which point the fishery had been in operation for seven years.

5. SUMMARY

Analysis of spatial data shows trends that are of concern for this fishery. While catch rates (Figure 6) for the entire fishery have increased since 1995 and appear to be relatively stable, this masks a contrary trend occurring on a finer spatial scale: prime fishing areas have shown a decline over this same period (Figure 7). Another way to express this is that the relatively stable overall catch rates for the Timor Reef fishery are the sum of declining catch rates from the established areas being compensated by higher catch rates as operators find new areas. The recent trend from 1999 onwards for operators to increase fishing effort in the Demersal Fishery immediately adjacent to the Timor Reef fishery also suggests that good catches may be harder to maintain in the Timor Reef fishery. Computer modelling results (which have not been presented in this paper) also show that biomass is declining.

6. FUTURE RESEARCH

To obtain a better picture of the dynamics of this fishery future research needs to be undertaken in the following areas.

- Tagging studies would give information on fish movements and fishing mortality and would provide inferences about interchange of adult fish between areas. A major problem with conventional tagging methods in deepwater is the effects of barotrauma on fish. An *in situ* tagging method is presently being developed by the NT Fisheries Division that may offer a solution for these problems.
- Fine scale spatial modelling of the fishery including, if possible, retrospective collection of spatially referenced data from the inception of the fishery.
- Improved knowledge of age structure of the population. Present data have all been collected from the commercial fishery. However the vulnerability of different age classes to gear leads to some uncertainty about the absolute age structure of the population. Fishery independent sampling using a more representative sampling method, such as a trammel net, would be of benefit.
- Continue dialog with Indonesia and East Timor to obtain better information on catch and effort in their sectors.

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Poole, S., R. Roberts, D. Williams, A. Ford & C. Knight 1991. The effects of trapping on the storage lives of selected iced commercial reef species caught in waters off the Northern Territory. Fishery Report, 23b. Northern Territory Depatrtment of Primary Industry and Fisheries. Darwin.

Evaluation of the activity of the Maltese small-scale fishing fleet

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1. INTRODUCTION

Maltese fisheries are of a typically Mediterranean artisanal type, which are not species selective and are frequently described as multi-species and multi-gear fisheries, with fishermen switching from one gear to another several times throughout the year. There are over 2200 fishing vessels registered in Malta with more than 92 percent measuring less than 10 m in length which, in regional terms, are considered as small-scale vessels. Annual landings recorded at the central fish market normally reach about 1000 tonnes with more than two-thirds of this weight attributed to large pelagic species. Most of the fish brought to this market are caught by the larger vessels. While a long time series of data on these landings is available, the activities of the small-scale fleet have seldom been monitored.

The collection of reliable catch and effort data for various fleet segments is widely recognised as being essential for scientific assessments of stocks and responsible fisheries management. In this context, a catch assessment scheme for the small-scale fleet has been set up in Malta to complement the monitoring of larger vessels, which is undertaken through a logbook scheme.

2. MATERIALS AND METHODS

Fleet and gear statistics were obtained from the database and information system of the Maltese fishing fleet register, MaltaStat (Camilleri *et al.* 2003), which contains data collected by a census and is updated on a daily basis.

Catch and effort estimates for the small-scale fleet were obtained using a sampling scheme (Coppola, Camilleri and Scalisi 2003) applied in six representative ports, which together contain 42.5 percent of the national small-scale fleet. Surveys took place in each port for six consecutive fishing days every other month between January and September, on a 12-24 hour basis resulting in a total of 881 interviews. The sampling frame for each port was adjusted each month according to the number of operational vessels. Data on catches, fishing effort, vessel activity and fishing zone were recorded by gear and species using purposely formulated interview and activity record sheets (Appendix 1). Fishing zones were recorded using a pre-set geographical grids of 5' by 5'.

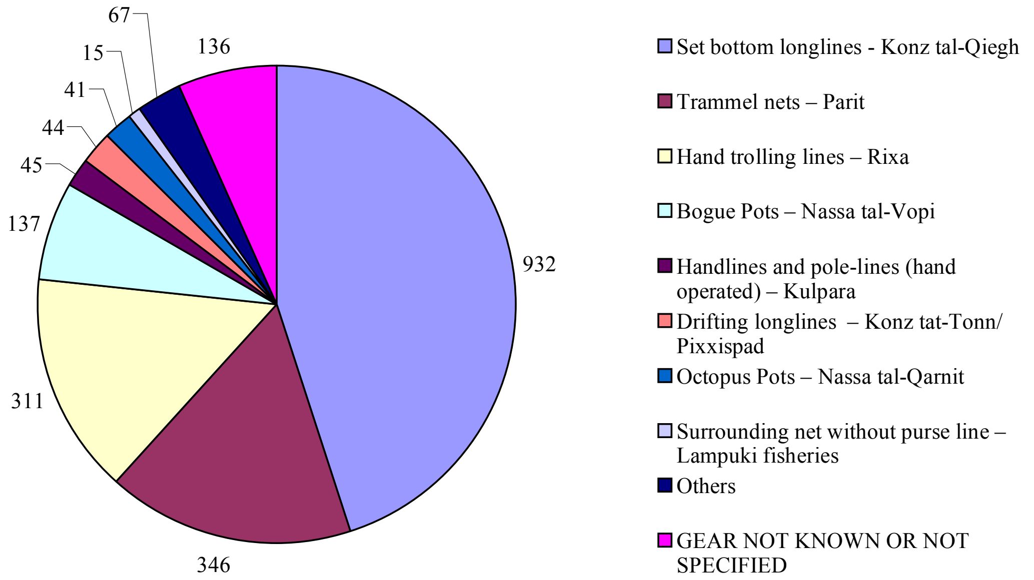
Results for each port and the entire country, by day, month, species and gear were obtained by applying time and area raising factors to the sampled data (Coppola *et al.* 2003). Selections of these results were summarized in order to give a general description of the activity of the small-scale fleet. An evaluation of slope (i.e. over 200 m depth) fisheries was also carried out using the available data.

3. RESULTS

3.1 Gear statistics of the small-scale fleet

The total number of registered vessels under 10m in length overall (small-scale fleet) was 2 074 with more than 60 percent using either trammel nets or bottom-set longlines as the main gears. Almost 15 percent of the vessels used hand-trolling lines and more than eight percent used pots and traps. Figure 1 gives summary statistics on the main gear registered for this fleet category.

FIGURE 1
Registered main gear of small-scale fleet



3.2 Activity of registered vessels

On average, about 67 percent of registered vessels were operational at any given time. Further, the fraction of operational vessels that went out fishing daily was limited with an average of only 20 percent being observed as active over the whole sampling period of the sampled ports. Table 1 summarizes the operational status and activity of vessels by registered gear.

TABLE 1
Estimates of vessel activity by gear based on data collected from all sample ports during the whole sampling period

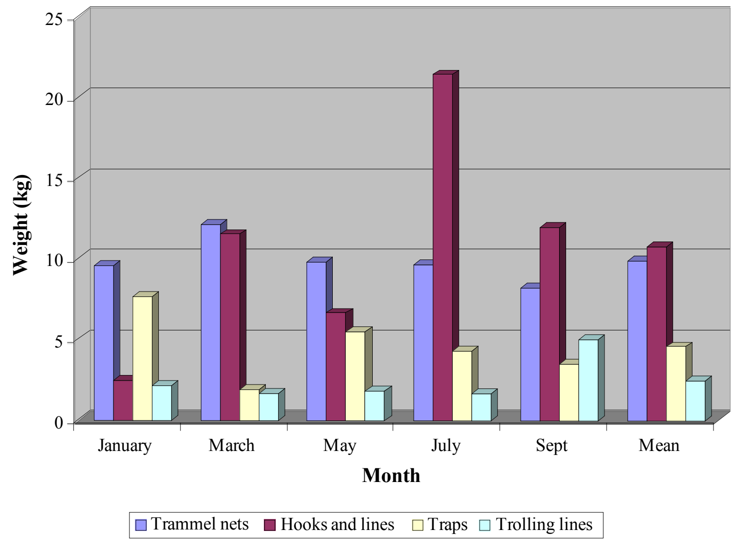
Gear	Operational vessels* %	Daily activity of operational vessels** %
Trammel nets	65.23	33.90
Hooks and lines	47.21	6.06
Traps	75.42	21.91
Trolling lines	80.97	19.05
Mean	67.21	20.23

* number of vessels present in port/number of registered vessels present in port *100
** number of vessels fishing daily /number of operational vessels *100

3.3 Vessel production

In general, small-scale vessels using trammel nets and hooks and lines had the highest daily catches averaging 9.86 kg and 10.79 kg/vessel respectively. However, the catch per vessel for the hook and line category reached 21.43 kg in July because of the use of surface longlines targeting large pelagic species, which have high individual weights. Catches of vessels using traps were found to be under 5 kg a vessel on average, while vessels using trolling lines reached a maximum monthly average of 2.15 kg a vessel except in the month of September when the average vessel catch reached 5.04 kg, largely owing to the occurrence of *Coryphaena hippurus* and other migratory pelagic species in Maltese waters at that time of year. Figure 2 summarizes the results obtained on the average daily catches per vessel by gear for the five sampled months.

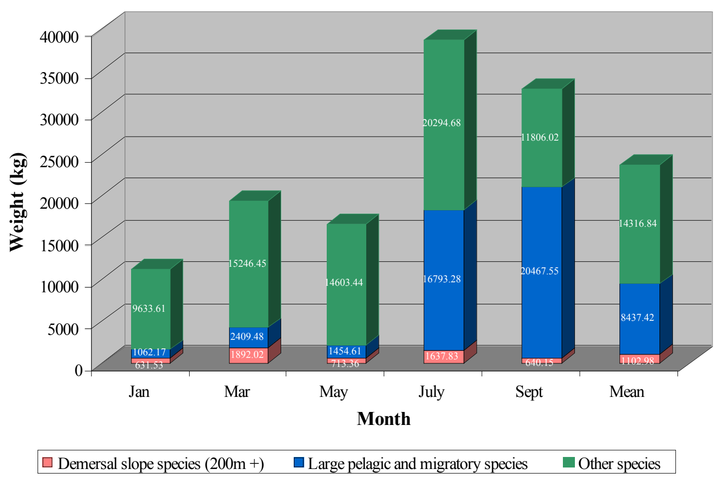
FIGURE 2
Average daily catches per vessel by gear and month



3.4 Estimates of landings

The average monthly landings for the whole sampling period was about 24 tonnes with the highest value being obtained in the month of July for which a total landing of almost 39 tonnes was estimated. The elevated production of the small-scale fleet in July and September is largely attributed to the landings of large pelagic species and other migratory species which are caught during this time of year. The landings of *Phycis* spp., conger eel (*Conger conger*), *Lophius* spp., *Helicolenus dactylopterus*, hake (*Merluccius merluccius*) and *Lepidopus caudatus*, which are normally abundant in fishing grounds deeper than 200 m depth (i.e. the slope), were found to be limited and averaged about 1 tonne a month. Estimate values of monthly landings are shown in Figure 3.

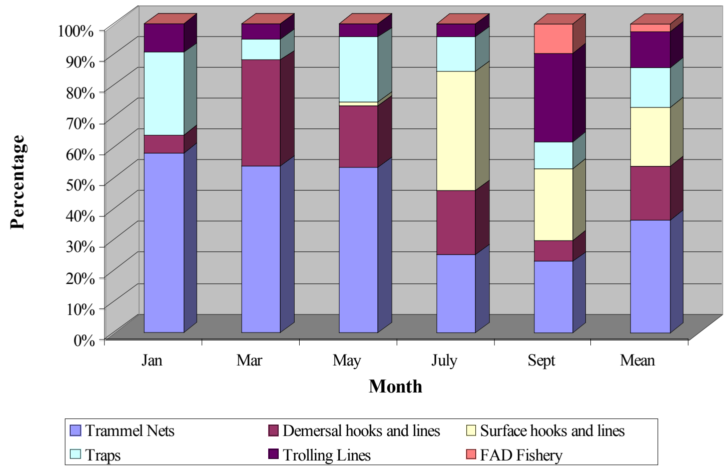
FIGURE 3
Estimates of total landings by month



3.5 Relative importance of gears

Trammel nets and demersal hooks and lines were generally the most important gears in terms of production with an average of 54 percent of landings and almost 90 percent of the landings originating from these two gears for the whole sample period and for the month of March respectively. Traps and trolling lines both contributed significantly to landings in all sample months, while surface hooks and lines and trolling lines jointly caught 52 percent of the catch in the month of September. More than 38 percent of the catches in July were caught by surface hooks and lines. Contributions from the *Coryphaena* fish aggregating device (FAD) fishery were detected in the month of September when the fishery commences. Figure 4 illustrates the percentage distribution by gear or fishery during the sampling period.

FIGURE 4
Percentage distribution of catches by gear or fishery



3.6 Operational statistics of main demersal gears

Summary statistics related to trammel net and bottom longline fishing operations are listed in Table 2. Results show that fishing trips were typically of less than one day and the gear dimensions were relatively small. Landings of both gears were of a highly multi-species nature.

TABLE 2
Gear dimensions, fishing time and number of species landed

	Gear	
	Trammel nets	**Bottom lines**
Average fishing time	13 h 42 mn	10 h 30 mn
Average length of net	128 m	–
Average height of net	1.2 m	–
Average number of hooks	–	646
Average number of species landed*	23	15

*Excluding unidentified and mixed box category.

3.7 Spatial distribution of fishing effort of main demersal gears

Rough estimates of the spatial distribution of the fishing effort of vessels operating from the six sample ports using bottom longlines and trammel nets are given in Figures 5 and 6 respectively.

4. DISCUSSION

Despite the large number of registered small-scale vessels, the results obtained clearly suggest that the fishing effort exerted by this fleet category is relatively small and is a function of the operational status and daily activity of the fleet, their effective fishing time, as well as of the dimensions and other physical parameters of the fishing gear used. It is also evident that the amount of activity, the gear used, the production and species composition vary seasonally.

FIGURE 5

Spatial distribution of fishing effort of vessels operating from six sample ports using bottom longlines

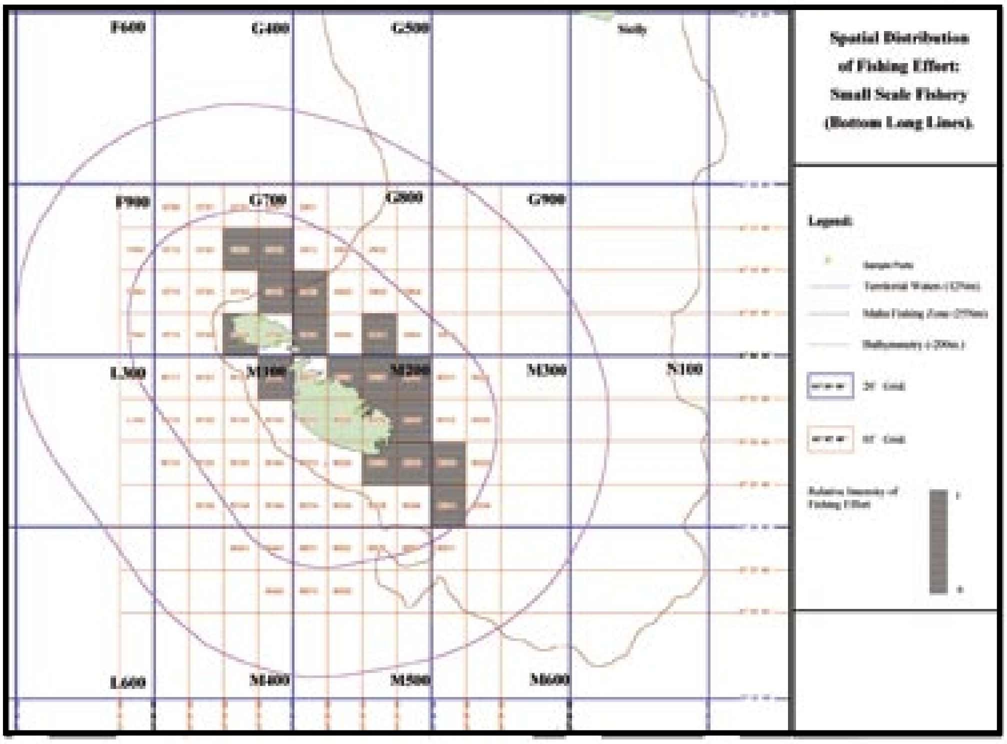
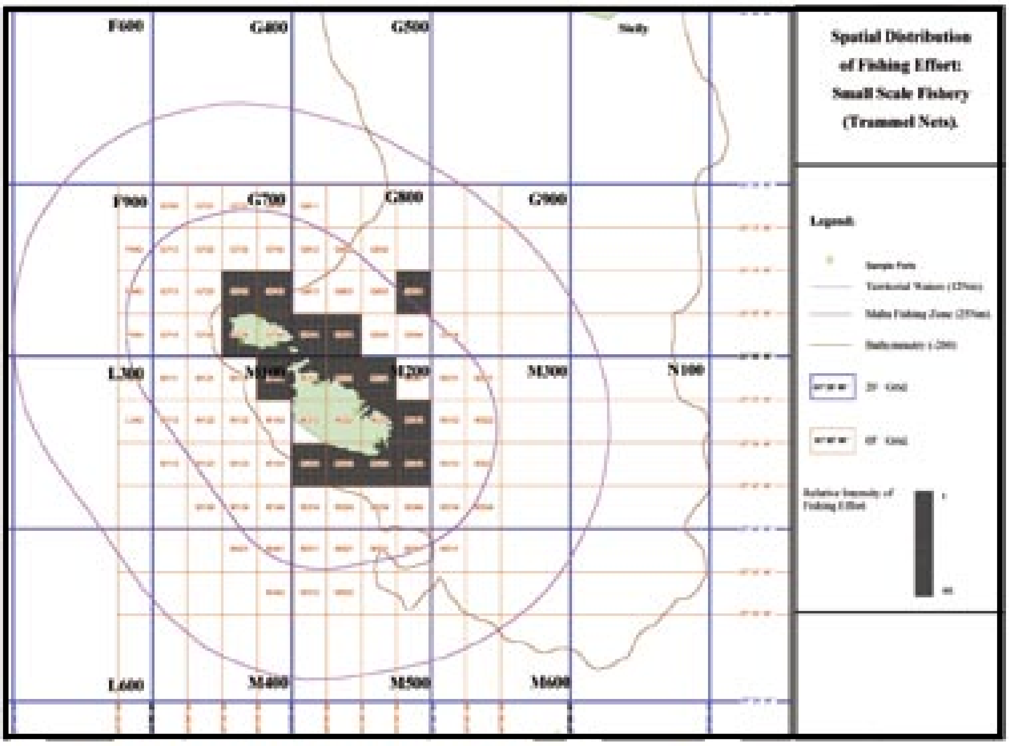


FIGURE 6

Spatial distribution of fishing effort of vessels operating from six sample ports using trammel nets



The landings estimates obtained in this survey indicate that the annual production of the small-scale fleet is less than one third of annual landings recorded at the central fish market. However, the great variety and quality of valuable species landed by this fleet category makes its contribution to the Maltese fishing industry significant.

The spatial distribution of fishing effort of the two main demersal gears show similar patterns. Fishing operations seem to be concentrated within areas close to the base port of the vessel, which, in the case of the investigated ports, occur almost exclusively in waters less than 200m deep (i.e. on the shelf). A limited exploitation of slope fisheries resources was detected off the island of Gozo where the sample ports are within close range of the 200 m isobath. Similarly, small-scale slope fisheries would also be expected off the western coast of Malta, however, the fishing effort in this area is probably low since there are only four ports along this coast harbouring less than seven percent of the national small-scale fleet.

Although the estimates of catches of deep water species by the small-scale fleet may be slightly underestimated, because of the absence of a sampling port on the west coast of Malta it could be concluded that deepwater small-scale fisheries are responsible for only four to five percent of the landings of this fleet category. However, there is evidence from recent trawl surveys, which have been carried out within the framework of a regional programme (Bertrand *et al.* 1997), that the abundance of demersal resources in Maltese waters on the slope (and shelf), is relatively high in comparison to other areas in the region and that they have not been adversely affected by excessive fishing pressure. This suggests that the areas where the small-scale fleet operates are not determined by the spatial distribution and abundance of the resources but by the geographical location of the base ports. This situation points to the fact that there may be fishing grounds, even in coastal areas, which are slightly exploited or maybe even not exploited by the Maltese small-scale fishing fleet.

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APPENDIX I

MINISTRY OF AGRICULTURE AND FISHERIES - MALTA

Department of Fisheries and Aquaculture

Small scale fishery (< 10 m. L.) Catch and Effort Sample Survey of Smale Scale Fishery

Daily Landings of Sampled Fishing Units

(a) Interviewer's Name: ________________ Code: ______ (b) Stratum: ____ (c) Site Name: ____________________ Code: ______ (d) Date: ___/___/______ Time: _______

(e) Sampled Unit Type: _____________ Code: ______ (f) Registry Number: _ _ _ _ _ _ _ _ (g) Auxiliary Boats: ______ (h) Prof. Fishermen: ______ (i) Part Time: _______

(l) Number of Trips in the Day: _______ (m) Fishing Area: ____________________ Code: ______ (n) Time Spent in Fishing: _______(Hrs) Boat Sample N: _______

Ref. N.	(o) Gear Name	(p) Gear Code	(q) Number of Sets	(r) Size, Length (m) or Number of units	Total (q*r)*o	(s) Gear Ref.	(t) Species Name	Species Code	(u) Number of Boxes (B) or Number of Animals (A)	B/A	(v) Box Weight (Kg) or Average Weight of the Animal (Kg)	(z) Total Weight (Kg)
1	Trammel Nets height (m): _______		Number of Net used	Length (m) of each net	(q*r)*o				Number of boxes Number of Fish	B A	Box Weight Average Weight	
2	Long Lines		Number of Lines	Number of Hooks per line	(q*r)							
3	Traps		1	Number of Traps per line	(q*r)							
4	Trawls		Number Trawls used	Mouth opening of the net (m)	(q*r)							
5	Gill Nets		Number of Net used	Length (m) of each net	(q*r)							
6	Trolling Lines		Number of Lines	Number of Hooks per line	(q*r)							
7	Surrounding Nets		Number of Net used	Length (m) of each net	(q*r)							
8	Kannizzati Fisheries		1	Number of Kannizzati fished	(q*r)							
9	Other Specify											
											Total Kg	

Number of boats sampled: _______

Comment:

MaltaCas Form 2.3

Restricted data - For statistical purpose only

MINISTRY OF AGRICULTURE AND FISHERIES - MALTA

Department of Fisheries and Aquaculture

Small scale fishery (<10 m. L.) - Monthly Sample Activity Data Sheet

Stratum: G1 **Site name:** Marsalforn **Code:** G11 **Reference period (month/year):** January / 2003

Recorder: E. Muscat **Code:** 11

Number of fishing days in the month: 29 **Number of sampled days:** 6

Sample day	day 1		day 2		day 3		day 4		day 5		day 6		day 7		
Date	25/01/2003		26/01/2003		30/01/2003		10/01/2003		12/01/2003		20/01/2003				
Number of boats Landed by gear class	**Total**	**Daytime**	**Total**	**Daytime**	**Total**	**Daytime**	**Total**	**Daytime**	**Total**	**Daytime**	**Total**	**Daytime**	**Total**	**Daytime**	**All days**
Trammel Nets															**0**
Long Lines															**0**
Traps								1		1					**2**
Trawls															**0**
Gill Nets															**0**
Trolling Lines															**0**
Surrounding Nets															**0**
Kannizzati															**0**
Others: specify															**0**
Total Boats Landed	**0**		**0**		**0**		**1**		**1**		**0**				**2**
Total Boats Sampled	**0**		**0**		**0**		**1**		**1**		**0**				**2**

Comments: N.B. number of fishing days per month is left blank due to that by the end of January the 6 day sample period was incomplete due to bad weather.

Source: MaltaStat CAS database: Malta2003.cas **MaltaCas Form 2.4** 30/05/2003 Page 1 of 12

Insert total landings for 24hrs periods, and Insert day-time landings from 7:00 to 16:00;

Deepwater snapper fishing gear and techniques used in the Pacific region

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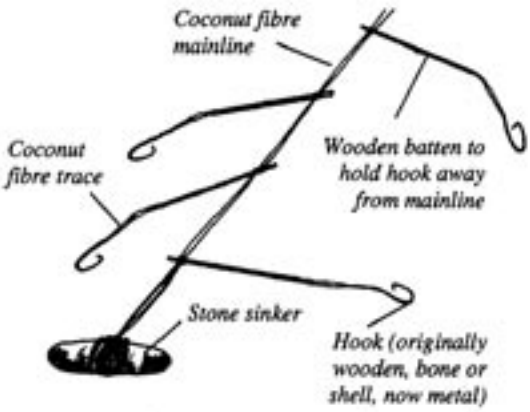
BP D5, 98848 Noumea Cedex, New Caledonia
<lindsayc@spc.org.nc>

FIGURE 1
Traditional Polynesian deep-bottom fishing rig



1. INTRODUCTION

Fishing for deepwater snappers in depths from 100 to 400 m, and sometimes deeper, has been practised for generations in some of the remote island communities of the Pacific (Preston *et al.* 1999). Traditionally, Polynesian fishermen used coconut fibre line, with a stone sinker and several wooden, bone or shell hooks attached (Figure 1) to fish for these species.

Since the introduction of more modern materials in the 1970s, Polynesian and other fishermen have experimented with a range of gears throughout the region in an attempt to harvest deepwater snapper species. From the late 1970s, the SPC has assisted most Pacific Island countries and territories in the region (Figure 2) to fish for these species using a range of fishing gears and methods.

FIGURE 2
The Pacific Island countries and territories in the region

In addition to the SPC's work in the region, other development organizations, including the FAO, UNDP, USAID, Japan, the European Union have funded fishing trials and development projects based on the harvesting of deepwater snappers. This paper summarizes the different fishing gear and techniques trialled or used over the last 25 to 30 years to target deepwater snappers in depths from 100 to 400 m and draws heavily on the information presented in Preston *et al.* (1999).

2. HAND REELS

The simplest reel introduced to the Pacific region in the late 1970s for deepwater snapper fishing was the FAO-design Samoan hand reel (Figure 3). The reel can be made from locally available materials and allowed small-scale fishermen to make them at minimal cost. The reel post was mounted to the side of small-scale vessels, while the spool with line and the rocker arm were removable for ease of storage.

Other commercially made hand reels have also been available for local fishermen. However, the cost of these reels has limited their use in the Pacific region. Commercially manufactured reels have been designed and built in Australia, Japan and the US (Figure 4) to name a few locations.

FIGURE 3
FAO design Samoan handreel

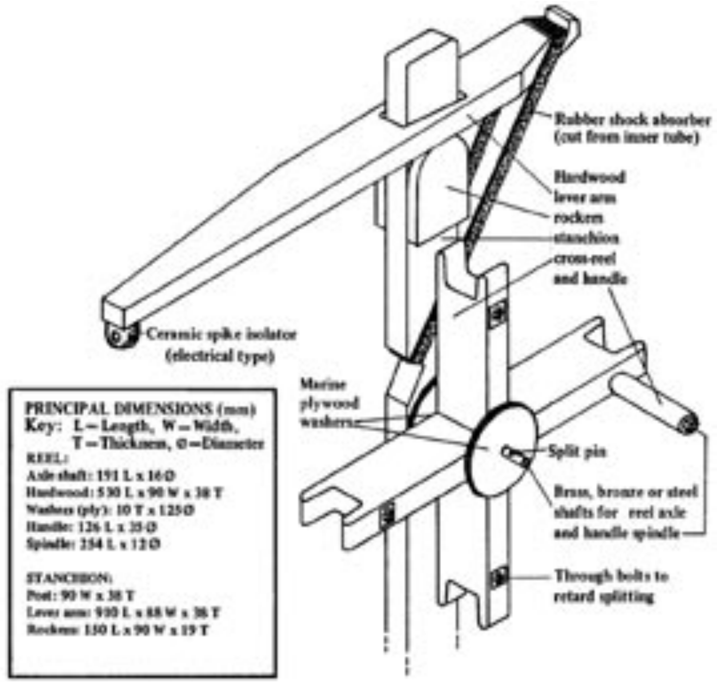
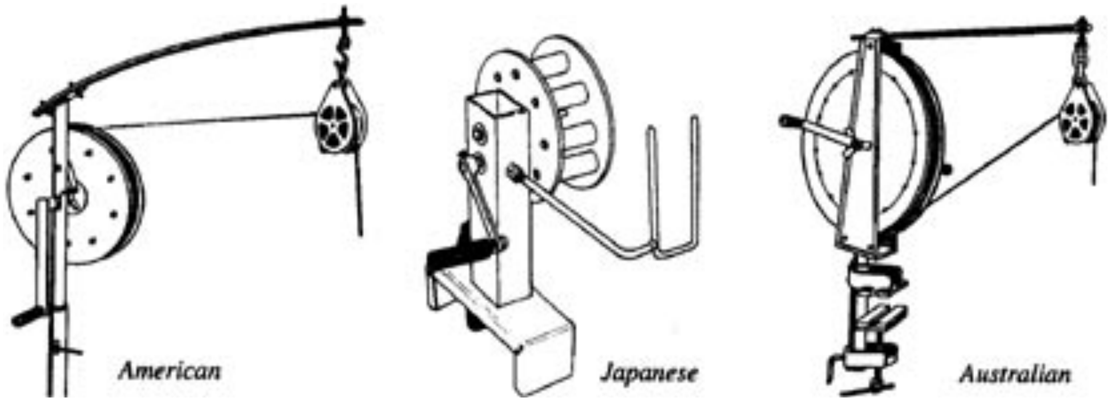


FIGURE 4
Commercially manufactured handreels used for deepwater snapper fishing



Other variations of low-cost handreels have been developed in the region. In Vanuatu, a French fisherman mounted a reel spool to a bicycle frame to come up with the 'velo' design (Figure 5). Other designs were merely modifications of the original wooden handreel, made larger from steel for larger boats (Figure 6), or smaller for mounting on traditional outrigger canoes (Figure 7).

FIGURE 5
Velo design deep-water snapper reel

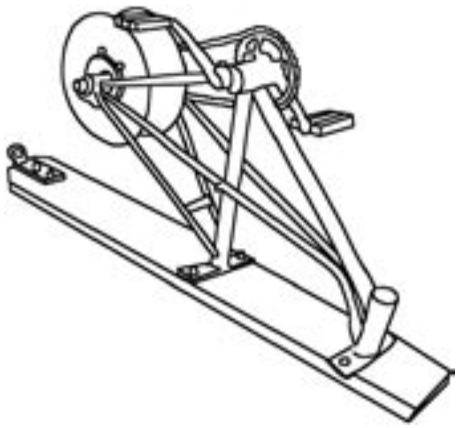
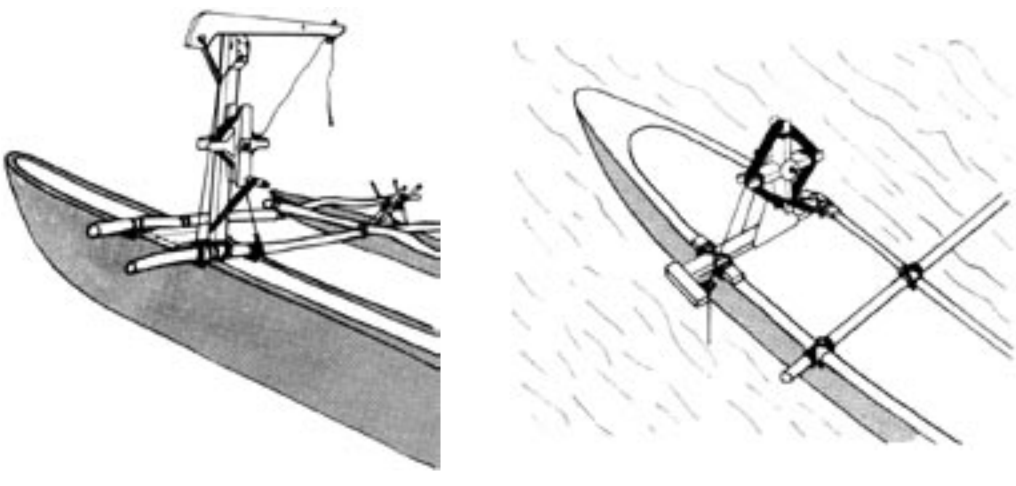


FIGURE 6
Steel version of a handreel

FIGURE 7
Modified handreel mounted on a traditional outrigger canoe



3. RIGS USED FOR FISHING

3.1 Mainline

The mainline used for fishing with handreels can be either monofilament or braided lines, such as super-toto. The line is wound onto the reel, with usually 400 to 500 m used depending on the size of spool and the depth of water to be fished. A terminal rig is attached to the end of the mainline. The terminal rig can be made of wire or monofilament and usually has three to five hooks attached (Figure 8). A chum bag can also be attached to the top of the terminal rig.

3.2 Anchor gear and use

The anchor gear used for deepwater snapper fishing is simple in construction and consists of a grapnel anchor made from rebar (Figure 9) and around 400 to 500 m of polypropylene rope. The size of the rebar and rope used depends on the size and weight of boat using the gear. A large PVC balloon buoy or float (Figure 9), or several longline floats tied together, are used in the retrieval of the anchor at the end of fishing

At the end of fishing a simple method is used to retrieve the anchor. The slack rope is pulled in until the rope is taught and vertical in the water. The rope is then secured to the boat as it speeds up and over the anchor, breaking it free from the bottom (Figure 10). As the rope streams out behind the moving boat, the buoy is attached to the rope and so slides back until it is trapped by the no-return barb that is whipped to the rope. With the rope floating on the surface, the boat is turned and motored along as one person pulls the rope in (Figure 10). When the anchor is reached, it too is pulled onboard.

FIGURE 8
Terminal rigs used for deepwater snapper fishing

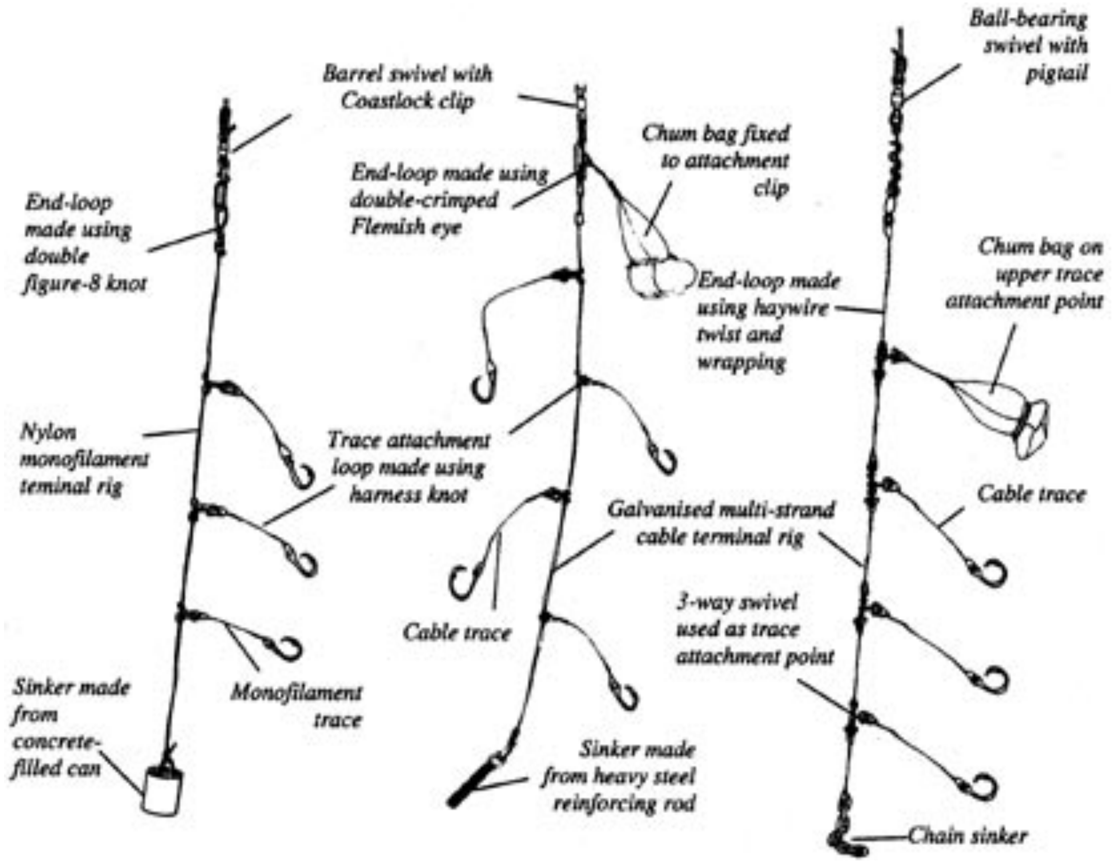


FIGURE 9
Anchor gear used for deep-water snapper fishing

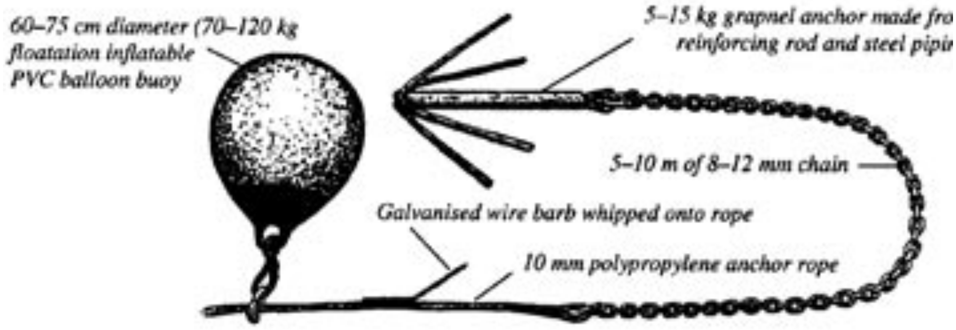
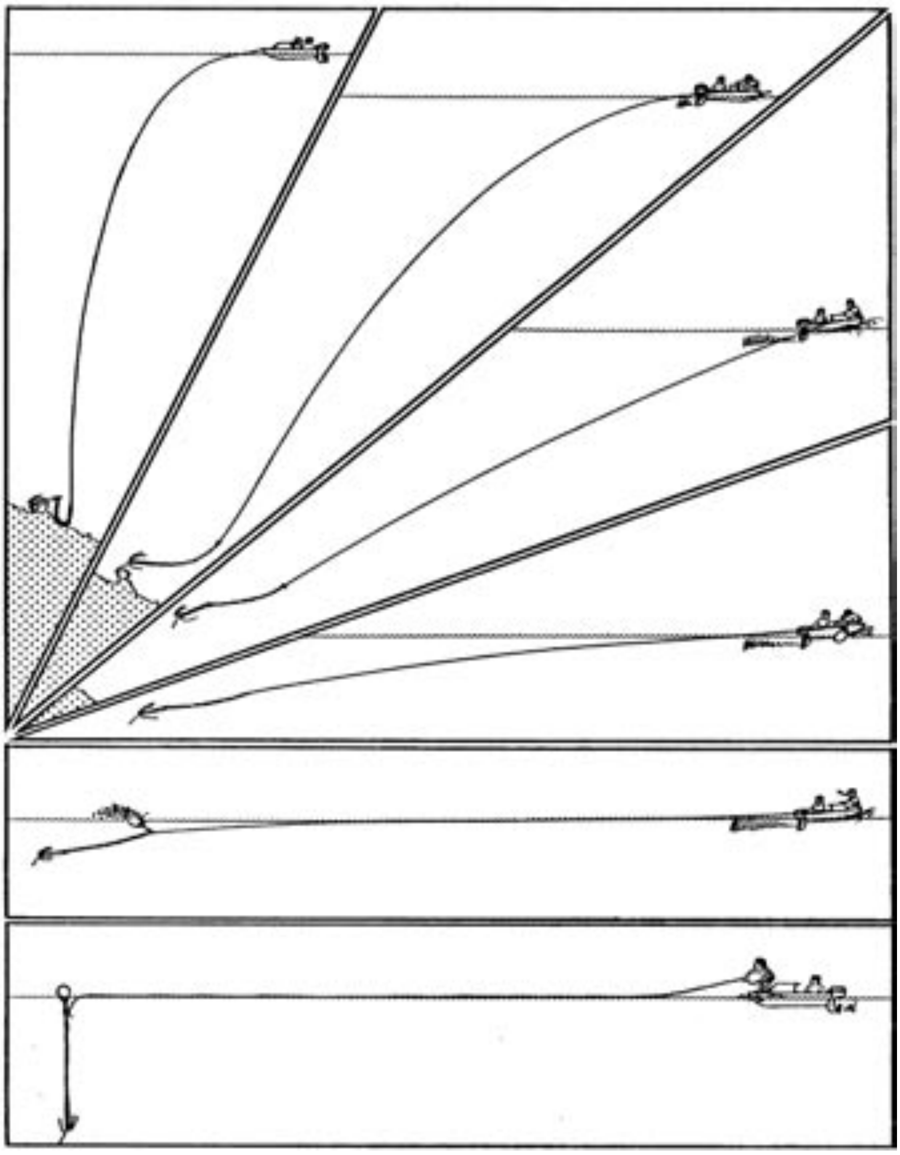
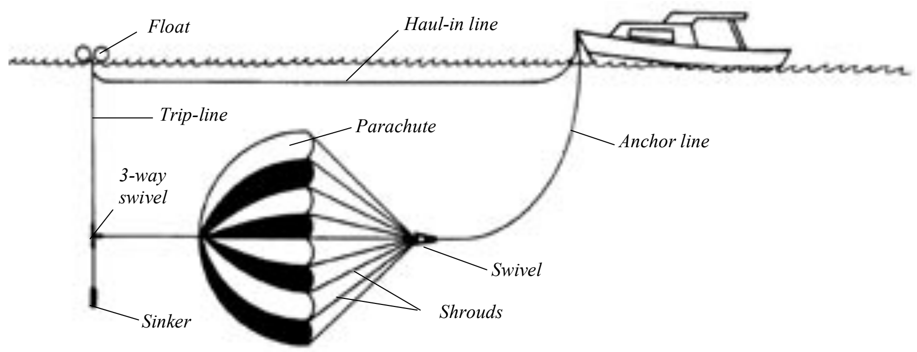


FIGURE 10
Retrieving the anchor after fishing



An alternative to anchoring to fish for deepwater snapper is to use a controlled drift. To do this a parachute sea anchor is needed (Figure 11). The size of the sea anchor will be determined by the size and weight of the boat it is used on.

FIGURE 11
Parachute sea anchor used for controlled drifting



To set a sea anchor, it is simply lowered over the bow of the boat. The trip-line and float attached to the apex of the sea anchor are also paid out as the sea anchor fills, and allowed to float free with no tension. Once some resistance is felt, the anchor rope is paid out to the desired length and secured. Hauling the sea anchor is the reverse of setting. The trip-line is hauled in to turn the parachute around so it is pulled in by the apex. Once this is retrieved, the anchor line is pulled in.

4. POWERED REELS

In some locations, handreels have been replaced by powered reels. The same principle applies; however, electric motors or hydraulics are used to wind the reel, and hopefully fish, up to the boat. There is a range of commercially made reels available. In the 1980s and 1990s, these reels were simple, with either the line wound onto a spool (Figure 12) or a pinch-puller (Figure 13) used to haul the line, with the line coiled into a basket.

Powered reels are becoming more sophisticated by the year, and newer versions have computer technology where they can be programmed (Figure 14) to lower the

FIGURE 12
Electric and hydraulic reels used with spools

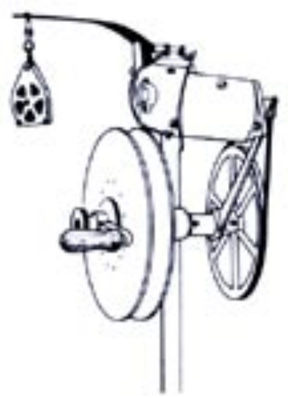


FIGURE 13
Pinch-puller used for hauling braided line

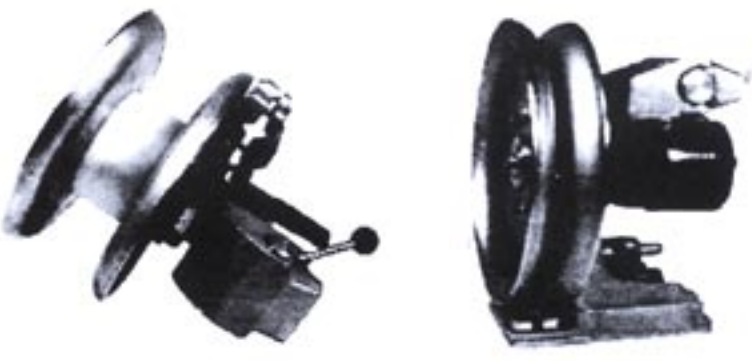
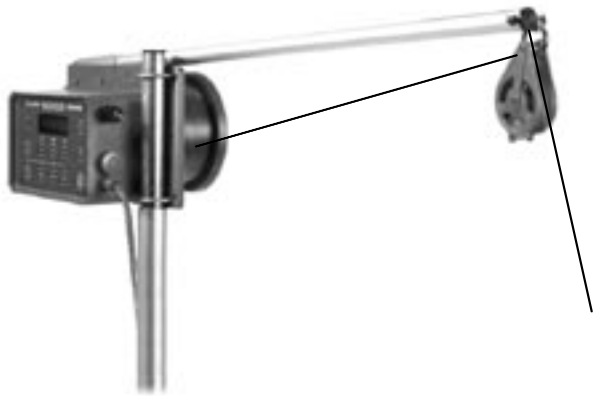


FIGURE 14
One type of programmable electric reel used for deepwater snapper fishing



line to a specific depth, jig the line if desired, and automatically haul up when weight is put on the line, such as a fish being hooked. The reel will also stop winding when the terminal rig reaches the surface, as this is all programmed into the reel as well.

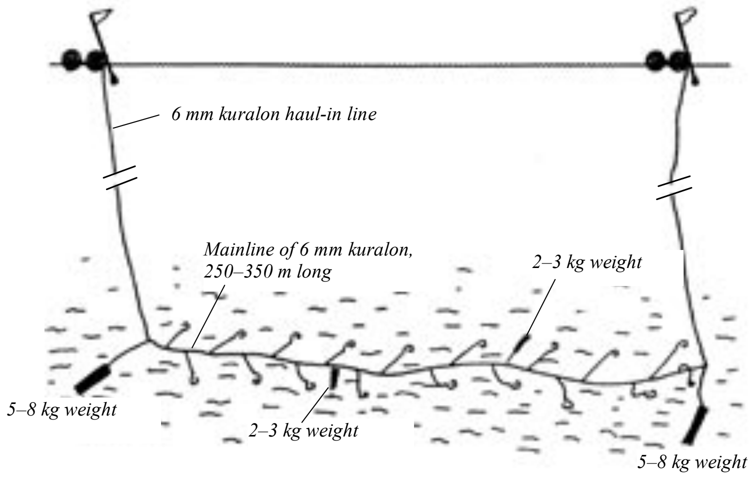
The types of terminal rigs used with powered reels are the same as for the handreels. The anchor gear and the sea anchor are also the same.

5. BOTTOM LONGLINES

5.1 Gear configuration

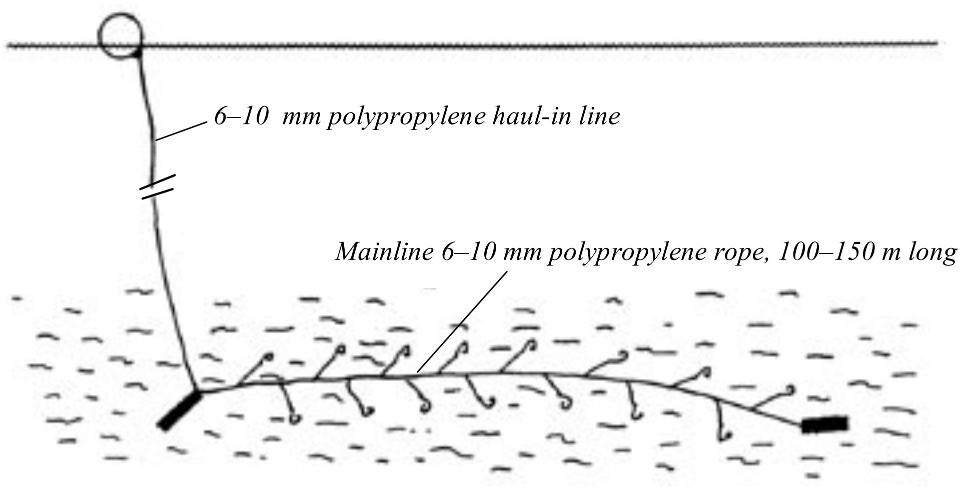
The next step up from using handlines is to use some form of longline, whether it be set horizontally or vertically. With bottom-set longlines, the mainline and baited hooks are set along and in contact with the ocean floor. The mainline is generally made from negatively buoyant rope so that it rests on the bottom. Sometimes additional weights are attached to the mainline to reduce the chance of fish or currents moving the mainline and getting it tangled on the bottom (Chapman 1990). The mainline usually has a haul-in line on each end with a float to mark the position and support the weight of the haul-in line (Figure 15). The mainline is generally 250 to 350 m long, although this can be altered to suit the operation of the boat and the depth of water being fished. A general rule is to have the mainline shorter that the depth of water being worked, so that when the first hook reaches the surface the fisherman knows the last hook is off the bottom. The hooks are on individual snoods around 30 to 40 cm long, with a longline clip on the other end. The snoods are snapped onto the mainline at around one-metre intervals. This type of gear is generally used on a flat bottom with few obstacles, to reduce the chance of the mainline becoming stuck on the bottom. This type of gear has not been very successful in the Pacific due to the rough nature of the bottom being fished, which has resulted in considerable gear loss.

FIGURE 15
One type of bottom longline with a haul-in line at each end



An alternative type of bottom-set longline is being used in some locations in the Pacific because of the rough bottom being fished. In this case, a short mainline of 100 to 150 m in length is used and the mainline is made from polypropylene rope, which is positively buoyant (Figure 16). The snoods and spacing along the mainline are the same as other bottom longlines, and there is generally only one haul-in line as the mainline is so short. This type of gear has been more successful in the Pacific as it is short and can be better targeted, and there is less chance of getting the gear snagged on the bottom with less gear loss.

FIGURE 16
Alternative bottom longline using polypropylene rope mainline



5.2 SETTING A BOTTOM SET LONGLINE

The most common and safest way to set bottom longlines from small craft is to use a shooting rail. The rail is a piece of aluminium 'U' or channel beam or equivalent. The snoods are prepared by baiting each hook and placing it in the 'U' or channel beam. The snap is allowed to hang down from the beam (Figure 17). The snap of each snood is then attached to the mainline in order, with around one metre of mainline between snaps (Figure 18). When all the snaps are attached to the mainline, it is ready for setting. The anchor or weight at the end of the mainline is let go and it starts to pull the baited hooks of the shooting rail in order as the boat motors forward. When all the snoods

FIGURE 17
Baited snoods lined up 'U' or channel beam

FIGURE 18
Snood snaps attached to the mainline in the ready for shooting the gear

FIGURE 19
One type of line hauler used to haul bottom longline

are set, the mainline is tied off and the boat stretches the mainline out to stop in settling in a pile on the bottom. When the mainline is stretched, the second anchor or weight is released and the haul-in line paid out. The float is then released and the gear allowed to settle and soak.

5.3 HAULING THE GEAR

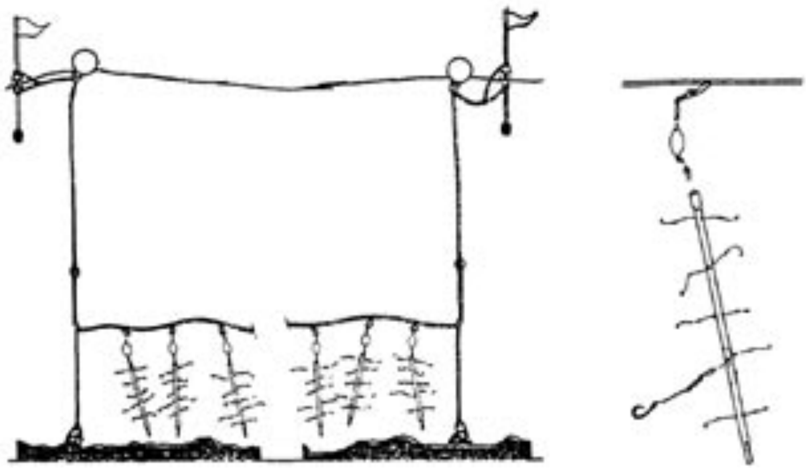
The gear is easily hauled using a line hauler that is mounted close to the side of the boat (Figure 19). The float is retrieved and the haul-in line passed over the line guide (Figure 19) or block and on to the hauler. The rope is then closely monitored as it is hauled until the first anchor or weight is reached. The hauler is stopped, the anchor or weight removed and the hauling continued slowly with each snap being removed from the mainline as it comes into reach. When larger fish are on the line, the hauler is stopped to allow the fish to be gaffed and boated.

6. TROTLINES

Trotlines are an alternative to bottom-set longlines. The main difference is that the mainline is suspended horizontally above the bottom, so it does not come in contact with the ocean floor and become stuck. There have been several types of trotline arrangements used or trialled over the years in the Pacific.

The ‘Florida fish stick’ uses short lengths of PVC tubing with a weight on one end and a pressure float and snap attached to the other (Figure 20). Holes are drilled through the PVC and a snood is passed through and secured, with a hook placed on each end. The fish sticks are then attached to the mainline as it is paid out during setting, so that the weight of each stick is on the bottom with the pressure float keeping it vertical in the water (Figure 20). Although this method has been used in several locations in the Pacific, it has not been successful as the fish sticks are costly, easily broken and difficult to handle on the boat. Consequently they are no longer used in the region.

FIGURE 20
The ‘Florida fish stick’ type of trotline



Other trotline arrangements have the trots or droppers made of monofilament, wire or light cord rather than PVC pipe. The basic design is the same; however, the trots are much easier to handle on the boat and easily stored. Another small difference is that the weight at the bottom of each trot is usually sacrificial, and is attached to the trot by a light cord. This is to allow it to break off if it gets stuck on the bottom. Figures 21 and 22 show two trotline arrangements.

The length of each trot is usually around 1.5 to 2 m, so that the three to five hooks are kept relatively close to the bottom. Trotlines are set and hauled in the same manner

FIGURE 21
A trotline arrangement with the mainline attached to the anchor or weight

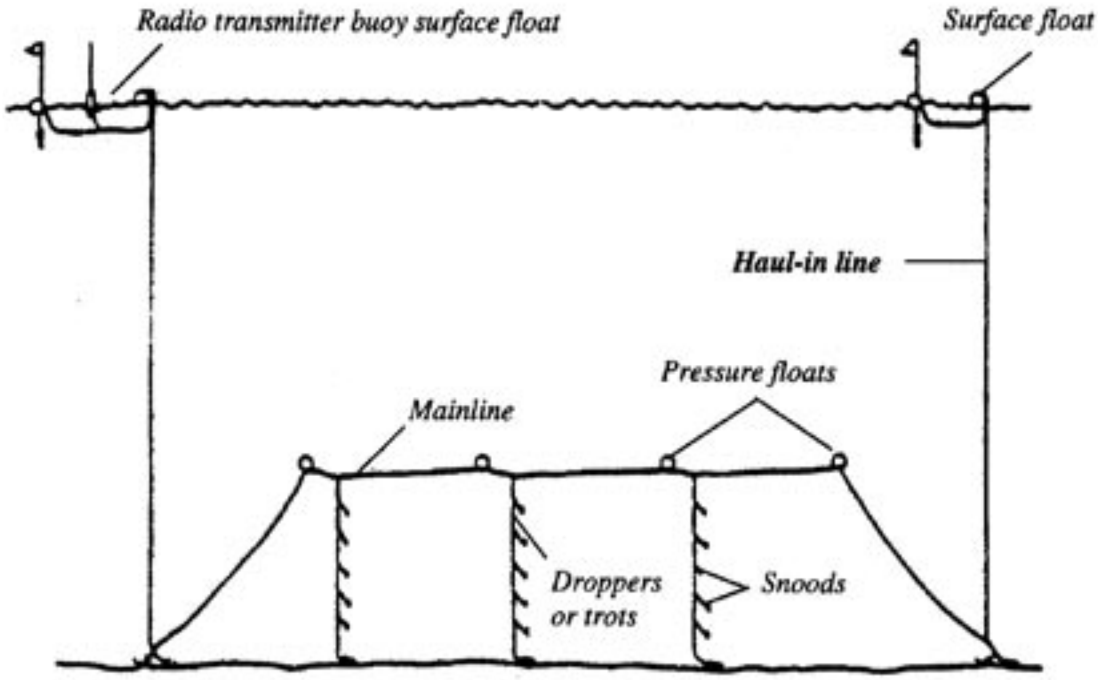
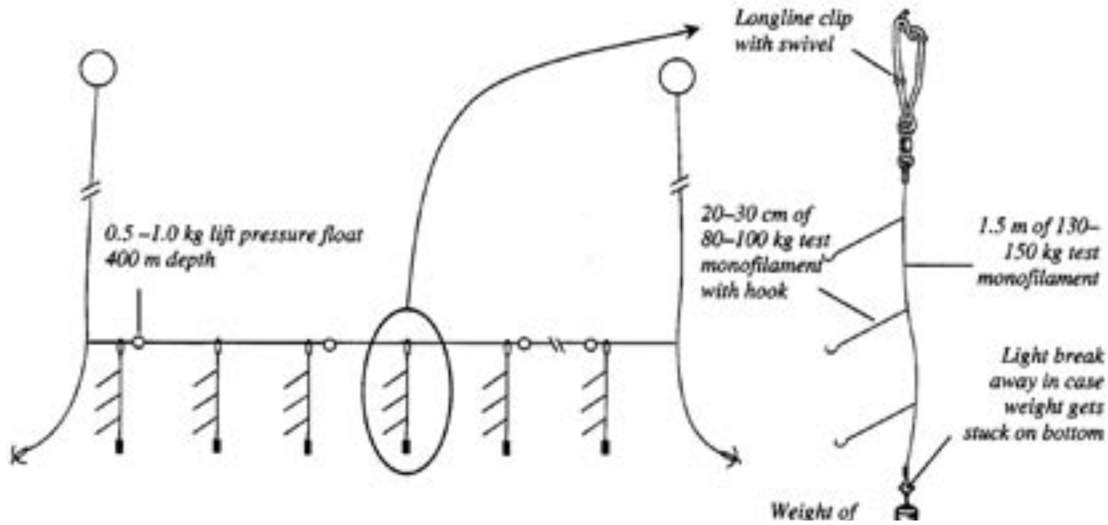


FIGURE 22
A trotline arrangement with the mainline attached to the haul-in lines

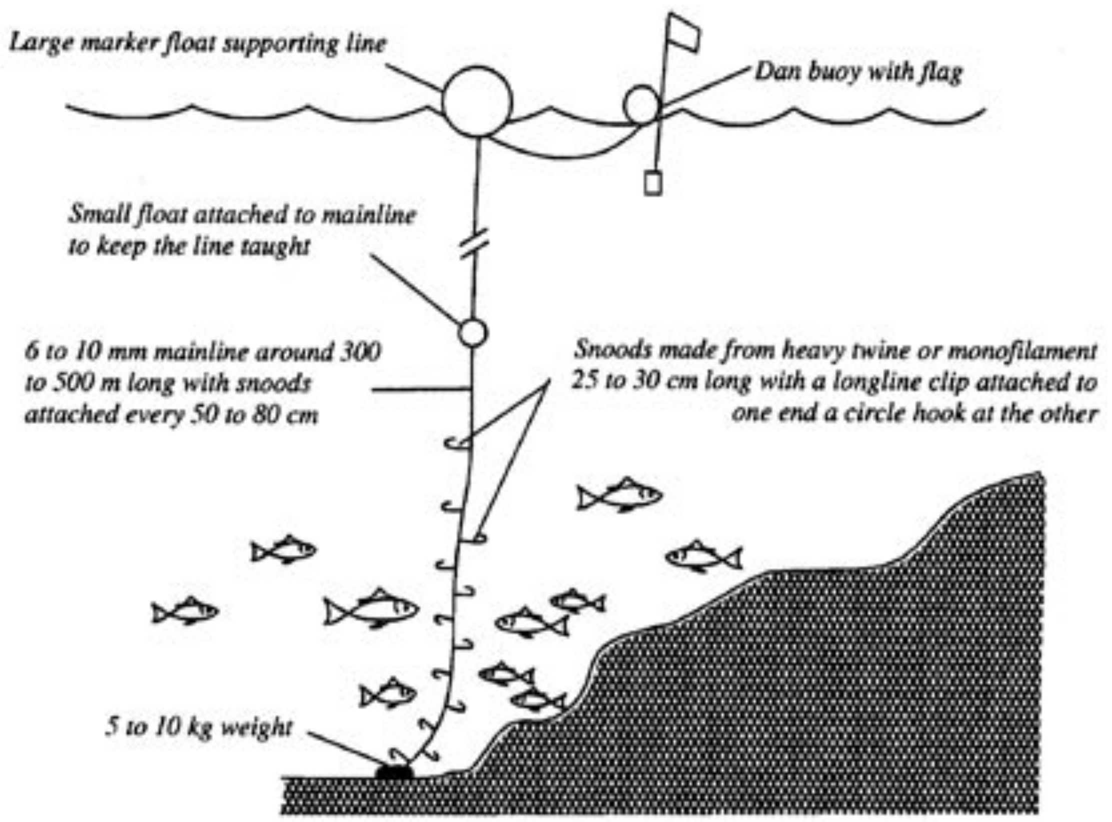


as bottom-set longlines. The main difference is that the trots are generally attached to the mainline as it is being paid out (no shooting rail used). Like bottom-set longlines, the length of the mainline is shorter than the depth of water being fished. These types of trotlines are still used in a few locations in the Pacific, especially some Melanesian countries.

7. DROPLINES

A few species of deepwater snappers are known to school and rise off the bottom. For these species, a dropline can be used. A dropline is a single line (haul-in line and mainline) set vertically, with a weight on the bottom and a marker float on the top (Figure 23). From 5 to 50 snoods can be spaced at 50 to 80 cm intervals along the bottom portion of the line from the bottom up (Figure 23). Just above the top hook, a small pressure float is attached to ensure the mainline is kept vertical and the hooks are kept off the bottom.

FIGURE 23
Dropline arrangement



Droplines are generally set using a shooting rail the same as described above for bottom-set longlines. The difference is that the boat is stationary so the weight takes the hooks straight down so the mainline is vertical. A rope line hauler is used to retrieve the gear, with the hooks unsnapped from the mainline as they come aboard. This method has been tried in the Pacific, but has not become popular and is rarely used at present.

8. TRAPS

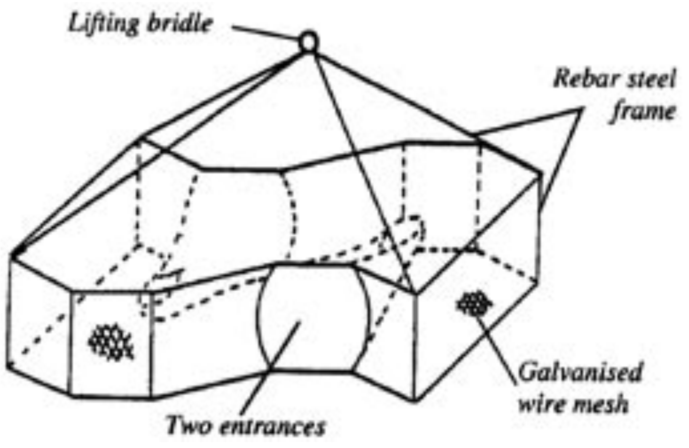


FIGURE 24
Basic 'Z' trap design

The 'Z' trap (Figure 24) has been trialled in several countries in the region with limited success. The design of the trap is such that it guides fish to one of two entrances in the wire mesh cage. Once inside, the fish find it difficult to escape. Although the catch rates for deepwater snappers have been low, it has been reported that in some locations large numbers of nautilus have been caught as well as some deepwater shrimps (when fine wire mesh is used). This method is not used in the Pacific at present due to the high cost of the gear, the low catch rates and the potential for gear loss.

9. TRAWLING

Trawling in the Pacific for deepwater snappers has been tried on a couple of occasions, especially on offshore seamounts where the trawl just passes over the top of the seamount where the fish tend to congregate. This is a method that is not used in the Pacific at present for fishing deepwater snappers. However, several countries in the region are looking at the possibility of deepwater trawling in depths of 500 to 2 500 m for other species and this may occur in the future.

10. CONCLUSIONS

The main gear used in the Pacific region for deepwater snappers continues to be the handreels and powered reels. This is due to the low cost of the equipment, their ease of maintenance and repair of the equipment and the generally limited fishing area for these species. This type of gear would be used to some degree in all Pacific Island countries and territories.

Bottom longlining and trotlining are the next most common methods used in the region for deepwater snappers, although these are mainly used in some of the Melanesian countries where there are larger fishing areas for these species. The boats used are equipped with hydraulics and the gear is more expensive. In Pacific locations demand in both local and export markets provides high prices for the fish, which warrants the increased cost of the boats and gear used.

11. LITERATURE CITED

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Preston, G., P. Mead, L. Chapman and P. Taumaia 1999. Deep-bottom fishing techniques for the Pacific Islands – a manual for fishermen. Secretariat of the Pacific Community, Noumea, New Caledonia. 82 pp.

Deepwater bottom fisheries of Fiji

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1. INTRODUCTION

The deepwater fish of the Fiji Islands are a diverse group of fishes found on the continental slope, pinnacles and seamounts at depths between 70 and 250 fathoms (130–460 m). There are two distinct capture zones the first of which is between 70 and 120 fathoms and the second between 180 and 220 fathoms. The first zone is dominated by *Pristipomoides* spp., *Aphareus rutilans, Paracaesio kusakarii, Seriola rivoliana* and *Wattsia mossambica*. The second deeper zone is characterized by *Etelis spp., Epinephelus* spp., and *Paracaesio stonei*. The most given common species found in Fiji are in the Table 1 with the common names, indicative prices from the Hawaiian market (quoted in Ocean Trader 2002) and export status.

TABLE 1
Export deepwater fishes of Fiji

Scientific name	Common name	Export prices 2002 US$/lb	Export status
Etelis carbunculus	Ehu	3.25	Dominant
Etelis coruscans	Onaga	4.25	Dominant
Etelis radiosus	Smalltooth snapper		Probably included in Ehu exports
Pristipomoides multidens	Purplecheek Opakapaka	3.5	This is the most common Fiji species and is well received on the export market
Pristipomoides flavipinnis	Yellow-Finned Opakapaka		An export species used in the whole deep-fried market because of its smaller size.
Pristipomoides filamentosis	Opakapaka		The most common sort after *Pristipomoides* spp.
Pristipomoides zonatus	Gindai		A specialty Hawaii export species
Pristipomoides typus	Red tailed Opakapaka		This species is not very common.
Aphareus rutilans	Lehi	3.25	Dominant
Wattsia mossambica	Large eye bream		Local market
Paracaesio kusakarii	Bedford		Local market
Paracaesio stonei	Stone's snapper		Local market
Lutjanus malabaricus	Rosi ni bogi		Occasionally exported to Hawaii
Epinephelus magniscuttis	Hapu		Exported
Epinephelus miliaris	Hapu		Exported
Epinephelus morrhua	Hapu		Exported
Epinephelus septemfasciatus	Hapu		Exported
Seriola rivoliana	Kahala		Not exported to Hawaii as banned because of ciguatera

2. BIOLOGY AND ECOLOGY

Deep-slope fishes, especially snappers, tend to have slow growth with low recruitment, which results in them being highly susceptible to over-fishing. They are usually top-level carnivores, feeding on fish, squid and deepwater shrimp (Smith 1992). Information on their biology and ecology is available in Moffit (1993). The Paracaesios often feed on pelagic salps.

3. THE FISHERY

The commercial bottom finfish fisheries of the Fiji islands consist of two dominant fisheries. The reef fishery is undertaken inside or close to reef structures and generally in waters shallower than 120 m. Fishing methods include day and night diving with spear gun, hook and line and gill net fishing. The outer reef fishery which uses hook and line for deepwater "bottom fish". This fishery is usually carried out in water depths exceeding 130 m.

Deep-slope fishes are caught with baited tuna-circle hooks with usually 4-5 hooks per drop using hand-operated, electric or hydraulic reels. Bottom-set longlines are also used in some areas. The flesh of virtually all species is of excellent quality and is free of ciguatoxin (Lewis 1985a, b).

4. DEVELOPMENT OF THE FISHERY

The first recorded catches of deep bottom fish were in the late 1960s when Captain Gordon Elliott returned from fisheries training in Hawaii. Elliott teamed with his Senior Fisheries Officer; Louis Devambez, obtaining small catches of *Pristipomoides* spp., *Aphareus* spp. and *Paracaesio* spp. outside the main Suva reef. Gear and fishing techniques were later improved with the introduction of an echo sounder and with fishing gear given to the author by the crew of the visiting Hawaiian research and commercial skipjack tuna vessel **Anela** in 1972.

The first commercial fishery for the deep-slope bottom fish began in 1979 using a 28' St. Pierre dory and hydraulic reels. A FAO boat building project was the catalyst for continued development of the commercial fishery along with the introduction of the FAO designed wooden hand reel. Initially all of the catch was sold locally until Richard Howell of the USA set up business in Fiji to pack fish for export (1982) having previously gained experience in American Samoa. With advice and technical assistance from the Fisheries Division, Howell was able to encourage a number of fishermen to enter the fishery enabling him to establish a small but viable export market.

The developing Fiji fishery became innovative as foreign fishermen introduced the use of larger most sophisticated fishing vessels, using commercial fish-finding sonars and deploying bottom long-lines and hydraulically operated reels rather than the simple wooden hand-reel. Lewis, Sesewa and Adams (1988) provide the best description of the Fiji deep-slope fishery prior to its demise after 1987. The Fiji deep-slope fleet comprised one 20 m Hawaiian long-liner, four larger local vessels (three dropline and one long-line) and a number of 9 m dories, similar to those used in Tonga. The larger vessels deploying hydraulic reels used lines with five or more hooks per line. Skipjack was rejected by the local cannery as bait throughout the fishery. The larger vessels used a palu or chum bag to aggregate fish and increase catch rates. At the peak of the Fiji fishery about 200 t of deep-slope fish were landed annually, with about 75 percent of this sold overseas.

The disruption in airline scheduling following political events in 1987 was a serious setback in the fishery, as profit margins were not large. However, the vessels involved in the fishery began to shift from demersal fishing to pelagic longlining to catch large high-value tunas such as yellowfin (*Thunnus albacares*) and big-eye (*T. obesus*). These species can be caught more reliably than deep-slope fishes, realize a much better return on overseas markets and the stocks are not nearly as limited as fish stocks on the deep-slope.

The expansion of the deep-slope fishery in Fiji was based largely on catches from virgin stocks and catch rates could fall by order of magnitude in a short period of time, particularly when fishing on seamounts. In 1989, there were at least 22 larger vessels locally involved in the fishery. Some of the commercial fishing areas began to show declines in catch per unit effort (CPUE) during the late 1980s and this and other economic factors prompted alternative investments by fishermen in longline gear for sashimi tunas and other pelagic species.

During the first six months of 1990, only 43.7 t of deep-slope snappers were exported from Fiji and exports were not expected to exceed 100 t for the entire year. In 1994 there were two large commercial vessels actively involved in the deep-slope snapper fishery, but several 8.6 m vessels supply deepwater bottom fish to hotels and other markets. Prices paid for these fish averaged between FJ$ 3-4 a kilogram.

5. VESSELS AND LICENCES, 2001–2003

Data obtained from the licensing section of the Fiji Fisheries Department for the years 2001 -2003 is show in Table 2. There may be some discrepancies in the data as a number of fishermen that are still fishing the outer reef slope and exporting through a pack house are not shown as having a licence. This may reflect a separate classification for smaller vessels. It should be noted that the deepwater snapper (DWS) licence has not been strictly monitored and catch data logsheets have not been submitted. This is unfortunate as although the overall Fiji catch as reflected in exports (Table 3) is way below the total allowable catch (TAC), catch data can be used in many ways to help develop and manage a fishery.

6. PRODUCTION

The catch in the Fiji deepwater fishery has not been recorded in recent years as most of the limited staff resources of the Fisheries Department have been redirected to the management of the tuna fishery. It is apparent that the Zone 1 (70–120 fathoms) fishery for deepwater snappers, apart from *Aphareus* spp., are almost all marketed locally while the Zone 2 caught fish are exported. This has resulted in a probable misreporting of the deepwater fishery by up to 50 percent.

The Fiji Fish Marketing Group (managed by Russell Dunham) has supplied data on the catch of their vessel, **F.V. Sasalu ni Wai Tui** (see Appendix) This vessel was supplied to the Fisheries Department as an extension vessel by Japanese Aid and was later sold to the private sector. This fibreglass vessel is hard chined, has a number of fish holds and has a low profile to decrease windage. A new captain has been given command of this vessel and the daily catch rate has increased substantially. The vessel is now very profitable and highlights the most important factor that has been obvious in the Skipjack and Longline fisheries, a good fishing master is paramount to success!

7. SPECIES EXPORTED 2002

Only four genera of deepwater fish were exported in 2002. (National Fisheries Authority Database) These were *Epinephelus*, *Etelis*, *Pristipomoides* and *Aphareus* (Table 4).

8. MARKETING

The market for Fiji deepwater fish has traditionally been Hawaii where the fishery for similar species has flourished for many years. This market however has had a number of incidences that have tended to keep the market prices static over the past twenty years. These include the developing fisheries of the South and Central Pacific and a limited market base in Hawaii and an even smaller market for "exotic" species on the US mainland. To counteract these effects, Hawaii State attempted to encourage the Hawaii and Pacific Fisheries to combine efforts and produce a "Hawaii and Pacific Island Marketing Alliance". This concept had merit but was beset with funding problems and consequently did not realize the envisaged marketing impact on the US mainland for Hawaii and Pacific Island fish.

TABLE 2
Deepwater fishing licences 2001–2003

	Deepwater snapper vessel licences	
	Vessels	**Company**
2001	1	C&J Enterprises
	2	ITS (Fiji) Ltd
	1	John Costello
	1	John Teaiwa
	1	Angus Joy
	1	Kaitani Seafoods Limited
	1	Lindsy Lee
	1	Michael Light
	1	Pasemaca Adi Tukana
	1	Pat Fuata
	1	Raseburu Moceicea
	2	Taniela Wainiqolo
	1	Trans Pacific Seafoods Limited
	Total	15
2002	**Vessel**	**Company**
	Apharaeus	Ocean Trader Limlted
	Kai Oni	ITS (Fiji) Ltd
	Sasalu ni Waitui	The Fiji Fish Marketing Group
	Shogun	Vista Fisheries Limited
	Shalom	Shalom Fishing Company
	Doolly	Orion marine Company Limited
	Valpoe 1	The (Fiji) Snapper Company Limited
	Lady Treza	Treza Fishing Company Limited
	Total	8
2003	**Vessel**	**Company**
	Fortuna #1	C&J Enterprises
	Sasalu ni Waitui	The Fiji Fish Marketing Group
	Kai Oni	ITS (Fiji) Ltd
	John G	Ocean Quest (Fiji) Ltd
	Nabau 11	Tolu Shipping Company Limited
	Kaela J	Lindsay Lee
	Narrelle	Patrick James Tripp
	Aphareus	Ocean Trader Ltd
	Shogun	Vista Fisheries Limited
	Total	9

TABLE 3
Annual export tonnage 1998 – 2002

Year	Weight (tonnes)
1998	25 .9
1999	37.51
2000	46.36
2001	54.44
2002	52.20

TABLE 4
Species and weight of deepwater fish exported by Fiji companies – 2002 (kg)

Company	Hapu	Ehu	Onaga	Lehi	Opakapaka	Total
Ocean Trader		3903.5	2655.3	3296	214.2	10068.6
Agape Fishing Enterprises	13	529.5	456.5	31.5		1030.5
Hangton Pacific Co. Ltd.			69.8			69.8
Information Technology	695.5	4157	5724	125		10701.5
Fiji Fish	1544.5	13676.3	9714.3	4389	879.1	30202.72
Tri-Pacific Marine					36.8	36.8
Tuna Pacific Co Ltd.	94					94
						52203.92
Total	**2347**	**22266.3**	**18619.9**	**7841**	**1130.1**	**52203.92**

Scientific name	Common name
Epinephelus spp.	Hapu
Etelis carbunculus	Ehu
Etelis coruscans	Onaga
Aphareus rutilans	Lehi
Pristipomoides spp.	Opakapaka

The airfreight problems have not recovered from the political upheaval in Fiji of 1987 and coupled with a shift in airline priorities from Hawaii to Tokyo and Los Angeles, the Hawaii freight space availability is now acute. Some respite was forthcoming with a number of Los Angeles distributors buying Fijian deepwater fish. However, the price is generally lower that the Hawaii price and costs slightly higher. The market on the US mainland has become one for skinless fillet and consequently the appearance factor is selling has been diminished. The stage is now set for Island processors to fillet and super freeze portioned control pieces for delivery to distributors who breakdown cartons for FedEx couriering to high-end restaurants.

Alas, the US dollar has plummeted in value over the second half of 2003 (25 percent) taking the small profit margin with it. It will be interesting to see the effect this has on the Hawaii price range. It is rather fortunate that the local market for the deepwater fish is evolving and with more effort and chef training an excellent tourist hotel market could develop.

9. STOCK STATUS

Lewis *et al.* (1988) gave estimates of maximum sustainable yield (MSY) for Fijian deep-slope stocks ranging between 550 to 1 600 t a year based on comparative data from elsewhere in the Pacific or on an estimate of 4 900 t from the results of a Japanese survey (Anon. 1987). More recently, an analysis by Nath and Sesewa (1990) of commercial catch data from four sea-mounts and three coastal areas showed that in all instances initial catch rates fell to a level where fishing became uneconomic. The potential yield range in MSY has been estimated at between 409 and 1 230 t a year (Dalzell and Preston 1992).

10. MANAGEMENT

10.1 Current legislation/policy regarding exploitation

In 1987, the Ministry imposed a Guideline prohibiting large vessels from fishing for deep-slope snappers around Vanua Levu and Viti Levu. In 1989 the Ministry (Anon. 1989) imposed further Guidelines on the issue of new licences pertaining to vessels over 11 m in length, under discretionary powers enabled by Section 5(1) of the *Fisheries Act (1992)* under the Guidelines:

- No new Outside Demarcated Areas (ODA) licences will be issued pertaining to vessels over 11 m to fish for deep-water snapper and
- no new ODA licences will be issued pertaining to vessels over 11 m that do not have a substantial, and legally verifiable, local financial shareholding.

The reasons behind the Guidelines were:

- it was thought the entire extent of Fiji's fisheries waters was only capable of sustaining a total catch of 1 000 t of deepwater snapper a year and the existing fleet had the potential to exceed this catch by a factor of two and
- to promote the involvement of small-scale and rural fishermen in the industry.

The 1989 Guidelines were superseded by *Legal Notice 25 of 1990 (LN 25/90)* which inserted three new regulations and three new schedules into the *Fisheries Act Subsidiary Legislation* (Cap. 158 as amended), to require a special licence for Fiji fishing vessels catching tuna or deepwater snapper in Fiji waters and to apply several compliance conditions. These conditions include catch reporting requirements and a requirement to accommodate observers on board licensed vessels. The "Offshore Licence" Regulations allow investment in offshore vessels for tuna longlining, but restrict the potential for overfishing deepwater snapper.

10.2 The Fisheries Management Bill 2002

The intention of this bill is to establish a National Fisheries Authority and to make provision for the management, development and regulation of fisheries within Fiji fisheries waters and Fiji vessels and nationals on the high seas in a manner consistent with Fiji's international obligations. Development in fisheries both at the regional and international levels necessitated legislative changes in order for Fiji to derive maximum benefit from her fisheries resources. The Bill repeals the *Fisheries Act (Cap 158)*, and the *Marine Spaces Act Chap. 158a.* Part 111 of the Act titled *Fisheries Management, Conservation and Development* contains the following clauses.

Clause 23. MANAGEMENT OBJECTIVES AND PRINCIPLES. This clause outlines the main objectives and principles of the Act. These objectives and principles will act as guides to the Minister, director of the authority, as they exercise their functions and powers under the Act. Any action taken, or decision made, by any person or body under the Act must be taken or made within the ambit of its objectives and principles.

Clause 25. LIMITS TO FISHING AND DESIGNATED FISHERIES. This clause is for conservation and management measures whereby the Director in consultation with the Chief Executive establishes fishing limits. Subclause (1) provides matters that could be subject to fishing limits such as total allowable catch, fishing effort, licences or permits. Subclause (2) gives the Minister power to make regulations in respect to of those matters specified in the subclause. Subclause (3) gives the Minister power to declare any fishery to be a designated fishery. This power is exercised on the advice of the Director.

Clause 26. FISHERY MANAGEMENT PLANS. This clause deals with the Fishery Management Plan. The Fishery Management Plan is perhaps the most important fishery management activity in Fiji. Under this clause, the Director in consultation with the Chief Executive shall prepare a management plan. Subclause (2) provides for the things that could be in the management plan.

Clause 27. RECORDS, RETURNS AND OTHER INFORMATION. This clause gives the Director power to require from those involved in the Fisheries to provide to the Director all relevant data or information as the Director shall require. Subclause (2) provides the types of data or information which the Director may require under this clause.

11. CONCLUSIONS

The Fiji deepwater snapper fishery has appeared to stabilize at an export volume of 50 t. This, however, does not reflect the calculated MSY or the fisheries potential. There are continued problems with freight space and exchange rates as well as the problem of market saturation. The deepwater fishery requires specialized vessels and equipment coupled with the need for an intelligent well-trained fishing masters. Once this has been attained then good results can be expected. It has been continuously emphasized that the fishery is capable of rapid overfishing and that the long-lived deepwater fish populations take time to regenerate. Until we have good records, sound scientific analysis and a functioning Management Plan, no clear guidelines can be established.

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APPENDIX

Catch data of the F.V. Sasalu ni Wai Tui, 2002

Month	Trip	Export (kg)	Bycatch (kg)	Catch/trip	Days/trip	Catch/day
FEBRUARY	1	123	25	148	6	25
	2	342	496.6	838.6	10	84
	3	214	302	516	11	47
MARCH	4	508	678	1 186	9	132
APRIL	5	779	1 028.9	1 807.9	12	151
	6	139.9	182.8	322.7	9	36
MAY	7	595	851.8	1 446.8	15	96
	8	62.8	123.8	186.6	3	62
JUNE	9	473	704.6	1 177.6	13	91
	10	348	493.8	841.8	11	77
JULY	11	226	367	593	13	46
	12	288	474	762	15	51
AUGUST	13	57	81.8	138.8	5	28
	14	214	289.5	503.5	12	42
SEPTEMBER	15	206	297	503	12	42
	16	172	225.8	397.8	12	33
OCTOBER	17	113	255.6	368.6	13	28
	18	329	141	470	10	47
NOVEMBER	19		25	25	4	6
	20	1632	454.6	2 086.6	9	232
	21	1 134.6	1 489.9	2 624.5	8	328
DECEMBER	22	1206	1686	2892	12	241
	23	1256	1 087.2	2 343.2	10	234
	24	1293	473	1 766	11	161
Total		**11 711.3**	**12 234.7**	**23 946**	**245**	**98**

Shore-based handling and processing of deepwater fish in Fiji

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1. SHORE-BASED HANDLING TECHNIQUES

Fish discharched at the wharf are inspected at the time of unloading for temperature and general condition, (e.g. in rigor). Species incriminated in any ciguatera poisoning outbreaks are rejected. Information from the skipper or his logbooks is used to confirm that the fish are caught in areas considered safe from ciguatoxin. The fish are transferred from the boat straight into ice in bins (drained) for the trip to the factory and for any subsequent storage prior to packing.

The fish are maintained in drained ice until time for processing and are then graded by species, size and general quality, e.g. unsuitable species, diseased or ulcerated fish, bruising, wounds in flesh, general condition and age. Unsatisfactory product is diverted into alternative local markets. The fish are processed to customer requirements. Fish may be sent whole gut-in, or head-on gilled and gutted, or head off and gutted.

Gilling and gutting requires considerable care to remove the gut intact and without piercing the belly cavity membrane. The cavity is washed with clean water. The fish are washed briefly with clean chilled water. Final packing is timed so that the fish are in the cartons for a minimum time before packing. For packing, fish are removed from the ice and the deep muscle temperature is checked (not greater than 2 °C) to make sure the fish are down to the required low temperature.

The individual fish are placed into a prepared carton and individual weights and species are recorded for each carton. The cartons are constructed of waxed, corrugated fiberboard and are lined with a heavy polyethylene liner to stop leakage. Insulation consists of layers of unprinted newsprint on all six sides. Frozen gel packs are added to the carton to help maintain low temperature during air shipment. Temperature data loggers may be added to one or more cartons to record any temperature rises that might occur during shipment. Packed cartons are placed into insulated truck for the 2.5 hour journey to the airport. Cartons may be transferred into a storage chiller at the airport. Air shipment is from Fiji to either Hawaii or US mainland, other destinations are Australia and New Zealand. Delays while waiting for connecting flights, total flight time can be up to 24 hours.

2. THE MANAGEMENT OF FISH TOXINS USING A HACCP PLAN

Fish toxins in fish offered for sale from various fisheries are caused by either mishandling of the catch or occur naturally in nature. The management of fish toxins is possible using HACCP-based food safety procedures although the toxins that occur naturally present a rather daunting control problem. Fish poisoning has always been a part of Pacific Island life. The poison may have been ciguatera, histamine or other toxins of the reef. While acceptance of the risk of fish poisoning may be acceptable to

Pacific islanders, it is a major issue for those wishing to export fish from the region and in particular for reef fish from certain areas.

The Pacific Islands have some of the most diverse and wonderful tasting fish in the world and it is imperative that rules, systems, methodology and research ensure that the world is able to savour the flavours of tropical fish without enduring the consequences of exposure to the occasional bloom of a toxic dinoflagellate or mishandled fish. As soon as skinless fish fillets leave Pacific Island shores fish identity is lost and abuse can occur. It is at this stage that unless the Competent Authority has all their required systems in place the Pacific could loose their markets due to ciguatera problems.

3. FISH TOXINS AND THE DEEPWATER FISHERIES

3.1 Types of hazards

The Food and Drug administration of the United States of America (FDA) have divided the fish toxins (Chemical Hazard) into two distinct types, Natural Toxins and Scombrotoxin (Table 1).

TABLE 1
Selected potential vertebrate species related hazards (FDA 2001)

Note:
i. CFP = ciguatera fish poison; G= gempylotoxin
ii. This table does not provide information about methyl mercury.
iii. X[4] This Hazard does not apply if the product is intended to be cooked by the consumer or end-user

Market names	Binominal names	Hazards				
		Biological	*Chemical*			
		Parasites CHP 5	Natural Toxins CHP 6	Histamine CHP 7	Chemical CHP 9	Drugs CHP 11
Amberjack	*Seriola* spp.		CFP	X		
Snapper	*Etelis* spp.		CFP			
	Pristipomoides	X[4]	CFP	X		
Escolar or Oilfish	*Lepidocybium flavobrunneum*		G	X		
	Ruvettus pretiosus		G	X		

Natural toxins are generally produced by species of naturally occurring phytoplankton. They accumulate in fish when they feed on the algae or on other prey fish that have fed on the algae. There are also a few natural toxins which occur in certain species of fish. Numerous sources of seafood poisoning have been identified in the Pacific involving reef fishes (ciguatera), sardines (clupeotoxism), puffer fishes (tetrodotoxism) and Escolar (gempylotoxin). Scombrotoxin formation is also considered a chemical toxin and is a result of time and temperature abuse of certain species of fish. The illness caused by these fish species is closely linked to the development of histamine in these fish.

3.2 Natural toxins affecting fish in the Pacific – ciguatera

The benthic dinoflagellate (*Gambierdiscus toxicus*) has been described as the primary causative agent of ciguatera fish poisoning in the Pacific. *Gambierdiscus* spp. lives under the surface mucus layer of "host" red, green and brown macroalga. Although traditional knowledge of toxic species or reef areas are established in the village situations, the general public, or city folk, do not know the identity of most of the reef fish and as simple as this may seem this is no doubt the cause of a substantial amount of fish poisoning. The often toxic red bass (*Lutjanus bohar*) is red and looks very similar to a number of deepwater non-toxic snappers all of which are red. It is also well known in Fiji that when it comes to the crunch and fish have to be rejected or kept for consumption the author has never seen one rejected. On a visit to the local Navua (Fiji) market on 15 June 2003 the author saw a number of *Lutjanus bohar* offered for sale. All would have been bought and consumed and at this time of the year (winter) probably be safe to eat though a risk the author would not take.

Many, if not all, island reef fish consumers have been poisoned at one time in their life and the traditional reaction is one of resignation and acceptance. Few Islanders die from ciguatera and although the affects at time of occurrence can be irritating it is soon forgotten or remembered subconsciously. Consequently, the bold and young will eat the known poisonous fish and on occasion where tradition is lost and someone weak or not in good health eats poison fish a tragedy will occur. The most probable explanation to the response is equated to gambling in Vegas: you know you cannot win but you still put the quarter in the slot.

The FDA have listed a number of fish species as being potentially capable of having ciguatera fish poison and it has been the experience of most of the Pacific Islands that some of those species listed have never displayed ciguatoxic tendencies. *Pristipomoides* spp. and *Etelis* spp. are two such fish genera. Possible reasons for this follow.

- In areas of high latitude these fish are captured in shallower water than in the central latitudes and accordingly encroach on the ciguatoxic herbivore habitat. For example *Pristipomoides* spp. can be caught to 115 m in Hawaii (Lat. 23 °N) but in Fiji. (Lat. 16 ° – 18 °S) do not occur in the fishery until 160 m. However there has been no recorded incidence of ciguatera poisoning from *Pristipomoides* spp. in Hawaii (Dr. John Kaneko, PacMar, Inc., Honolulu, pers. comm.)
- *Pristipomoides aquilonaris* or Wenchman occur in the depth range 24–370 m in the Western Atlantic: North Carolina, USA and the Caribbean Sea to Guiana and have had reports of ciguatera poisoning attributed to it (Olsen, Nellis and Wood 1984). This is most likely the cause of the FDA listing.

There is no explanation for the inclusion of *Etelis* spp. in the ciguatera listing.

3.3 Fisheries where ciguatera is likely to occur – The fresh and frozen reef fish trade

There has been a huge migration of Pacific Islanders to the USA, Australia, Canada and New Zealand consequently developing a demand for ethnic food products in those areas. The pressure on the reef fish stocks is therefore even more acute and accordingly reefs and areas never before fished are being harvested. All reef fish large enough to be eaten are harvested as there is always someone who will relish a fish considered inedible by others.

International markets and national health authorities have been slow in responding to the possibility of ciguatera affecting the consumers of those countries. However, exceptions occur. It is anticipated that as more countries and companies recognize the dangers of importing reef fish from countries that have inadequate controls on their exports then the market place will become very restricted. Therefore, it is imperative that immediate steps be taken to implement legislation that will enable National Fisheries Authorities to have some form of control over species being exported.

The Secretariat of Pacific Communities (SPC) have suggested that urgent action should be taken to pre-empt closing of all Pacific Island reef fish exports. The points considered by SPC are incorporated in the final conclusions to this paper. This is a most important issue when it comes to skinless fillets. Recently the author was asked how *Pristipomoides multidens* could be poisonous as the company involved had complaints from a number of customers who had bought skinless fillets. After questioning the staff for some days it was revealed that a large *Aprion* had snuck into the *Pristipomoides* fillet line and that this appeared to be the cause of the problem.

3.4 Some other natural fish toxins that occur in the Pacific

3.4.1 Deepwater snapper poisoning
In work done at USP it was found that the liver of the highly-prized, edible deep-sea snapper (*Etelis carbunculus*) fish was toxic after a family was poisoned in Taveuni, Fiji. (Yasumoto, Raj and Bagnis 1984, pp. 39-40).

3.4.2 Gempylotoxin
Escolar or oilfish (i.e. *Lepidocybium flavobrunneum* and *Ruvettus pretiosus*) contain a strong purgative oil called gempylotoxin that may cause diarrhea when consumed (FDA 2001). These fish are implicated in histamine poisoning. Two relevant reports from the University of Southern California, Davis, listserve are noted below:

- Nick Ruello <*nick@ruello.com*> Date: Mon 4 February 2002 – 23:35:17 PST

"In Australia several thousand tonnes of *Ruvettus* and *Lepidocybium* species are eaten, generally with little problem other than keriorrhoea a laxative effect where oil is passed per rectum by some individuals. This word was coined 21 years ago by South African researchers who reported eating 500 g of *Lepidocybium* without any visceral discomfort. Both species nevertheless are delicious and I can recommend them grilled; if well handled (i.e. no hint of histamine problems) they are no more harmful than eating prunes or figs."

- Barry Cohan <*Cohan@Earthlink.Net*> Date: Wednesday 6 February 2002 – 2:27 a.m.

"Something quite wrong here, or at least the subject of continuing mis-identification. I have been selling "escolar" for years, like 10 years, in fact, a few thousand lbs a week, without so much as a single incident. This harks back, in all likelihood, to the confusion between the so-called smooth skin and "pineapple" skin escolars (respectively, *Lepidocybium flavobrunneum* and *Ruvettus pretiosus*). I have seen these fish referred to separately as Escolar and "Oilfish", but then they also both get referred to as oilfish. It seems clear, however, that the culprit is this pretiosus puppy, and frankly I wouldn't get within barking distance of a piece of "frozen fillet of *escolar*" as it is in just such a manner that an onboard processor might negligently or ignorantly strip the lacerative skin off the offending oilfish and send it heading for your plate. You would be able to rest fairly assured that your local dealer would not lightly risk the hands of its' cutters let alone its' reputation by even taking Ruvetus out of a box. You'd have to see this skin to believe it. Very dangerous. At any rate, please be assured that *Lepidocybium* spp. offers a harmless and pleasant eating experience. Just make sure that that is what you're getting."

Both these reports indicate a discrepancy in fish identification and marketing. The management message is simple. Get it right and market the right species!

3.5 Scombrotoxin affecting fish in the Pacific – histamine
Scombrotoxin formation as a result of time and temperature abuse of certain species of fish and can cause consumer illness. The illness is most closely linked to the development of histamine in these fish. In most cases histamine levels in illness-causing fish have been above 200 ppm, often above 500 ppm. There are indications that decomposition can result in the production of other toxins that have the potential to cause illness, even in the absence of histamine formation. Such illnesses have been reported in a number of fish species. Histamine is not eliminated by cooking or canning.

Scombroid poisonings have primarily been associated with the consumption of tuna, mahi mahi, and Spanish mackerel. However, Table #3-1 of the FDA Fish and Fisheries Products Hazards and Controls Guidance lists a number of species that are also capable of developing elevated levels of histamine when temperature abused (Table 1).

3.6 Management methodology

The histamine-forming bacteria usually grow rapidly only at high temperatures. At 32.2 °C, unsafe levels of histamine may appear within six hours; at 21 °C, 24 hours. Because wide variations occur between individual fish even under the same conditions, it is necessary to consistently remove heat rapidly from the freshly harvested fish and maintain a low temperature until the fish are prepared for consumer use. Particularly for large fish, special precautions and equipment are required for the rapid removal of heat. Periodic increases in product temperature during storage can result in more histamine being formed. Sensory analysis is an effective screening method that reduces the risk of accepting histamine-containing fish; however, histamine may form without the usual odors of decomposition. Chemical analysis for histamine is also possible. A detailed knowledge of the temperature history of the product provides the best control method.

3.7 FDA's approach to histamine controls

3.7.1 Vessel harvest records approach

Methods used by vessels and export factories to control possible formation of histamine are as follows (FDA 2001):

i. Fish are place into chilled seawater, preferable slush ice immediately after capture.

ii. With some harvesting practices, such as long lining, death can occur before the fish is removed from the water. Under the worst conditions histamine formation can already be underway before the fish is landed on the vessel. This condition can be aggravated when the fish are allowed to remain on the line for a period of time after death, a situation that in certain bottom fish species may cause its internal temperature to increase to a more favorable growth range for the enzyme forming bacteria.

iii. Rapid chilling of fish immediately after death is the most important element in any strategy for preventing the formation of scombrotoxin, especially for fish that are exposed to warmer waters or air. It is recommended that once fish has reached that temperature, size affects timing, transfer the fish to fish hold and cover with ice, or in the case of fish to be frozen transfer to blast or brine freezer. Further chilling towards the freezing point is also desirable to safe-guard against longer-term, low temperature development of histamine. Additionally, the shelf-life of the fish is significantly compromised when product temperature is not rapidly dropped to near freezing.

iv. The time required to lower the internal temperature of fish after capture will depend upon a number of factors, including:

§ the harvest method

- o Delays in removing fish from a long line may significantly limit the amount of time left for chilling and may allow some fish to heat up after death
- o The quantity of fish landed in a purse seine, pole and line or on a long line may exceed a vessel's ability to rapidly chill the product

§ the size of the fish

§ the chilling method

- o Ice alone takes longer to chill fish than does an ice slurry or recirculated refrigerated sea water or brine, a consequence of reduced contact area and heat transfer
- o The quantity of ice or ice slurry and the capacity of refrigerated sea water or brine systems must be suitable for the quantity of catch.

§ Once chilled, the fish should be maintained as close as possible to the freezing point (or held frozen) until it is consumed. Exposure to ambient temperature should be minimized. The allowable exposure time is dependent primarily upon the speed with which the fish were chilled on-board the harvest vessel and whether the fish has been previously frozen (e.g. on-board the harvest vessel).

v. Unfrozen scombrotoxin-forming fish has a safe shelf life (days before elevated levels of histamine are formed) that is dependent upon the harvest methods, the on-board handling, and the time and temperature exposures throughout processing, transit and storage. This safe shelf-life can be as little as five to seven days for product stored at 4.4 °C. Any exposure time above 4.4 °C significantly reduces the expected safe shelf-life. For this reason, fish that have not been previously frozen should not be exposed to temperatures above 4.4 °C for more than four hours cumulatively if any portion of that time is at temperatures above 21 °C; or the fish should not be exposed to ambient temperatures above 4.4 °C for more than eight hours, cumulatively, as long as no portion of that time is at temperatures above 21 °C after chilling on board the harvest vessel. The safety of these limits is dependent upon proper handling at sea.

vi. Fish that have been previously frozen can safely withstand considerably more exposure to elevated temperatures during post-harvest handling. Such fish should not be exposed to temperatures above 4.4 °C for more than 12 hours cumulatively if any portion of that time is at temperatures above 21 °C or the fish should not be exposed to ambient temperatures above 4.4 °C for more than 24 hours cumulatively as long as no portion of that time is at temperatures above 21 °C, after chilling on board the harvest vessel. The safety of these limits is again dependent upon proper handling at sea.

vii. Keep fish well covered with ice or freeze to – 18 °C.

viii. For fresh fish storage prior to sale should be limited to two weeks maximum.

ix. When unloading ensure quick discharge to refrigerated truck, place the fish on a bed of ice and then cover them with more ice. Probe fish for temperature before them placing in the truck, and record temperature and consider rejecting if their temperature is above critical limits.

x. Probe fish on arrival at factory and consider rejecting if their temperature is above critical limits.

xi. Place fish in ice bins or chillers.

3.7.2 Management tools used to ensure fish temperature is kept within limits to prevent formation of histamine (see Appendix 2)

These are:

- follow approved supplier standard operating procedures declaration from vessels
- follow approved supplier shore based standard operating procedures.
- use a fish purchase log and
- use a fish processing chart.

4. MANAGEMENT PRACTICES AND TOOLS THAT SHOULD BE INTRODUCED BY THE PACIFIC ISLAND REGION AND PACIFIC ISLAND COUNTRIES TO PREVENT THE SALE OF TOXIC FISH SPECIES

The most obvious conclusion of this review is that the management of natural fish toxins in the Pacific has been neglected. Efforts need to be made to develop tools to prevent poisoning by these toxins. It is therefore suggested that the following points be implemented as soon as possible.

- Develop a project document for a Pacific Regional Ciguatera Initiative. Ciguatoxin is the major fish toxin and hazard in the Pacific and more work should be focused on the dangers posed by this toxin. A centre for marine toxins in the Pacific should be set up. The centre should be based in a known science establishment with an accredited laboratory. The University of the South Pacific (USP) is a leading academic institution in the South Pacific and the Institute of Applied Science (IAS) food analysis laboratory located at the USP is unique in the region. It is suggested that IAS host the proposed Centre for Marine Toxins. Work has to progress now before the initiative is lost. Queries to the two institutes, the SPC and IAS, did not produce any positive response as to direction and progress of the recommendations of the workshop. As reef fish fisheries could be a major contribution to the economies of the Pacific Islands and that the dominant hazard in the fishery is a fish toxin, then this initiative should not be lost.

- Legislate for the creation of competent authorities or the equivalent
- Creation of a ciguatera team and data base within the competent authorities
- Reactivate the Pacific region ciguatera database (SPC)
- Monitoring of the dinoflagellate abundance in the natural environment including the identification of the dominant *Gambierdiscus* species. This would involve local Fisheries Departments collaborating with an appropriate research institute that has the capability and facilities to do this part of the work.
- Evaluation of the toxin reservoir accumulated at the different levels of the food web
- Encourage more research on the ecology of ciguatera and environmental parameters responsible for outbreaks
- Identification of toxic fish species
- Education of local processors and the public on toxic fish species identification
- Setup a Pacific regional ciguatera website with relevant links to sources of information, research institutions, etc.
- Use of an effective ciguatera test kit. Kits so far developed have proven to be inadequate in areas other than Hawaii, consequently the development of an effective test kit is considered as urgently needed.
- Initiate a long-term in-country algal based field monitoring programme by Fisheries Departments
- Develop practical HACCP plans for ciguatera-prone countries. These plans should take into account the individual situation within companies.
- The Final Product Inspection Checklist for Chilled/Frozen Fish which is part of the Fish Quality Control Standards should be modified to include fish toxin inspection.

5. LITERATURE CITED

FDA 2001. Fish and Fisheries Products Hazards and Controls Guidance, Third Edition, June 2001.

Olsen, D.A., D.W. Nellis & R.S. Wood 1984. Ciguatera in the Eastern Caribbean.. Mar. Fish. Rev. 46(1):13-18.

Yasumoto, T., U. Raj & R. Bagnis 1984. Seafood Poisoning in Tropical Regions. This publication was prepared in conjunction of the "Symposium on Seafood Toxins in the Tropical Regions" held at Research Center for the South Pacific, Kagoshima University, Kagoshima, 26 September 1983. Sponsored by the Toyota Foundation. Published in 1984 by the Laboratory of Food Hygiene, Faculty of Agriculture, Tohuku University, Japan. 74 pp.

APPENDIX 1

Approved supplier standard operating procedures declaration for fish handling

FISHING VESSEL: ____________________

OWNER: ____________________ (date :__________)

CAPTAIN: ____________________ (date :__________)

This is to verify that the following standard operating procedures for on-board fish handling are practiced on this vessel and that any significant deviation from these practices will be noted and the receiver notified prior to unloading. This VSOP is submitted in cooperation with the receivers HACCP – based Quality Assurance Program especially those efforts focused on the prevention of ciguatera and histamine accumulation in susceptible fish species.

Fishing method:

Refrigeration method:

Sanitation:

The fish holds are cleaned and sanitized after each trip using dilute chlorine bleach solution (specifically, sodium hypochlorite solution of 100ppm). Clean new ice made from potable water is loaded into the fish hold at the start of each fishing trip.

Fish holds are not used to store fuel. Fish holds are kept free of chemicals and lubricants used on-board the vessel.

Fish handling method:

Fish are handled carefully, kept clean and chilled rapidly in order to prevent the potential formation of histamine in susceptible fish species.

Fish are landed individually by hook and line, gaffed and immediately. The fish are rinsed with seawater and placed immediately into an ice slurry. This process takes no more than 15 minutes.

Fish are allowed to chill in the slurry for no less than 6 hours. Fish should be chilled to an internal temperature of 50^{o}F within 6 hours of capture. Fish are placed in ice or refrigerated seawater for the final chilling period.

On ice vessels ice is repacked around the fish after 6 hours to ensure proper chilling. Fish temperatures are brought down to 32^{o}F within a total of 24 hours of capture. Fish are kept properly iced during storage on-board the vessel to maintain a constant 32^{o}F until unloading.

On refrigerated seawater vessels the temperature of the RSW is maintained at a temperature of 28^{o}F

Fish species:

The following fish species will be treated as export fish and treated in the manner described in the HACCP Plan. Fish not on this list will be stored separately and not included in the **APPROVED SUPPLIER STANDARD OPERATING PROCEDURES DECLARATION.**

Common name	Scientific name
Pink snapper, Opakapaka	*Pristipomoides filamentosus*
Longtail snapper, Onaga	*Etelis coruscans*
Red snapper, Ehu	*Etelis carbunculus*
Red jobfish, Lehi	*Aphareus rutilans*
Purple cheek opakapaka	*Pristipomoides multidens*
Yellow-fined opakapaka	*Pristipomoides flavipinnis*

APPENDIX 2
Approved supplier shore based standard operating procedures

Supplier Name ______________________________

Suppliers Address ______________________________

Suppliers Signature ______________________________

The names and positions and the persons responsible for the maintenance of the Approved Supplier Agreement (ASA) by both parties;

Supplier's ASA manager name___________________________& Signature________________________

The Gourmet Food Company ASA manager name______________________& Signature
____

The scope of the ASA (which input materials are covered);

The specifications of the input material, such as microbiological, labeling requirements and other intrinsic factors such as temperature, ciguatera certificate, Aw, etc.;

Specific controls which the supplier must have in place during production and or distribution

Specific analytical tests which must be conducted and copies of certificates which must accompany lots.

Criteria for the selection, monitoring and verification of supplier(s).

The Quality Management Plan must contain the following details of the verification procedures:

The name and position of the person who is responsible for the verification activities;

Name: _________________________________

How the verification is to be conducted; (On-site audit)

Method: _________________________________

The frequency of verification.

Frequency: ______________________________

Records of the results of monitoring and verification and any corrective actions arising from the evaluations shall be maintained.

FISH PURCHASE LOG

Date	Batch no.					
Item	**Data**					
Fish species						
Purchased from						
Boat name						
Method of preservation (Ice)						
No. of pieces						
Weight of fish purchased						
Cost per kilo	$					
Total Value	$					
Cheque No.						
Internal temp of fish at purchase				If temperature greater than 5^{o} C Reject		
Organoleptic test of individual fish				If fish smells or looks bad Reject		
Method of transport to factory						
Temp in truck						
Time fish spent in truck	Time put in truck		Time arrival at Factory		Total time	
Fish stored in refrigerator or freezer (at Delivery)						
Daily temp record chart #						
Data transferred to log sheet 2.						
Signature of purchaser / Driver						

FISH PROCESSING CHART

Date	Batch no.			
Item	**Data**			
Species verification				
Date unloaded				
Organoleptic and visual assessment of quality (CCP)			Reject if test fails	
Internal Temperature @ depot arrival (CCP)			If greater than 4.4 C Consider reject / time	
Stored in Chiller in ice				
Date removed from Chiller				
PRODUCT DESCRIPTION				
Time fish packing begins & ends & internal temperature (CCP)	Time begin		Time end	
	Temp		Temp	
Internal Temperature @ Removal From Chilling medium (CCP)			If greater than 4.4c consider reject	
Temperature final product stored in cartons in Chiller @				
Destination & date shipped				
Production problems:				
Action(s) taken:				
Factory Supervisor				

Status of deep-sea line fisheries other than for tuna species in the Philippines

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1. INTRODUCTION

1.1 Geographical location

The Philippines lies in Southeastern Asia, an archipelago between the Philippine Sea and the South China Sea, east of Vietnam and comprises over 7 000 islands. The marine surface area covers 2 200 000 km^2 and the coastal waters an area of 266 000 km^2. The oceanic waters cover an area of 1 934 000 km^2. The shelf area, to a depth of 200 m is 184 600 km^2 in area. The area of coral reefs is 27 000 km^2 and are located within the 10–20 fathoms where reef fisheries occur (Fig.1).

FIGURE 1
Philippine marine jurisdictional boundaries

1.2 Major fisheries

Major pelagic fisheries target surface fish species in coastal waters during monsoon winds and in most open waters during calm weather. Fishes caught include roundscad, sardines, chubmackerel, Spanish mackerel, anchovies, cavallas, big-eyed scad, yellowfin tuna, skipjack and frigate mackerel. Demersal resources are usually caught by trawlnets, modified Danish seine, bottom gillnets, longline, and handlines. Fishes caught by this gear include *Nemipterus* sp., *Leiognathus* sp., *Upeneus* sp., *Mugil* sp., *Secianidae* sp. and crustaceans such as prawns, lobsters, shrimps, crabs, squid and cuttlefish. The demersal fisheries may also include reef fisheries (BAS 1997).

1.3 Fisheries production

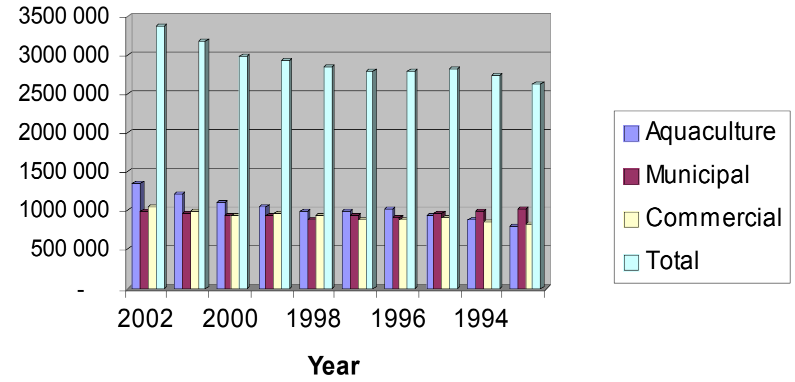
The country's fisheries sector is categorized into municipal, commercial and aquaculture. Generally, municipal fishing refers to fishing within the municipal waters using fishing vessels of three gross tons or less, or fishing not requiring the use of fishing vessels. Commercial fishing refers to the taking of fishery species by passive or active gear for trade, business or profit using vessels of more than 3 gross tons.

In 2002 (BFAR 2002), the fishing industry performance showed a 6.4 percent growth compared to the previous year of 5.8 percent. Production grew from 3 166 530 t in 2001 to 3 369 306 t in 2002 (Fig.2). Out of the total fish production for 2002, commercial fisheries represented 30.9 percent (1 042 193 t) and municipal fisheries 29.4 percent (988 938 t). In terms of value, 5.9 percent growth was realized from a total of P106.9 billion attained in 2001 to P113.2 billion in 2002. Table 1 shows the volume of fish production, by sector from 1993 to 2002.

TABLE 1
Volume of fish production (tonnes)

Year	Aquaculture	Municipal	Commercial	Total
2002	1 338 175	988 938	1 042 193	3 369 306
2001	1 220 456	969 535	976 539	3 166 530
2000	1 100 902	945 945	946 485	2 993 332
1999	1 048 679	926 339	948 754	2 923 772
1998	997 841	891 146	940 533	2 829 520
1997	984 439	924 466	884 651	2 793 556
1996	1 007 676	909 248	879 073	2 795 997
1995	940 589	972 043	893 232	2 805 864
1994	869 083	992 578	859 328	2 720 989
1993	793 620	1 013 969	824 356	2 631 945

FIGURE 2
Trend of fish production (1993–2002)



Fisheries production increased from 2 632 million tonnes at P70.2 billion in 1993 to 3 369 million tonnes at P113.2 billion in 2002. The annual growth rates attained during these periods were 2.8 percent (volume) and 5.4 percent (value).

In terms of commercial fisheries production by gear sector, 51.8 percent is taken by purse seine, followed by ringnet (17.0 percent). For municipal fisheries production, gillnet is the highest production (32.2 percent), followed by hook and line (21.4 percent).

TABLE 2
Average percentage share of total production by major fishing gears, 1992–1995 (tonnes*)

Fishing gear	1992	1993	1994	1995	Average	% share
Commercial	804 866	824 356	859 328	893 232	845 446	100.00
Purse seine	467 498	425 261	400 246	459 229	438 044	51.81
Ringnet	109 418	138 195	182 614	145 676	143 976	17.03
Trawl	90 547	86 965	88 423	66 089	83 006	9.82
Danish seine	45 342	78 061	74 509	93 325	72 809	8.61
Bagnet	53 396	53 889	76 499	77 891	65 419	7.74
Hook and line	24 894	26 330	21 173	24 270	24 167	2.86
Others	13 831	15 655	15 864	26 752	18 025	2.13
Municipal	854 687	803 194	786 847	785 369	807 524	100.00
Gillnet	283 854	249 860	249 710	258 021	260 361	32.24
Hook and line	153 157	166 792	183 902	187 502	172 838	21.40
Beach seine	55 673	44 850	57 216	40 101	49 460	6.12
Fish corral	66 829	48 943	38 155	31 056	46 246	5.73
Ringnet	34 294	34 955	32 308	40 516	35 518	4.40
Baby trawl	36 705	41 923	27 277	23 517	32 356	4.01
Spear	15 311	25 540	25 142	27 910	23 476	2.91
Long line	19 937	25 244	22 936	24 885	23 250	2.88
Danish seine	21 142	27 259	17 146	11 776	19 331	2.39
Fish pot	11 739	17 811	19 361	16 532	16 361	2.03
Bagnet	23 951	17 352	13 838	8 663	15 951	1.98
Crab lift net	32 273	15 863	7 913	6 148	15 549	1.92
Purse seine	11 296	22 491	10 214	14 576	14 644	1.81
Others	88 526	64 311	81 729	94 166	82 183	10.81

* Note: Fish production by fishing gear is only available up to 1995.

2. MARINE WATERS

Municipal waters include the marine area between two lines drawn perpendicular to the general coastline from points where the boundary lines of the municipality touch the sea and a third line parallel with the general coastline including offshore islands and 15 km from such coastline. National waters include marine water areas beyond 15 km from coastline, which can be considered a commercial jurisdiction. It may also include the exclusive economic zone (EEZ) beyond and adjacent to the territorial sea; the EEZ extends 200 nautical miles from the baselines defined by existing law.

3. DEMERSAL FISHERIES RESOURCES

The marine fish resources may be classified into pelagic and demersal fish. The soft-bottom demersal fishes are caught by bottom trawls and include slipmouths, flatfishes, goatfishes, nemipterids, croakers, whitings, mojarras, theraponids, pomadasids, lizard fishes and other related species. The hard bottom demersal fishes include those taken on coral reefs. These are fishes occupying hard grounds or reef areas where bottom trawling cannot be conducted. At present "pa-aling" is the most common and efficient gear used for the large scale exploitation of snappers, siganids, lethrinids, surgeon fishes, leaf fishes and other related species.

It is estimated that there are 4.4 million hectares of coral reefs within the 40 fathoms contour interspersed with the country's 7 100 islands. Within the 10–20 fathoms contour, where the majority of reef fishing occurs, coral reefs cover approximately 2.7 million hectares.

The demersal fish landings comprise between 25 percent and 40 percent of the total marine landings and are carried out primarily over the local shelf (0–200 m). Slipmouths have consistently dominated demersal catches in recent years representing on the average 15.5 percent of the total landings. Shrimp and squid are also important species in the demersal fishery because of their high value on international markets. Squid is seen as having potential for expanded fishing effort since local stocks are believed to be substantially underutilized. (FSDP 1988).

Demersal fish and invertebrate stocks in the Philippines are estimated to have a potential annual yield of 500 000 t to 700 000 t. The lower limit of this potential yield had essentially been reached with the adoption of increasingly more efficient harvesting practices, particularly in nearshore areas. Fishing effort already exceeds sustainable levels in major bays.

4. FISHING GEARS/METHODS FOR DEMERSAL DEEP-SEA RESOURCES (LINE GEARS)

4.1 Introduction

At present, only the marine fish resources of the continental shelf areas are exploited by fisherman, particularly by trawlers, purse seiner and gillnets. The fishing grounds in deeper areas have not been harvested to their maximum yet because of limited technology and investment though there are already some fishing gears exploiting these resources. However, the available data are insufficient to plan development and research is necessary to determine resource abundance and distribution.

Deepwater fishing are defined as those in more than 100 metres depth. Trawl, fish trap, hook and line, bottom gillnet and modified drive in net "pa-aling" are some of familiar fishing gears used for the capture of demersal resources (Munprasit *et al.* 1995).

4.2 Bottom set longline

Different fishing areas in the country have specific types of fishery resources. One species is the spiny dogfish shark (Family Squalidae), which is exploited by the bottom set longline gear. The shark has an economic value as fish meat and is processed into fish ball and fish meal and the liver is used for its oil (crude squalene oil).

The fishing grounds are sandy and muddy and the average depth of the water is about 395 fathoms. The gear used is a modification of the Japanese longline set as a bottom longline. There are three sections of the gear, namely; the anchorline, mainline and the branch lines.

Anchor lines consist of two pieces monofilament about 3 mm diameter with a breaking strength of about 260 lb/m. The accessories attached to the anchor lines are (a) two units of bamboo raft buoy, (b) two pieces of flagpoles, each about 10 feet long and (c), two pieces of suspension weight for the flagpoles. The anchor line is held in a vertical position from the water surface to the bottom by means of the bamboo raft buoy and the anchor weights. The total length of the anchor line depends on the depth of the fishing ground.

Mainlines vary from 1 500 to 3 000 m length and is made of monofilament about 2.5 mm in diameter with a breaking strength of about 210 lb/m. Two or more mainlines may be linked to each other by a swivel made of brass or stainless steel. Lead sinkers (no. 2) are tightly clamped along the mainline 20–25 m apart. The number of lead sinkers depends on the total length of the mainline.

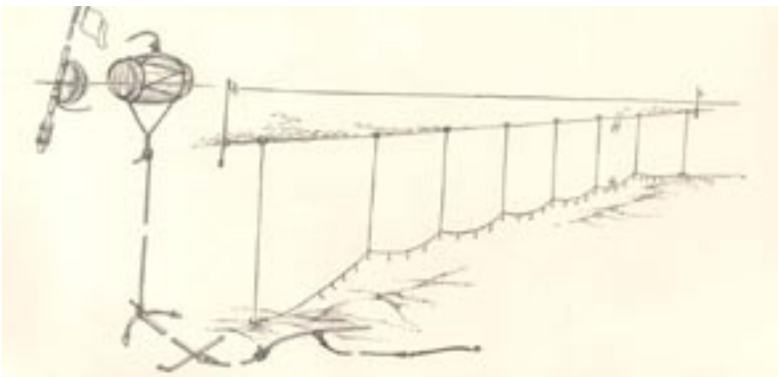
Branch lines are made of monofilament about 1.5 mm diameter with a breaking strength of about 110 lb. At the free end of the line is the wire leader holding the hook. Each branch line is about 1.5 m long and is hung from the mainline at intervals of 3.5 m. The leader wire is about 5 inches long and of wire gauge no. 7 with a breaking strength of 69 lb. The number of hooks depend on the number of branch lines.

The fishing craft are motorized bancas with an outrigger measuring about 8 m long by 0.5 m wide and 0.5 m deep. They are powered by gasoline engines of 16 HP. The fishing craft is usually manned by two fishermen. The gear is set at night and allowed to lie on the seabed for about five hours until about sunrise and then hauled manually. The main catch is dogfish, followed by eel fish, grouper, elephant fish and several species of common sharks. The estimated catch rate is one shark per nine hooks.

4.3 Bottom vertical longline

The primary mainline is suspended horizontally 20 m above the sea bottom (Figure 3) It is held in place by two buoy lines at each end. Each buoy line is tied to a float at one end and to a weight at the other. The secondary mainline hangs vertically from the primary mainline and is attached every 50 m along the mainline. It is held in place vertically with a float at the upper end and a weight that touches the seabed. Each secondary mainline holds a series of seven hooks, distributed equidistantly. The hooks are attached to the secondary mainline with a branch line, which consists of a 0.3 m cord, attached to a 0.9 m stainless steel wire, which in turn is attached to the hook.

FIGURE 3
Bottom set longline



The bottom vertical longline can be used both in moderately deep and in shallow and rough fishing grounds where other fishing gears cannot be used. The bottom vertical longline can be operated on any type of seabed, which is its advantage over the traditional bottom set longline.

The traditional bottom set longline is more liable to be damaged when the fishing gear touches the bottom and the set hooks may become entangled with rocks and other bottom obstacles. This may cause the loss of the entire gear. On the other hand, the primary mainline of the bottom vertical longline is suspended at a distance of 20 m from the bottom. Only the weights touch the bottom, thus reducing the chance of the hooks fouling the seabed. The gear also has the same limitations as other line gears such as, (a) the catch is limited by the number of hooks, (b) suitable baits for target species must be obtained and (c), the boat has to be kept above the shoal or edges of the island slope or ocean banks during fishing operations.

Bottom vertical longlines consist of:

i. Buoy lines: two pieces of polyamide (PA), 6 mm in diameter, 200 m long, which are used to keep the primary mainline horizontally in place. The upper ends are tied to marker buoys and the lower ends are held down by weights. It is provided with a foot-long eye splice at both ends to make tying and untying of parts easy. (See Table 3 for gear specifications)

ii. Primary mainline: a 2 250 m long polyamide 5 mm in diameter, provided with a 30 cm eye splice at both ends tied to the buoy lines. The secondary mainlines are attached to this line.

TABLE 3
Fishing gear specifications (Bottom Vertical Longline)

No.	Gear parts	Materials	Sizes	Length	Quantity pieces
A	Buoy line	Polyamide PA	6 mm	200 m	2
B	Primary mainline	-do-	5 mm	50 m	50
C	Secondary mainline	-do-	4 mm	20 m	50
D	Branch line	Monofilament	1.5	1	300
E	Stainless wire	Steel	14	20 cm	300
F	Hooks	-do-	12, 13, 14	-	300
G1	Float	Synthetic	3 000 g	-	6
G2	Float	-do-	650	-	50
H1	Sinker	Lead	8 kg	-	2
H2	-do-	-do-	700 kg	-	50
I1	Swivel	Brass	0/6	-	50
I2		-do-	0/4	-	300

The fish baits used are frigate mackerel, round scad, big-eyed scad and other similar species. The sizes of the baits ranges from 15 to 20 pcs/kg. About 20 kg of fish are needed to complete one setting operation of a longline with 300 hooks.

The bottom vertical longline is set once or twice a day, either before sunset or at sunrise. The fishing gear is baited and prepared by the crew upon reaching the fishing ground. The location, depth, nature of bottom, current and wind direction are noted to determine the length of float line to be used. The boat s speed is about 2–3 knots during the shooting of the gear. The boat stops whenever there are snags until the line is released.

The shooting of the gear starts with the release of the flagged marker buoy and the laying out of the buoy line, weights and primary mainline. This is followed by attaching the secondary mainline at distances of 50m until last of the 43 pieces of secondary mainline has been released with a marker buoy at the end. The gear is left in the water for three hours before hauling. An improvised line hauler is used to lift the gear. While the primary mainline is being rolled, the secondary mainline, are detached and coiled separately. The fishes caught are removed from the hooks and placed in baskets.

4.4 Fleet handline fishing

In Palawan waters there are many coral reefs and continental slopes. A group of fishermen (5–10) is formed to use one banca each and they operate over coral reefs or continental slopes using a hook and line. The 5-meter bancas are carried in a bigger banca (10 m x 1 m x 1 m) that has a wide outrigger platform. The mother boat is powered by a diesel engine and carry provisions for a month-long trip including crushed ice to preserve the catch.

Upon reaching a good fishing ground, the small bancas are released and handline for the whole day. Before sunset, their catches are taken by the mother boat into the fish hold, recorded by weight, species, and name of the fishermen. When the fish hold is full or when the provisions are consumed, the mother boat returns to its homeport and sells the catch. Salaries of the fishermen are paid by the owner after deducting operating expenses.

The major species caught are snapper, grouper, nemipterids and other coral reef fishes. The scheme of operations is successful since the area is not frequented by many typhoons and is a productive fishing area for demersal species.

4.5 Single banca hook and line fishing

The hook and line structure varies in design and modes of construction. In general, a handline consists of a mainline, secondary mainline, hook and sinker. Other accessories include a wooden or bamboo spool for coiling the line, a swivel to prevent the line from twisting and a stainless wire to protect the hook from loss due to fish bites.

A simple hook and line has only one hook but several hooks are now common, especially for catching sea bream, grouper and snappers. Hook and lines can be used for either pelagic, mid-water or demersal species. Natural baits such as fish, squid and artificial baits such as plastic and silk materials which resemble a shrimp, squid or octopus are used.

Fishermen use single and multiple hooks for demersal fishes. They use an outriggered banca measuring 4 to 5 m. Nylon monofilament, 1.2 to 2.00 mm, is used. The primary and secondary mainlines have multiple hooks and branch lines of 0.45 mm to 1.0 mm connected to the swivels of the mainline. Hook size and shape vary depending on the target species. The swivels of different sizes and shapes are made of brass. One peculiar innovation in the bottom hook and line is the provision of a bait bag in which small fish, or ground up fish, are placed. As it reaches the desired depth, the line is jerked to release the bait attracting fish schools and thus increasing the catch.

5. REGULATIONS ON MARINE FISHERIES

5.1 Municipal fisheries

The management of contiguous fishery resources such as in bays which straddle several municipalities, cities or provinces, should be done in an integrated manner and should not be based on political subdivisions of municipal waters, to facilitate their management as single resource systems. The local government units (LGUs) that share or border such resources may group themselves and coordinate with each other to achieve the objectives of integrated fishery resource management.

Under Section 17 on the *Grant of Fishing Privileges in Municipal Waters* (Senate of Philippines 1998), preference shall be given to registered fisherfolk organizations and cooperatives in the grant of fishery rights by the Municipal or City Council. These are special agencies or offices vested with jurisdiction over municipal waters by virtue of special laws creating these agencies such as, but not limited to, the Laguna Lake Development Authority and the Palawan Council for Sustainable Development.

Section 23 of the legislation provides that if there is a need to regenerate fishery resources in the water based of evidence of overfishing, the LGU shall prohibit or limit fishery activities in the said waters. Under Section 24, support to municipal fisherfolk shall be provided through appropriate technology and research, credit, production and marketing assistance and other services such as training for supplementary livelihoods.

5.2 Commercial fisheries

Various regulations have relevance to deepwater fisheries. Under Section 32 of the legislation, fishing vessels of Philippine registry may operate in international waters or waters of other countries that allow such fishing operations with provisions for compliance to manning and other requirements of the Philippine Coast Guard, Maritime Industry Authority and other agencies concerned and requires that they secure an international fishing permit and certificate of clearance from the Department. Fish caught by such vessels shall be considered as caught in Philippine waters and therefore shall not be subject to all import duties and taxes when landed in duly designated fish landings and fish ports in the Philippines. Crews on Philippine-registered vessels fishing beyond the Philippine EEZ are not considered as overseas Filipino workers. Section 35 provides incentives for commercial fishers to fish farther into the EEZ to encourage fishing vessel operators.

Section 38 provides that the detailed reports of the actual fishing operation are required by the Department for recording information and management purposes.

Section 42 states that foreign fishing vessels wishing to use land, air and sea facilities in the Philippines to transport fishery products, which are caught outside Philippine territorial waters, to final destinations may only call at duly designated government owned or controlled regional fishport complexes after securing clearance from the Department. Rule 42.2 indicates that the Bureau of Fisheries and Aquatic Resources in cooperation with the PFDA shall designate regional fishing ports as authorized transshipment points.

6. FUTURE PLANS

One programme within the ASEAN-SEAFDEC 5-year Plan is for harvesting of underexploited resources in member countries. SEAFDEC will be conducting a workshop and project proposals will be submitted. There are also initiatives from neighboring countries where there exists deepsea fishing especially for deep-sea red snapper.

A workshop will be conducted on 20–21 January 2004 in collaboration with the Southeast Asian Fisheries Development Center for the preparation of standardized methods on research and assessment of fishes in continental shelf slope, rough bottom and deep-water areas where bottom trawls cannot be operated.

In the Philippines, there are many non-trawlable grounds such as the Palawan area, Polillo, Batanes, Catanduanes, Sulu and Eastern and Southern Mindanao. Most of the fisheries in these areas are underexploited. Many commercial fishes are known to be found on the continental shelf slope or rough bottom areas where the depth of waters is more than 150 m and can only be harvested by bottom longline, bottom gillnets and traps.

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Bottomfish management and monitoring in the main Hawaiian islands

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1. INTRODUCTION

The deep-slope red snappers, the onaga (*Etelis coruscans*), or ulaula koae (in Hawaii), and the ehu (*Etelis carbunculus*), or ulaula (in Hawaii), have been the focus of a comprehensive management programme by the State of Hawaii's fishery management agency, the Department of Land and Natural Resources' (DLNR) Division of Aquatic Resources since 1995. These fish are found throughout the Hawaiian Archipelago at depths of 100–150 fathoms (183–274 m) and can occasionally be caught deeper. They are considered to be part of the Hawaiian bottomfish fishery, which catches deep-slope snappers, groupers, and jacks with vertical handline gear, sometimes operated with electric or hydraulic reels, in depths of 50–150 fathoms (91–274 m). The opakapaka, or pink snapper (*Pristipomoides filamentosus*), well-known in fine restaurants, is also caught in this fishery, as well as the hapuu, the Hawaiian grouper (*Epinephelus quernus*). An overview of the fishery can be found in Haight, Kobayashi and Kawamoto (1993).

The 2 400 km long Hawaiian Archipelago consists of 132 islands and atolls (Figure 1). The Main Hawaiian Islands (MHI) are the eight major inhabited islands from Hawaii

FIGURE 1
The Hawaiian Archipelago

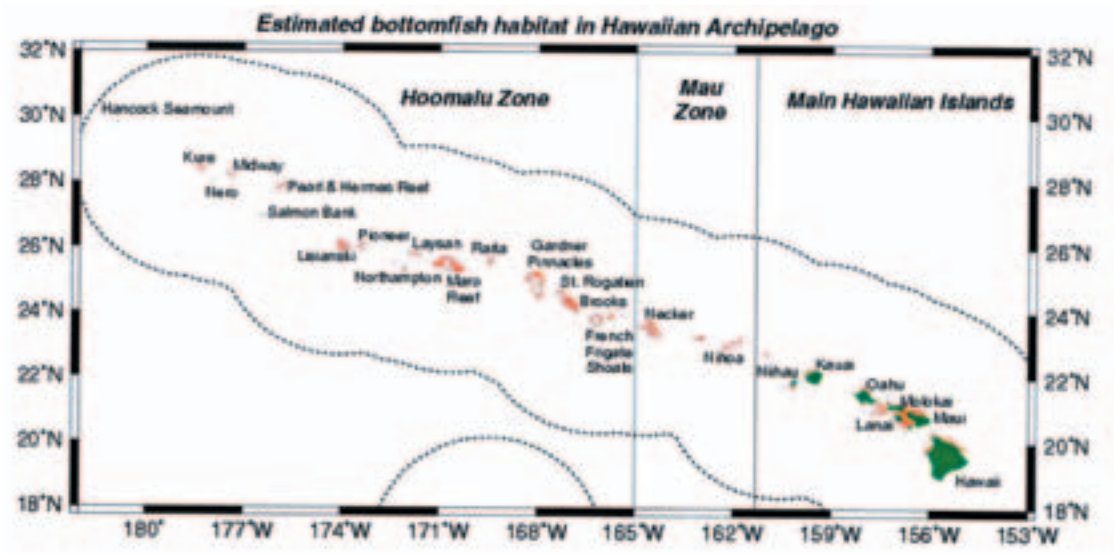


FIGURE 2
Targeted CPUE for MHI Onaga (*Etelis coruscans*) and Ehu (*E. carbunculus*)

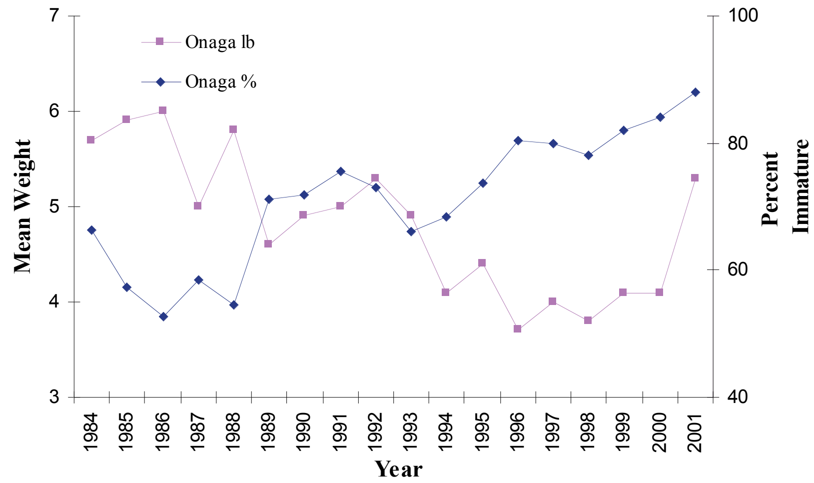
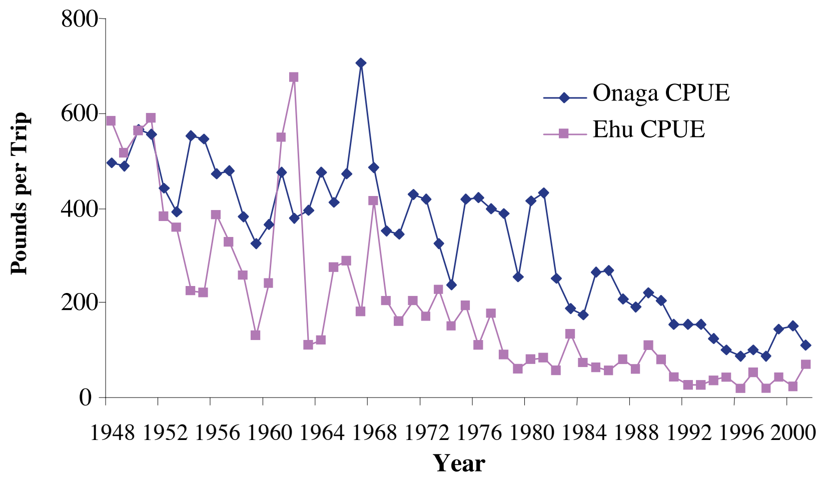


FIGURE 3
MHI onaga (*E. coruscans*) mean weight and percent immature



at the southeast end of the archipelago up through Kauai and Niihau. The Northwestern Hawaiian Islands (NWHI) are the largely unpopulated islands, atolls and reefs northwest of Kauai and Niihau. Traditionally, these two areas were managed separately, although the populations of onaga and ehu are now considered genetically indistinguishable across the archipelago. The Western Pacific Regional Fishery Management Council manages limited entry fisheries in two zones in the NWHI, the Hoomalu zone (NW half of the archipelago) and the Mau zone, the small area between the Hoomalu zone and the MHI because about 80 percent of the bottomfishing grounds in the NWHI are in the federal exclusive economic zone (EEZ). About 80 percent of the bottomfishing grounds in the MHI are within state waters and managed are by the DLNR.

There were 225 904 kg of all species of bottomfish landed commercially in 2000 from the Main Hawaiian Islands. Of these, 119 090 kg were landed from the Northwestern Hawaiian Islands. Of those landed in the MHI in 2000, 40 454 kg were onaga and 15 909 kg were ehu. An estimated 495 vessels made 3 810 trips in the MHI for bottomfish in 2000. In comparison, 41 818 kg of onaga and 5 909 kg of ehu were harvested by 11 vessels making 83 trips in the NWHI (WPRFMC 2003).

Ex-vessel revenues from the bottomfish fishery in the entire Hawaiian Archipelago were $US2 550 000 in 2000. The aggregate ex-vessel price of all species of MHI bottomfish combined was $US8.00/kg. The all-species aggregate price for NWHI bottomfish was generally lower ($US7.92/kg). The 2000 onaga average ex-vessel price was $US11.11/kg and for ehu was $US8.58/kg (both MHI and NWHI).

2. WHAT WAS THE PROBLEM?

The onaga and ehu have always been a highly valued fish in Hawaii. Their bright red color signifies good luck in Asian culture and these fish are often served on ceremonial occasions where the symbolic meaning is important. The red snappers are popular, even raw as sashimi, in both restaurants and for home consumption. They have unique Hawaiian names, reflecting that they were caught and valued by early Hawaiians as well.

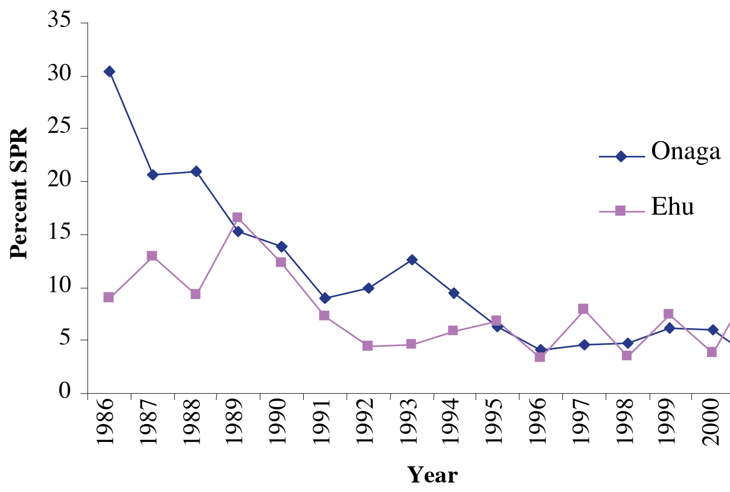
The Division of Aquatic Resources has kept statistics on commercial landings of fish since 1948. There were estimates of landings before 1948, but only since then was a system developed for fishermen to report their catches to the Hawaii territorial, then to the State government. The reports indicate clearly that the catch rates of onaga and ehu have declined steadily since the early 1950s and have dropped even more steeply in the 10 to 15 years previous to 1998 (Figure 2). As the catch rates have dropped, so has the proportion of mature fish in the landings. About 84 percent of the commercial landings of onaga from the main Hawaiian Islands in 2000 were immature (Figure 3). Onaga live for 7–10 years, and must attain a large size, to reach maturity. The high proportion of immature fish in the landings may indicate that the spawning population has been depleted in the MHI.

Researchers at the National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration, U.S. Department of Commerce, have been studying the bottomfish fishery for many years. NMFS scientists have been reporting that onaga and ehu in the Main Hawaiian Islands have been overfished since at least 1989. They base their assessment on several indicators, including the high proportion of immature fish in the landings, declining catch rates and the dynamic Spawning Potential Ratio (SPR). The SPR uses catch rates and size-frequencies to calculate an index that compares the estimated spawning biomass of the current year's fish population to an estimate of the virgin spawning biomass (WPRFMC 2003).

The Western Pacific Regional Fishery Management Council (WPRFMC) manages domestic fisheries in the U.S. EEZ of Hawaii, Guam, American Samoa, Commonwealth of the Northern Mariana Islands and other U.S. Pacific islands by mandate of the Magnuson-Stevens Fishery Conservation and Management Act. The Council established that an SPR of 20 percent represents a "red light" threshold for overfishing in the Hawaiian Islands bottomfish fisheries. In the Main Hawaiian Islands for 2001, onaga SPR was about three percent and ehu SPR about 11 percent, based on targeted catch rates (Figure 4, WPRFMC 2003). MHI onaga SPR has been below 20 percent since 1989 and ehu SPR below 20 percent since at least 1986. In contrast, the SPR for onaga and ehu in the Northwestern Hawaiian Islands are well above 20 percent. In addition, MHI onaga have a high proportion of

FIGURE 4

Targeted spawning potential ratio for (MHI) onaga and ehu



immature fish in the landings and recent MHI ehu catch rates are less than ten percent of the catch rate in 1948.

3. STATE OF HAWAII MANAGEMENT ACTIONS

3.1 Consultation process

The WPRFMC had been urging the State of Hawaii to take action to manage and conserve onaga and ehu in the Main Hawaiian Islands since the early 1990s. In 1995, the DLNR Chairperson Michael Wilson committed the DLNR to develop a comprehensive management plan for MHI onaga and ehu. Wilson established an *ad hoc* advisory task force of recreational and commercial fishermen from all over the state, representatives from the fishing industry, and fishery managers, scientists, and enforcement personnel from other government agencies. Under the leadership of the Division of Aquatic Resources (DAR), the task force met throughout 1995 and developed a set of management proposals.

The key conservation measure favored by the task force was the Restricted Fishing Area wherein bottomfishing would be prohibited. They believed that RFAs would provide more long-term protection and opportunity for rebuilding the population than measures such as closed seasons or minimum sizes. Closed seasons provide no protection for spawners outside the limited closure period. Minimum size measures work well for fish that can be released safely, reducing mortality on undersized fish, but would not likely be successful for bottomfish, which are difficult to bring to the surface without embolizing and inevitably subsequent high mortality.

The task force proposals were presented to groups of fishermen statewide in informational roundtable discussions to get feedback and suggestions for the proposals. The feedback included suggestions for locations of the RFAs. Then DAR turned the proposals into a draft administrative rule, which was presented at further statewide public informational meetings with fishermen.

Finally, the draft administrative rule was presented and reviewed at formal public hearings statewide. A required step in establishing administrative rules is public hearings where proposed regulations are presented to the public and testimonies from the public are collected. In all, more than 42 meetings (including advisory panel meetings and informal meetings) were held with fishermen all over the state. Fishermen were actively sought out for their suggestions and comments. Many responded with ideas and recommendations, some of which were used in the final administrative rule.

The administrative rule was revised and presented to the Board of Land and Natural Resources on 13 March 1998 for approval. The rule was revised slightly and resubmitted to the Board and approved on 24 April 1998. The Attorney General approved the revised rule and Governor Benjamin J. Cayetano signed it on 22 May 1998. The rule went into effect 1 June 1998, thereupon having the effect of law.

3.2 Summary of the regulations

The new regulations are contained in Hawaii Administrative Rule Chapter 13-94. The rule established new regulations on fishing for certain deep-slope snappers and groupers commonly called bottomfish in Hawaii. The purpose of the Chapter was to establish management of these species and regulate the fisheries that affect them in the main Hawaiian Islands, extending from the island of Hawaii to Niihau. The following is a summary of the rule.

§13-94-5 Bottomfish Species

"Bottomfish" are defined as the seven deep-slope species for the purposes of this Chapter. They include onaga, ehu, kalekale (*Pristipomoides sieboldii*), opakapaka, ukikiki or gindai (*Pristipomoides zonatus*), hapu`u, and lehi (*Aphareus rutilans*). These species are included because their depth ranges overlap onaga and ehu and because the fishery is a multi-species fishery. It would be difficult to conserve onaga and ehu inside a closed area if the other species were allowed to be harvested, since onaga and ehu would likely be caught incidentally.

§13-94-6 Restricted bottomfish fishing gears
This article prohibits use or possession of nets, traps, trawls or bottomfish longline when fishing for bottomfish species defined in 13-94-5. Possession of both prohibited gear and bottomfish is a violation. This is intended to prevent ghost fishing, habitat destruction or use of too-efficient gears. It is intended to allow the use of traditional vertical handline gear only.

§13-94-7 Non-commercial bag limits
This article limits a non-commercial fisherman (without a valid Commercial Marine Licence issued by the department) to possessing a maximum of five onaga or ehu, or five in total of both.

§13-94-8 Bottomfish Restricted Fishing Areas
This article prohibits bottomfishing and, or, possession of bottomfish within restricted fishing areas. It is unlawful to take, or possess, bottomfish while in a vessel drifting or anchored within a restricted area except for emergencies. The DLNR will select areas, considering where adult onaga and ehu are caught, close 20 percent of onaga and ehu fishing areas, distribute restricted areas statewide, consider suggestions from bottomfish fishermen, etc. Areas can be modified or established by a formal Board of Land and Natural Resources meeting. The Board of Land and Natural Resources may, in a publicly advertised Board meeting, modify or rate new restricted fishing areas. Restricted fishing areas are to be reviewed and evaluated for effectiveness by the DLNR in consultation with fishermen and other relevant parties no later than 1 July 2003. The RFAs do not prohibit other activities, such as fishermen transiting the area or trolling or handlining for pelagic species.

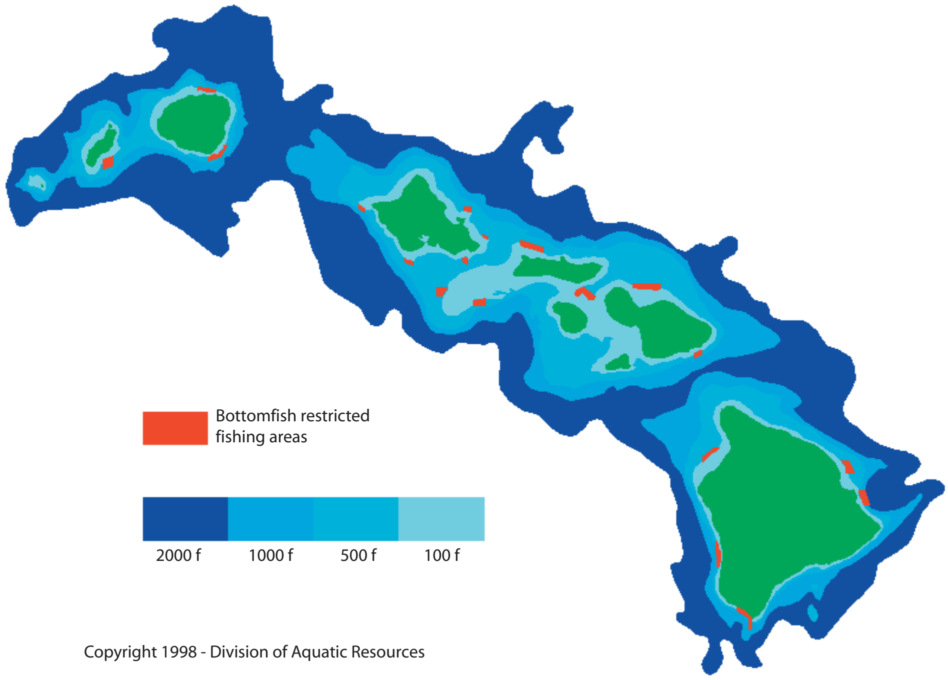
Figure 5 shows the general locations of the Bottomfish Restricted Fishing Areas (in red) in the Main Hawaiian Islands. Note: the inside boundaries of the areas generally follow the 100 fm (183 m) contour. The areas were arbitrarily selected based on several factors.

- total area to approximate 20 percent of the 100 fm (183 m) contour within each county
- focus on fishery statistical areas showing historically high density of onaga and ehu landings
- input from fishermen via interviews, public meetings and hearings and
- spread RFA locations around islands and close to access points to facilitate enforcement.

§13-94-9 Bottomfishing fishing vessel identification
Vessel owners must register their vessels with the DLNR to obtain an identification number. It is unlawful for any vessel to take, or possess, bottomfish species without a departmental registration.

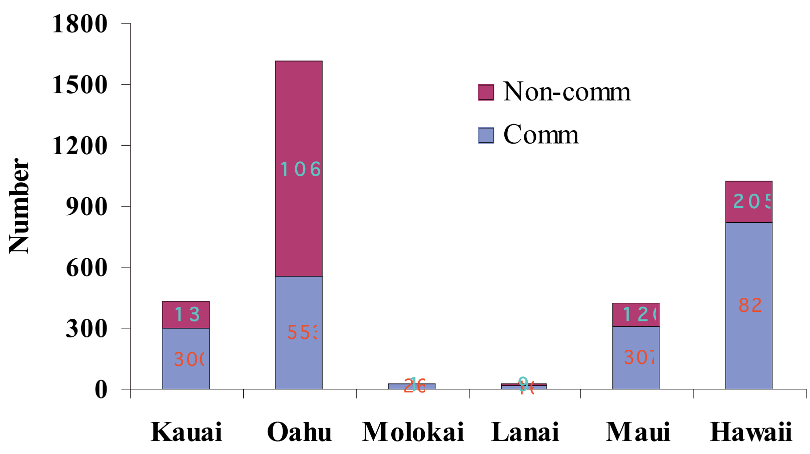
The identification number makes use of existing vessel numbering systems where established and displayed including state vessel registration, federal fishery permit numbers, or US Coast Guard vessel documentation numbers. Registered vessels display the letters BF to ndicate that they are registered with the department to fish for bottomfish.

FIGURE 5
Bottomfish restricted fishing areas in the main Hawaiian islands



A total of 3 552 vessel owners registered their vessels for bottomfishing from June 1998 through October 2004. About 57 percent are commercial fishing vessels and the rest are non-commercial vessels, which could be classified as recreational, although it is likely that many of the so-called recreational vessels may sell a portion of the catch. The lengths of registered vessels range from 8–65 ft (2.4–19.8 m), with a mode at 19 ft (5.8 m). The registrations by island show that non-commercial vessels tend to dominate on the main island of Oahu, which is more metropolitan than some of the other islands (Figure 6).

FIGURE 6
BF vessel registrations by island, as required by Hawai'i Administrative Rule Chapter 13-94



§13-94-10 Establish control date

This regulation sets a date that may be used to qualify applicants for a future limited entry programme for commercial bottomfish fishing, if one is developed by the DLNR. It does not bind the DLNR to establish a limited entry programme, but if it does, fishermen entering the fishery after the control date may not be guaranteed that they will get a limited entry permit. The control date was set on 1 June 1998. The full administrative rules, including maps, can be obtained at <*http://www.hawaii.gov/dlnr/dar/library/har_toc.htm*>.

3.3 Public outreach and education

As part of a public education programme, 38 000 copies of a bottomfish management brochure were printed and distributed to inform fishermen of the new regulations and restricted fishing areas. The brochure included maps and coordinates marking the locations of the RFAs. Extensive coverage of the campaign was provided by local newspapers and media. A web site was created to provide information and registration instructions see <*http://www.hawaii.gov/dlnr/dar/bottomfish/index.htm*>.

4. RESEARCH

4.1 DLNR-HIMB Bottomfish Project

The DLNR has supported a long-term research programme since 1997 led by Dr Christopher Kelley at the University of Hawaii's Hawaii Institute of Marine Biology. This programme began with a number of objectives.

i. Identify and characterize critical habitat, particularly nursery grounds, for onaga, ehu, opakapaka, and kalekale within the main Hawaiian Islands
ii. Develop methods to capture live specimens for the purpose of conducting experimental studies on their physiological tolerance ranges, growth and reproduction
iii. Conduct a genetic analysis of fish captured from different locations to determine the population structure of these species in the Hawaiian Islands
iv. Develop methods to maintain live fish in captivity and initiate experiments on survival and growth rate under different physiological conditions.

These goals have been expanded to include development of an acoustic method for identifying bottomfish species and quantifying mixed species aggregations *in situ*, high-resolution mapping (Benoit-Bird *et al.* 2003), characterization of bottomfish habitats with multibeam sonar (Kelley *et al.* 2000), development of a GIS database, development of acoustic tagging and tracking of bottomfish species and development of egg, fry and juvenile production technology for bottomfish.

There are three divisions working on different parts of the project.

Field: Identify and characterize essential fish habitat, particularly nursery grounds, for onaga, ehu and other species of deepwater snappers in the main Hawaiian Islands. This has included high-resolution mapping of bottomfishing grounds, observation of bottomfish habitat and environment *in situ* from a research submersible and a remote-operated underwater vehicle, fishing surveys of grounds and assistance in developing non-lethal assessment methods.

Laboratory: Conduct genetic analysis of onaga and ehu captured from different locations in the Hawaiian Archipelago and the Pacific to determine the population structure of these species in the Hawaiian Islands (Chow *et al.* 2000). This analysis has been extended to hapuu.

Hatchery: Develop methods to maintain deepwater snappers in captivity and initiate experiments on survival and growth rate under different physiological conditions. The hatchery staff succeeded in maintaining opakapaka for extended periods and inducing spawning in captivity (Figure 7). They have recently succeeded at releasing second generation opakapaka juveniles back into the wild (C. Kelley, Hawaii Undersea Research Laboratory, pers. comm.). They have also kept ehu alive in captivity for limited periods and hatched onaga larvae in the laboratory from strip-spawned onaga at sea.

FIGURE 7

130 day old opakapaka (*P. filamentosus*) spawned and raised in captivity

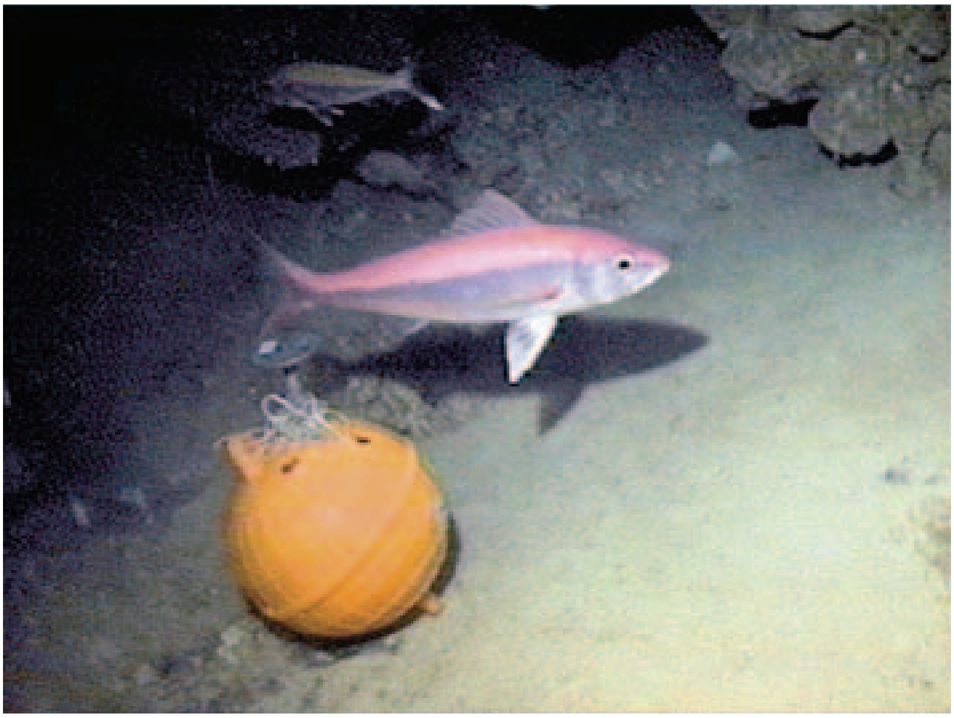
(courtesy of A. Moriwake, Hawai'i Institute of Marine Biology)

The results of surveys from submersible dives indicate that essential habitat for these snappers consists of a hard substrate that can either be carbonate, basalt or mudstone. Suitable substrate had a relatively large number of holes and crevices that served as shelter for the smaller fish and shrimp that onaga and ehu presumably feed on. In pinnacle habitats in particular, the abundance of small fish and invertebrates was similar if not greater than that observed in shallow water coral reef habitats. Onaga and ehu, as well as their potential prey species were absent over sand substrates as well as hard substrates with few holes. The presence of one species of potential prey fish, *Symphysanodon maunaloae*, appeared to be highly correlated with the presence of ehu and onaga on these dives as well as subsequent dives undertaken as part of a related project. Several potential competitor species were also observed in these habitats including the hogo (*Pontinus macrocephalus*), moray eels, (*Gymnothorax berndti* and *G. nuttingi*), kalekale (*Pristipomoides sieboldii*) and the hapuu (*Epinephelus quernus*). Bait stations have resulted in excellent video images of onaga and ehu species that are considered to be difficult to photograph due their avoidance of light (Figure 8). Lights-out bait stations also provided some new insights into the coloration and appearance of these fish under their natural lighting conditions. Of particular interest was the fact that yellow bars and stripes produced distinctive black markings at depths of 300 m that are likely to be species recognition signals. (Kelley, Mundy and Grau 1997, Kelley *et al.* 2000, Kelley 2002a, 2002b).

4.2 Interactions of nonindigenous blueline snapper (Taape) with native fishery species

Dr James Parrish and graduate students at the Hawai'i Cooperative Fisheries Research Unit (HCFRU) at the University of Hawai'i studied the effect that the introduced blue lined snapper (*Lutjanus kasmira*) might have on native bottomfish (Parrish *et al.* 2000). There are a number of potential interactions between taape and deep-water snappers

FIGURE 8
Onaga (*E. coruscans*), in foreground, and ehu (*E. carbunculus*) at a bait station
(courtesy of C. Kelley, Hawai'i Undersea Research Laboratory)



that could affect the fishery. These include: (a) predation by taape on snappers or vice versa, (b) competition for food between taape and snappers and (c), co-occurrence and sharing of habitat.

Dr Kelley and his DLNR Bottomfish Project staff assisted Dr Parrish and his team by providing fish samples and survey data. In addition, HCFRU team members participated in the Hawaii Undersea Research Laboratory 1998 and 1999 research submersible and remotely-operated vehicle cruises. No taape have been observed occurring with juvenile or adult onaga or ehu on any of the research fishing surveys by Dr Parrish's team.

During 130 hours or more of underwater observations from manned and remote submersible vehicles at depths between about 80 and 400 m, taape were seen on only two occasions, both at depths of less than 100 m, once two individuals were seen at night and a school was once seen in daylight.

4.3 Evaluation of non-lethal methods for assessment of overfished deepwater snapper resources

Robert Moffitt from the National Marine Fisheries Service (NMFS) led cruises aboard the University of Hawai'i research vessel **R.V. Ka'imikai O Kanaloa** in 1998, 1999 and 2002. The submersibles **Pisces IV** and **V** and the remotely operated vehicle **RCV-150** were evaluated for observing and assessing bottomfish populations around the Main Hawaiian Islands. Dives were made in the RFAs and adjacent open areas on Penguin Bank, Moloka'i and off Makapu'u, Oahu. The University of Hawai'i's Hawai'i Undersea Research Laboratory (HURL) and the NOAA National Undersea Research Programme provided support for this research (see: <*http://www.soest.hawaii..edu/HURL/*>).

Although the scientists still have hundreds of hours of videotape and notes to analyze, there are some observations that stand out. Submersible transect and bait station techniques show the most promise as assessment tools. Both ehu and onaga were observed with each of these techniques. Ehu were observed to be closely associated with benthic cover (holes or ledges) whereas onaga tended to swim higher in the water column. The ROV produced some high quality video transects at night, but snappers were rarely observed. It is possible that these snappers migrate diurnally as some of the shallower species do and were not present in the habitat at night when the ROV operations were conducted. It is also possible that the greater noise and brighter lights associated with the ROV (compared to the submersible) kept the snappers out of view.

One of the most interesting observations resulting from these dives is that researchers found a nursery ground utilized by both juvenile ehu and onaga. Both species were found associated with small, low carbonate (limestone) features scattered over an otherwise sandy bottom. Second, researchers were successful in feeding a dummy sonic tag to an ehu and were nearly successful in feeding one to an onaga. Lessons learned on these dives indicate that we should be able to introduce sonic tags to either species with a fair success rate.

Researchers also observed that juvenile onaga and ehu can occur in the same depths as adult onaga and ehu, unlike opakapaka where there is clear separation between juvenile and adult. What was also interesting is that onaga and ehu look quite different underwater than they do on the surface. Onaga appear silvery-gray in the distance because their scales are very reflective, but the red color becomes more evident as they get closer. Their tail fins have distinctive black tips. Ehu are red and yellow and have distinctive white spots on the pelvic and lower tail fins. With the sub lights off, ehu have dark stripes running longitudinally down their body. The gindai (*Pristipomoides zonatus*) show dark vertical bars. Large amberjacks (*Seriola dumerili*) were also observed in similar depths with onaga and ehu.

5. MONITORING AND EVALUATION OF BOTTOMFISH RESTRICTED FISHING AREAS

As noted earlier, the Division of Aquatic Resources has been collecting commercial fisheries data since 1948. These data are used extensively by all fishery management agencies in Hawaii as they facilitate long-term comparisons of landings and value. Commercial fishermen are required to obtain a Commercial Marine Licence and to submit reports of catch, landings and value to the Division on a monthly basis. However, specific fishing effort in terms of gear units and time fished were never collected. The system had undergone few changes in its 55 year history and not until late 2002 were new report forms implemented. The new reports require sufficient detail on fishing effort so that gear units, specific effort and bycatch can now be characterized. Nonetheless, relative effort and long-term trends can be derived from the historical data and have been used to monitor and assess commercial fisheries effectively.

Unfortunately, the same effort has not been put into collecting recreational or subsistence fishing catch and effort. Occasional creel survey projects have been executed, but with varying sampling designs and coverages previous to 2001. Since 2001, the Division has instituted a new recreational fishing creel survey project as a cooperative agreement with the federal National Marine Fisheries Service, which provides part of the funding. The new Hawai'i Marine Recreational Fishing Survey interviews private boat fishermen, charter boat captains and clients, and shoreline fishermen. Preliminary data are available for 2002 (see: <*http://www.hawaii.gov/dlnr/dar/surveys/ index.htm*>).

The restricted fishing areas are the primary conservation measure in the DLNR's bottomfish management plan. The administrative rule requires the DLNR to evaluate the effectiveness of the RFAs and recommend additions or modifications. The Division of Aquatic Resources has developed a plan for evaluation and is leading the effort to collect and compile the data needed for the analysis. Commercial catch data are being analyzed for effects of the RFAs on onaga and ehu abundance.

The data from the fishery independent research submersible and bait station surveys are still being compiled. The task requires analysis of hundreds of hours of video and audio data and may be completed before the end of 2004. NMFS and Hawaii Undersea Research Laboratory researchers are working with a DAR biologist to evaluate the data and provide information for a small working group of scientists, fishermen and enforcement that will provide management recommendations to the DLNR.

6. MANAGEMENT ISSUES

Problems with enforcement of the administrative rule and compliance by fishermen remain. The enforcement division of the DLNR is responsible for enforcing all department rules and state conservation laws on state lands and waters. These duties include drug enforcement and enforcing state park parking rules. As a result, they are not always able to deliver sufficient effort to the enforcement of the restricted fishing areas, which are inherently more difficult to enforce than other management measures such as a closed season. While many fishermen voluntary comply with the RFA regulations, some consistently violate them.

Fisheries independent research to complement life history data and support stock assessment are generally lacking. Although the DLNR has supported research into specific areas of bottomfish life history, specific research needed to support stock assessments and to assess or test the effectiveness of alternative management measures has not occurred. The Division of Aquatic Resources does not generally function as a research agency and must depend on collaborating agencies and researchers to supply scientific expertise. It has also been difficult to assess the effectiveness of protected areas for conserving or rebuilding bottomfish, unlike coral reef species, which are readily observable by SCUBA divers. Classic fishery dependent assessment measures are not likely to be effective for monitoring closed areas.

The Western Pacific Regional Fishery Management Council recently sponsored a Bottomfish Stock Assessment Workshop in Honolulu to assess the available data and to recommend approaches to assess bottomfish stocks (January 2004). The report of the workshop is available at <*http://www.wpcouncil.org/bottomfish.htm*>. Education and outreach efforts need to be continued to improve compliance and to help change perceptions of the need for conservation and the long term benefits of resource management.

7. FUTURE PLANS

The DLNR realizes that no fisheries management plan is perfect or is guaranteed to work as first conceived. It views the bottomfish management plan as an evolutionary plan that will change and be improved as we learn more about bottomfish and how best to conserve them at a sustainable level. The DLNR, as much as staffing and resources will allow, will support research and assessment studies of onaga, ehu and other bottomfish in the Main Hawaiian Islands to obtain more biological and fishery information on these fish. Improvements have been made to collection and analyses of fishery data. The Enforcement Division has been provided with portable GPS units and aircraft rental time to facilitate enforcement of regulations. Whether these ambitious programmes can be continued is highly dependent on the support the department gets from the community and from the state legislature.

8. ACKNOWLEDGEMENTS

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William Devick, DAR Administrator, and DAR staff; Robert Moffitt and Donald Kobayashi (NMFS), Christopher Kelley and the DLNR Bottomfish Project staff, Terry Kerby and HURL dive operations staff, Mark Mitsuyasu (WPRFMC), James Parrish, Eric Conklin, and Greta Aeby (HCFRU), William Aila (DLNR Boating and Ocean Recreation), DLNR Bottomfish Task Force members, numerous fishing and boat clubs, and the U.S. Coast Guard, NMFS Office of Law Enforcement, and DLNR Division of Conservation and Resource Enforcement. Mahalo to Ms. Kitty Simonds, Executive Director (WPRFMC) and DLNR for support of the travel and arrangements for this workshop. Appreciation is extended to Andy Burnell (DAR) for useful comments on the draft.

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Biological data and stock assessment methodologies for deep-slope bottomfish resources in the Hawaiian archipelago

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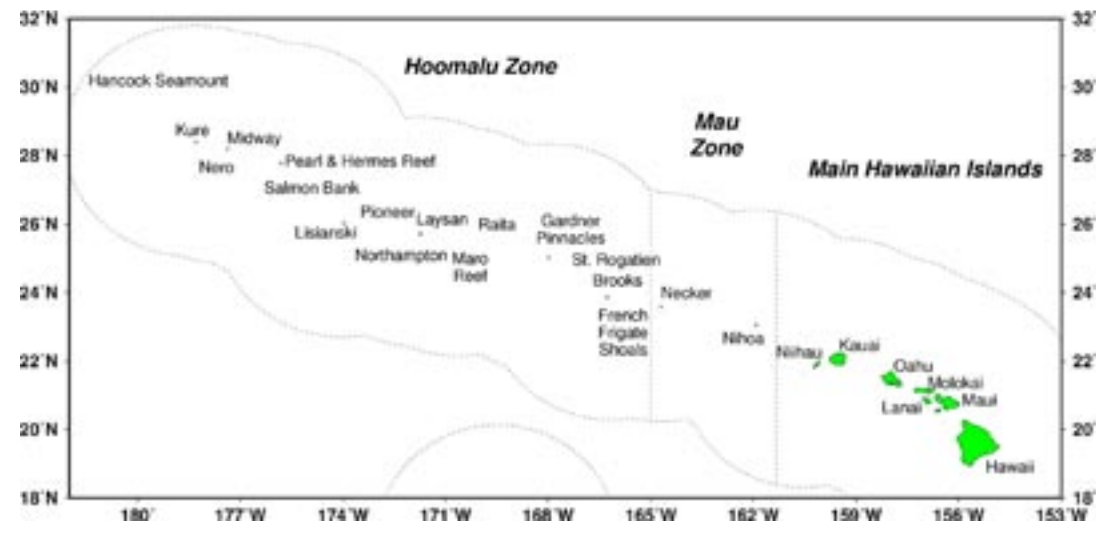
1. INTRODUCTION

Deep-slope bottomfish of the families Lutjanidae, Serranidae and Carangidae comprise a valuable small-scale fishery resource throughout the central and western Pacific. They have been commercially exploited in Hawaii for over 100 years with landings data collected by the State of Hawaii since 1948. The National Marine Fisheries Service Honolulu Laboratory and others have sporadically conducted biological research on these species since an increase in fishing activity in the Northwestern Hawaiian Islands (NWHI) started in the mid 1970s. In the late 1980s the Hawaiian Archipelago was divided into three management zones (Figure 1). The main Hawaiian Islands (MHI) zone surrounds the inhabited islands with most of the bottom-fishing habitat situated within state waters (to 3 nm from shoreline). The uninhabited northwestern Hawaiian Islands were split into two zones; the smaller Mau zone is situated closer to the MHI and the larger Ho'omalu zone extends beyond the Mau zone to the end of the archipelago. The NWHI zones are both currently federally-managed limited-entry zones with bottom-fish habitat predominantly in federal waters.

FIGURE 1
Map of Hawaiian Archipelago Bottomfish Management Zones



2. BIOLOGICAL DATA

2.1 Species and distribution

Commercial landings in Hawaii are dominated by four species of eteline snapper, *Pristipomoides filamentosus*, *Etelis coruscans*, *E. carbunculus*, *Aprion virescens* and a single species of grouper, *Epinephelus quernus*. Several other species of eteline snapper and carangids of the genera *Caranx*, *Pseudocaranx*, and *Carangoides* are also caught. These species are generally found in patchy aggregations near high relief features at depths ranging from 100–400 m. *Aprion virescens* can also be found on the shallower flat areas of the banks at depths less than 40 m where they can be caught with trolling gear.

2.2 Reproduction

Examination of gonadosomatic index and histological staging of ova has shown that several species of snappers are serial spawners. They spawn several times over a protracted summer breeding season making annual fecundity estimates difficult to obtain (Kikkawa 1984, Everson and Kikkawa 1984, Everson, Williams and Ito 1989). Size at sexual maturity has been estimated for the major species of snapper (Table 1).

TABLE 1
Length at maturity (L_{50}) for Hawaiian snapper species

Species	Fork length (mm)	Literature source
Pristipomoides filamentosus	430	Kikkawa 1984
Etelis coruscans	610	Everson *et al.* 1989
Etelis carbunculus	300	Everson 1984
Aprion virescens	470	Everson *et al.* 1989

2.3 Larval and juvenile stages

Little is known about the larval and juvenile stages of Hawaiian bottomfish. Eteline snapper larvae have been collected in small numbers from samples collected in late summer and early fall (Clarke 1991). Newly settled juveniles of *Epinephelus quernus*, still retaining pelagic stage coloration, are taken in early summer in lobster traps. Otolith examination has revealed these approximately 25 mm long fish to be about 50 days of age at settling (NMFS unpublished data). On the other hand *Pristipomoides filamentosus* juveniles first appear on the bottom at 70–100 mm in length and an age of approximately 180 days (Moffitt and Parrish 1989). In both cases these juveniles are found in habitats very different from the adult habitat described above. The newly settled groupers are found on the bank flats at depths of 30–50 m, but the actual bottom type is not known. The largest concentration of snapper juveniles found to date occupies featureless sand and mud flats off Kaneohe Bay, Oahu, Hawaii at depths of 60–100 m (Moffitt and Parrish 1989). These snappers remain in this habitat for approximately six months, reaching lengths of about 200 mm, before moving out to more typical high-relief slope habitats.

2.4 Age and growth

Age and growth studies have been conducted on several species using otoliths and length-frequency information (Uchida, Ito and Uchiyama 1979, Uchida, Tagami and Uchiyama 1982, Ralston and Miyamoto 1983, Ralston and Kawamoto 1987, Morales-Nin and Ralston 1990, Smith and Kostlan 1991, DeMartini, Landgraf and Ralston 1994, Moffitt and Parrish 1996). Ageing tropical bottomfish can be challenging. Annual marks have not been identified on the otoliths of the Hawaiian snappers and groupers, so otolith aging has relied on enumeration of presumed daily increments. This is not only a time consuming process, but one that leads to uncertain results. Ralston and Miyamoto (1983) found that daily increments could be reliably enumerated in fish up to about three years of age. Aging older fish was unreliable due to episodic otolith deposition. Also, many otoliths display only intermittent areas of discernable increments within larger cloudy unreadable areas. Ralston and Williams (1988) developed an integration method of aging fish from these otoliths, but some question remains on the accuracy of resulting age estimates (Morales-Nin 1988).

Similarly, problems are encountered when attempting length-based ageing studies. We have not collected length data from our fisheries on an extensive or regular basis. The only size information we routinely collect is obtained from the fish markets, where we receive information on the number of individuals and total weight of species specific lots, which gives us an average weight of individuals from each lot sold. We do have some length data collected from sporadic research studies, but the small sample size collected, the extended breeding seasons, longevity and variable individual growth rates of our bottomfish species lead to few, if any, discernable modes in length frequency distributions that could be used for age and growth estimation. One of the most successful data sets we have is that for juvenile *Pristipomoides filamentosus* (Moffitt and Parrish 1996), but this data covers only a narrow size range for this species and does a poor job estimating L_∞.

2.5 Mortality

Mortality estimates for many Hawaiian bottomfish species have been calculated using a length-based regression estimator of L_∞ and the ratio of total mortality (Z) to the growth coefficient (K) (Wetherall *et al.* 1987, Polovina 1987). When the length–frequency distribution is obtained from an unfished stock, total mortality equals natural mortality (M) and, with an independent estimate of K, natural mortality can be estimated from the Z/K ratio. Alternatively, natural mortality can be estimated using an empirical relationship with K such as that suggested by Ralston (1987) where $M = -0.0666 + 2.52\,K$. Since both methods use an estimate of K to calculate M, the resulting estimate of M is only as accurate as the value of K used, and, as mentioned above, we are not confident that we have reliable estimates of K.

TABLE 2
Range of estimates of L_∞, K, and M for the major Hawaiian bottomfish species

Species	L_∞	K	M
Pristipomoides filamentosus	664 – 971 mm	0.146 – 0.31	0.250 – 0.715
Etelis coruscans	894 – 957 mm	0.137 – 0.143	0.278 – 0.360
Etelis carbunculus	639 – 1 183 mm	0.064 – 0.190	0.16 – 0.61
Aprion virescens	1 165 mm	0.12	0.236 – 0.241
Epinephelus quernus	1 080 – 1 186 mm	0.119 – 0.126	0.233 – 0.253

3. STOCK ASSESSMENT

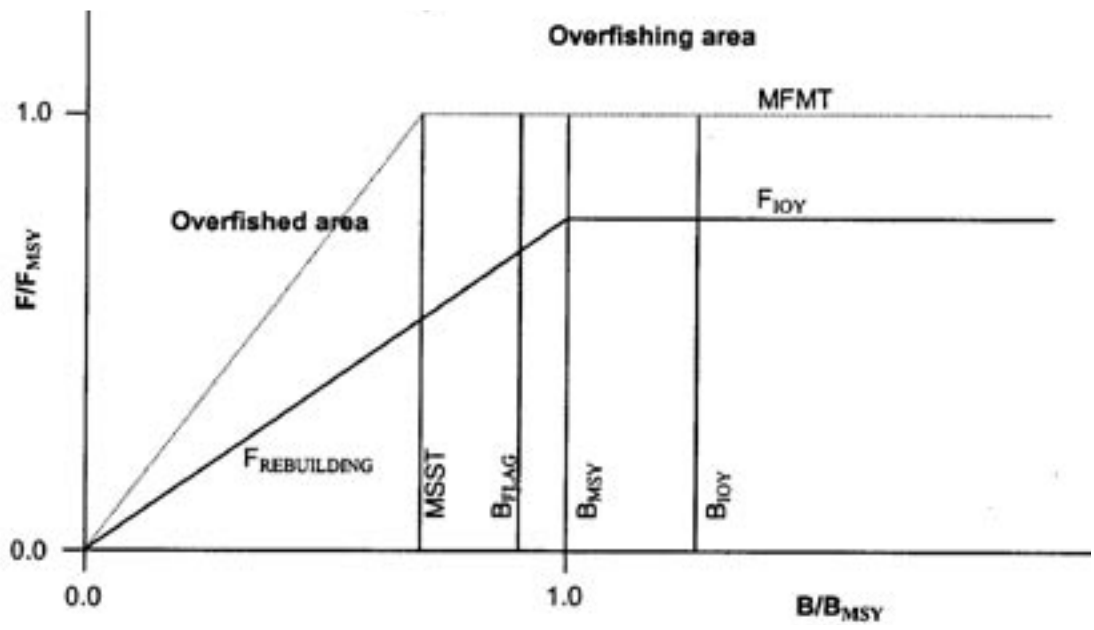
The Western Pacific Regional Fishery Management Council (WPRFMC) has produced an annual report on the Hawaiian bottomfish fishery since the adoption of the Bottomfish and Seamount Groundfish Fishery Management Plan (Bottomfish FMP) in 1986. Assessment of the status of the stocks has relied on the long-term landing data collected by the State of Hawaii, which extends back to 1948. In 1990 an amendment to the Bottomfish FMP established procedures whereby bottomfish stocks were considered healthy as long as their spawning potential ratio (SPR) remained above 0.20. If, however, the SPR for any species dropped below the 0.20 level it would be considered recruitment overfished and the WPRFMC was mandated to develop and adopt management measures that would increase the SPR value to above the 0.20 overfishing threshold level. Somerton and Kobayashi (1990) developed a simple method of calculating SPR requiring input data of catch per unit effort (CPUE) and the percentage of mature individuals by weight in the catch. SPR is estimated as the ratio of the product of current CPUE and percent mature values to that of the unfished stock, estimated as the average of the CPUE and percent mature for the first few years of the fishery, i.e.

$$SPR = \frac{CPUE_{current} \text{ X Percent Mature}_{current}}{CPUE_{unfished} \text{ X Percent Mature}_{unfished}}$$

Using this definition of overfishing, no species of bottomfish in the Hawaiian archipelago has been overfished to date (WPRFMC 2002). However, when SPR estimates are calculated for the main Hawaiian Islands alone, rather than the archipelago as a whole, values for both *Etelis* species are well below the 20 percent threshold, indicating local depletion.

Changes in fisheries management legislation in the *Magnuson-Stevens Fishery Conservation and Management Act of 1996* required modification of all United States fishery management plans. Following published guidelines (Restrepo *et al.* 1998) a new definition of overfishing was developed for the Bottomfish FMP (Moffitt and Kobayashi 2000, WPRFMC 2002). Future assessments, starting with the 2003 annual report, will use these definitions. The new rules establish a minimum stock size threshold (MSST) expressed as a fraction of biomass at maximum sustainable yield (B_{MSY}) and a maximum fishing mortality threshold (MFMT) tied to the fishing mortality experienced at MSY (F_{MSY}). When stocks fall below the MSST, they are considered overfished requiring adoption of management measures that will allow rebuilding of the stock. When fishing mortality rises above MFMT, overfishing is occurring and management measures must be adopted to reduce fishing mortality. The thresholds, relative to a ratio of current biomass ($B_{current}$) and fishing mortality ($F_{current}$) to B_{MSY} and F_{MSY}, respectively, are incorporated into a management control rule (Figure 2). Proxies for fishing mortality and biomass may be used in situations where direct measurements are not available. For deepslope bottomfish resources in the Hawaiian Archipelago, we use fishing effort (E) as a proxy for fishing mortality and CPUE as a proxy for biomass. Estimates of CPUE and E at MSY ($CPUE_{MSY}$, E_{MSY}) are used as proxies for the reference

FIGURE 2
MSY and target control rules for bottomfish stock complexes



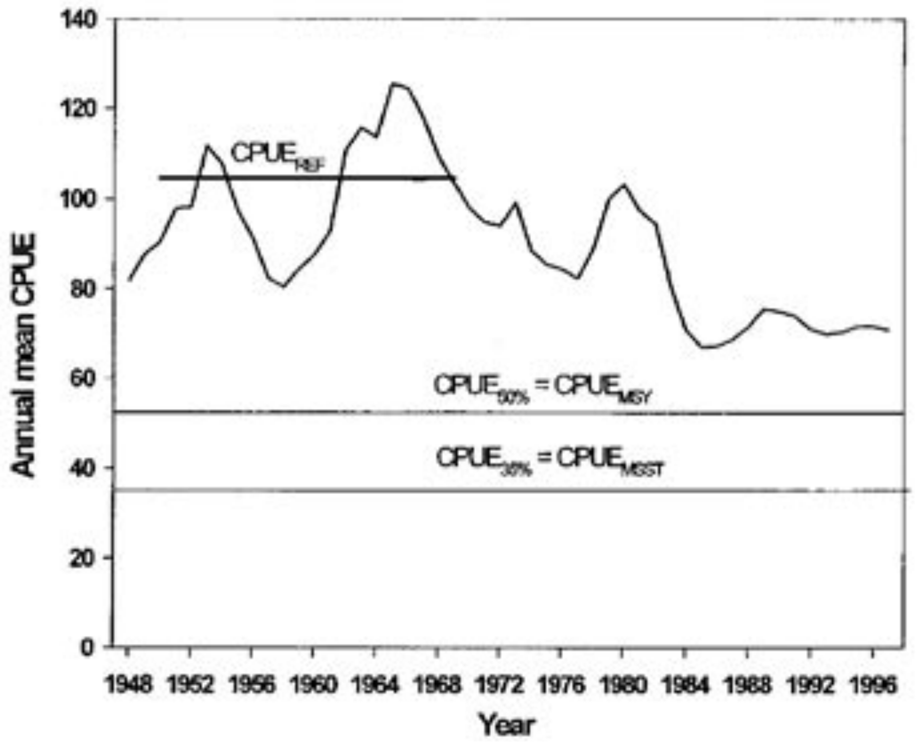
points in calculating MSST and MFMT. Warning thresholds are incorporated into the control rule as a precautionary measure to reduce the chances of overfishing (i.e. B_{Flag} and F_{OY}). When no information on MSY is available thresholds cannot be establish using the above methods. In these situations a time series of CPUE and effort data can be used to establish reference and threshold values until better data becomes available (Figure 3).

With the difficulties involved in obtaining information on adequate MSY, CPUE and E for individual species within the bottomfish complex, we are applying the above method to the multispecies stock as a whole. To ensure the health of all component species within the multi-species stock, we are continuing to monitor SPR for individual species and, as in the past, require adoption of management measures whenever any species-specific SPR drops below the recruitment overfishing threshold of 20 percent (Moffitt and Kobayashi 2000, WPRFMC 2002).

To date a few estimates of Hawaiian bottomfish MSY have been suggested. Ralston and Polovina (1982) applied an equilibrium Schaefer surplus production model to commercial catch per unit effort (CPUE) data from a portion of the Main Hawaiian Islands resulting in an estimate of catchability and MSY of 272 kg per nautical mile of 100 fathom isobath. This value can then be applied to the rest of the Hawaiian chain using the length of the 100 fathom isobath for the entire archipelago to obtain an archipelago-wide MSY estimate of 606 t (335 t for the NWHI). However, the use of an equilibrium model and the need to estimate a large number of parameters, increases the uncertainty of these estimates.

Kobayashi (1996) applied a dynamic production model using independent estimates of catchability obtained from Leslie model depletion studies conducted on isolated fishing areas in the Commonwealth of the Northern Mariana Islands and American Samoa to reduce the number of parameters and uncertainty. These estimates of

FIGURE 3
Use of a time series of CPUE to establish a MSY reference



catchability, in conjunction with CPUE data from the NWHI bottomfish fleet, were used to estimate carrying capacity, MSY, $CPUE_{MSY}$ and E_{MSY} for the two bottomfish management zones in the NWHI. There is some concern on the appropriateness of using catchability estimates obtained from outside the study area, but the model does appear to fit the data fairly well. The resulting value constitutes the best available estimate of MSY to date of 266 t for the NWHI (approximately 216 kg per nautical mile of 100 fathom isobath).

4. ISSUES

Even with all the research and data collection on Hawaiian bottomfish, we still must consider our situation to be "data poor". Although we have some life history data for several species, most parameters for any one species remain ill defined with estimates varying widely between studies and techniques applied. Because of a suboptimal fishery-independent survey program we are forced to rely solely on commercial landings and sales reports for annual assessment data. There are several major concerns with relying on this fishery dependent data. First of all, we do not have a good idea of total landings in Hawaii. Reports from the commercial fishers and fish buyers give us a good idea of the commercial landings. There may be some under reporting, but it is not thought to be a major problem. What is a major problem is the lack of data on the recreational and subsistence components of the catch. These landings are not apt to be large in the remote uninhabited NWHI, but are certainly a major concern in the MHI where over 3 000 vessels are registered and are potential bottomfishers. It will be difficult to manage a fishery based on MSY when we do not have an accurate measure of landings.

The use of commercial CPUE data is also an area for concern. In order for a long time series of CPUE data to be useful in an assessment, it must be related to resource abundance in a consistent manner. In other words, the catchability coefficient needs to be consistent. In Hawaii several technological advances over the years have made fishing easier, e.g. power-assisted reels, fish finders and global positioning systems (GPS). These advances have undoubtedly changed the relationship between CPUE and abundance for Hawaiian bottomfish resources. Unfortunately, we do not have information on when the various vessels (or fleets) started using any of this equipment and we don't know how great an influence any one of these has on the catchability coefficient. Obviously, standardization of CPUE over time is required. Similarly, standardization of CPUE between vessels in the same fleet is needed. Each vessel has its own ability to catch fish or fishing power. This may be related to size of the vessel, on board equipment, crew ability, etc. In small fisheries, such as the NWHI bottomfish fishery, entry or exit of individual vessels from the fleet may alter the fleet-wide fishing power and subsequent relationship between reported fleet-wide CPUE and stock abundance. In a larger fleet, such as that found in the MHI, this relationship is less likely to change significantly with entry or exit of only a few individual vessels.

Accurate recording of effort is also important and is not always as straight forward as it seems. In our case we have commercial landings data collected by the State of Hawaii starting from 1948. Unfortunately, when the data collection program was started, the interest was solely economic, i.e. pounds landed and prices paid. To use these data in assessments, we have had to try to attach units of effort to the recorded catches. The best we were able to approximate was the catch-per-trip for individual vessels with no information on trip length or any possible changes in average trip duration over time. More recently we have required the commercial fishers to supply considerably more data on effort. Now we collect information on a daily basis including the number of hours, lines and hooks spent bottomfishing and trolling and the number of hours spent searching for bottomfishing sites. Both hours spent searching and hours spent actually fishing are important information for use in making good CPUE calculations.

Another problem we have with fishing effort is our inability to allocate the effort between various species making stock assessments of particular species impossible. If fishers could target particular species exclusively, and we knew how much time was spent fishing for each individual species, we could assess the stocks of the individual species separately. In real life, however, the ability to target single species is incomplete with several species being caught at the same place, often on the same line. Also, on longer trips, fishers will purposely target a variety species in order to maximize the price received for the catch.

Finally, the establishment of restricted fishing areas (RFAs) and other marine protected areas (MPAs) has confounded the use of commercial CPUE as an indicator of stock abundance. This is not to say that MPAs are a bad idea. Their use to improve stock abundance and recruitment to the fishery should certainly be investigated. The concentration of fishing effort resulting from their presence, however, does change the relationship between commercial CPUE and stock abundance in an unknown manner. Without some sort of correction, assessments based solely on CPUE would likely under-represent actual stock abundance.

In conclusion, the importance of collecting detailed and consistent catch and effort data from the beginning of a fishery cannot be over-emphasized. Our stock assessment methods rely on comparisons of current stock abundance to that of the unfished stock. Although our estimates of current CPUE, and therefore relative abundance, are adequate, we lack equally reliable estimates of initial CPUE to reflect unfished stock abundance.

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Management of the northwestern Hawaiian islands deep-slope bottomfish and seamount groundfish resources

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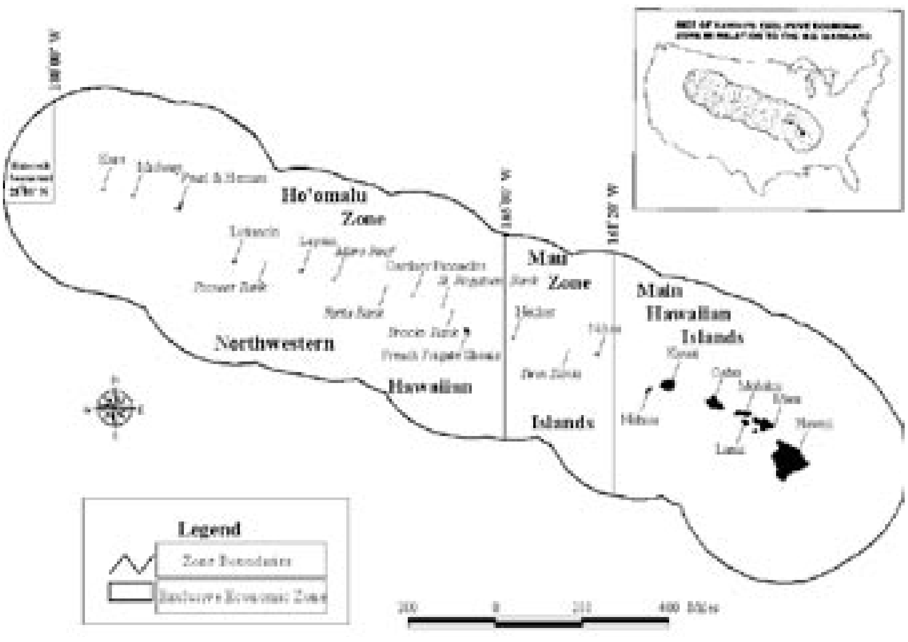
1. INTRODUCTION

The Hawaii deep-slope demersal fishery targets species of eteline snappers, carangids and a single species of grouper at depths ranging from 30–150 fm (60–300 m). The fishery is divided into two primary geographical areas: the inhabited main Hawaiian Islands (MHI) with their surrounding reefs and offshore banks; and the Northwestern Hawaiian Islands (NWHI), a chain of largely uninhabited islets, reefs and shoals extending 1 200 nm across the North Pacific. For management purposes the NWHI fishery has been separated into the Mau Zone (between 161° 20' W longitude and 165 °W longitude), closer to the MHI, and the Hoomalu Zone (west of 165 °W longitude) (Figure 1). A limited access programme has been established for each zone in addition to logbook reporting, vessel size limitations, observer coverage and other requirements.

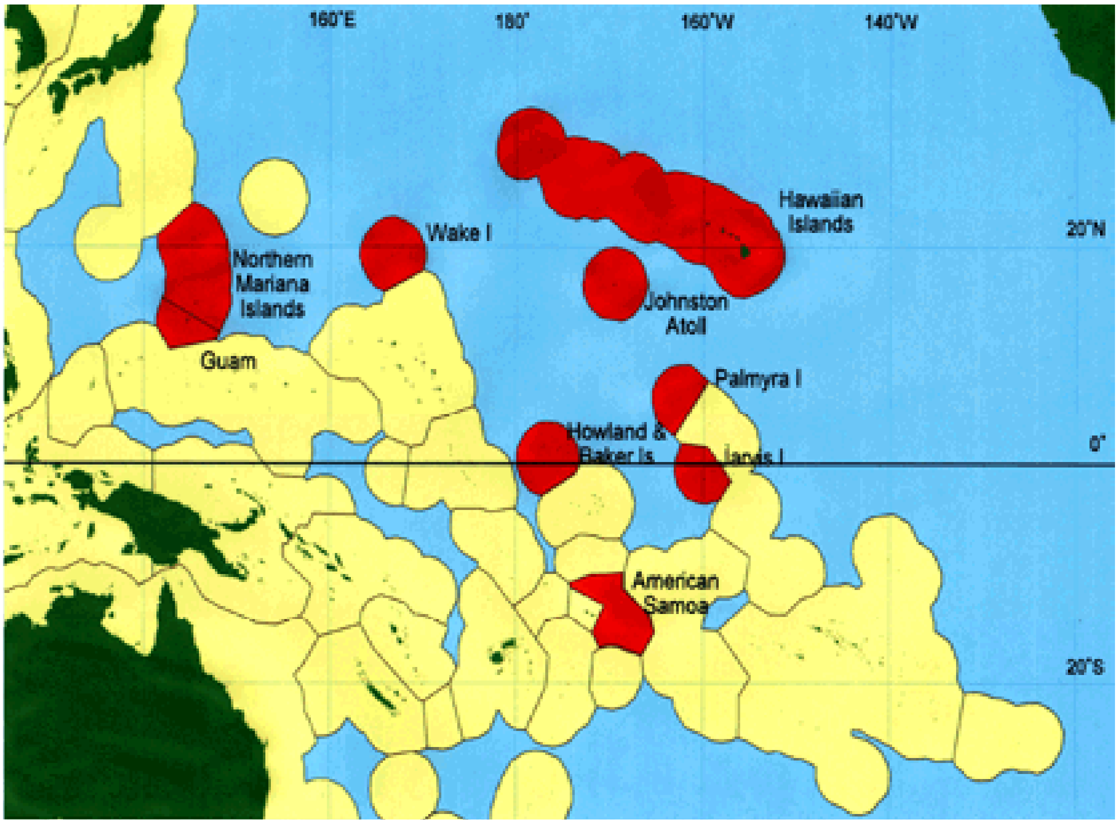
FIGURE 1
Hawaiian archipelago bottomfish management zones



In addition to the deep-slope fisheries in the MHI and NWHI, there is potential for a seamount groundfish fishery in the northern most extent of the Hawaiian archipelago. A trawl and bottom longline fishery targeting alfonsino (*Beryx splendens)* and armourhead *(Pseudopentaceros richardsoni*) at the southeast Hancock Seamount in the NWHI was started by Russian and Japanese fishing vessels in the late 1960s (Okamoto 1982).

This paper discusses the management authority and process by which bottomfish resources are managed in the US Western Pacific region (Figure 2) and reviews the fishery characteristics and history of utilization of the NWHI bottomfish fishery. The development of management strategies and resulting regulatory regime is presented and the paper examines present management issues and future challenges for fishery managers.

FIGURE 2
United States Western Pacific Region



2. MANAGEMENT

2.1 Authorities

In 1976 the United States Congress passed the *Magnuson Fishery Conservation and Management Act*, which established eight quasi-federal regional councils to manage fisheries in the exclusive economic zone (EEZ) surrounding the United States. Under this act, subsequently reauthorized as the *Magnuson-Stevens Fishery Conservation and Management Act*, the Western Pacific Council is the policy-making organization for the management of fisheries in the 200 nm EEZ adjacent to the Territory of American Samoa, Territory of Guam, State of Hawaii, the Commonwealth of the Northern Mariana Islands and the US Pacific island possessions of Jarvis, Johnston, Wake, Howland and Baker Islands, Kingman Reef and Palmyra and Midway Atolls. The inner boundary of the fishery management area is a line coterminous with the seaward boundaries of the state and territorial waters (the "3 mile-limit"). This area of 1.5 million nm^2 is the largest management area of the US regional fishery management councils and comprises about half of the total EEZ waters under US jurisdiction.

The main task of the Council is to protect fishery resources while maintaining opportunities for domestic fishing at sustainable levels of effort and yield. The Council manages and monitors fisheries throughout its region by developing and implementing fishery management plans. Plans are developed in compliance with National Standards (see following box) and scientific requirements of the *Magnuson-Stevens Act*, along with consideration of the social, cultural and economic values and realities of island communities.

Magnuson-Stevens Act National Standards

(1) Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry.

(2) Conservation and management measures shall be based upon the best scientific information available.

(3) To the extent practicable, an individual stock of fish shall be managed as a units throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination.

(4) Conservation and management measures shall not discriminate between residents of different states. If it becomes necessary to allocate or assign fishing privileges among various United States fishermen, such allocation shall be (A) fair and equitable to all such fishermen; (B) reasonably calculated to promote conservation; and (C) carried out in such manner that no particular individual, corporation, or other entity acquires an excessive share of such privileges.

(5) Conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery resources; except that no such measure shall have economic allocation as its sole purpose.

(6) Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches.

(7) Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.

(8) Conservation and management measures shall, consistent with the conservation requirements of this Act (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to (A) provide for the sustained participation of such communities, and (B) to the extent practicable, minimize adverse economic impacts on such communities.

(9) Conservation and management measures shall, to the extent practicable, (A) minimize bycatch and (B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch.

(10) Conservation and management measures shall, to the extent practicable, promote the safety of human life at sea

2.2 Management process

Management of fishery resources in the US is based on a "bottom-up" or "grassroots" approach to the development of fishery policy. The 16 members of the Western Pacific Council include representatives from the fishing community and state and federal governmental officials responsible for managing and conserving fishery resources in the Western Pacific Region. Half of the Council members are appointed by the US Secretary of Commerce from people nominated by their respective island governors. Other members represent government agencies that are responsible for fisheries, including the US National Marine Fisheries Service (NMFS), US Fish and Wildlife Service, the US Coast Guard and the State Department. Meetings of the Council are held throughout its jurisdiction.

The process for creating and implementing fishery management plans (FMPs) is dynamic and continuous. Development of these plans, or amendments, involve a systematic assessment of present conditions; identification of management alternatives and regulatory actions; evaluation of the likely environmental, biological, economic and social effects of the management alternatives; and estimation of future conditions if no action is taken. The Council currently has five multi-species FMPs — Pelagics, Bottomfish and Seamount Groundfish, Crustaceans, Precious Corals and most recently the Plan for Coral Reef Ecosystems.

The management process is transparent and open to the public at every decision step. As part of decision making, the Council receives advice from advisory bodies, federal agencies, state fisheries agencies, non-profit organizations and the general public. Citizen appointments on four Advisory Panels (Commercial, Recreational, Subsistence and Indigenous, and Ecosystem and Habitat) represent broad geographic areas and diverse cultures. Advisory Panel membership reflects different segments of the fishing community including processing, marketing, commercial, recreational and subsistence fishing, environmental organizations, researchers and other related sectors.

Plan Teams are established for each fishery management plan and consist of federal and state fishery managers, scientist and academics. The primary responsibility of each team is to assist in development of FMPs or amendments, annually review the status of fishery and provide recommendations to the Council for improvements to the management regime. A Scientific and Statistical Committee reviews proposed management actions and provides expert scientific advice to the Council.

2.3 Monitoring and reporting

Annual reports and evaluations are a critical part of each FMP as they ensure the need for change is identified systematically. Each FMP provides a basis for cooperation between NMFS, local agencies, and other organizations to collect and analyze data from the fisheries through an established monitoring programme. Fisheries are evaluated each year by the Council's Plan Teams, which produce annual reports for each FMP and, or other reports addressing special problems within specific fisheries. Evaluations are based on Council programme principles and objectives. Recommendations are formulated, which are then reviewed by the Council and its advisory bodies, including the Scientific and Statistical Committee. Priorities are assigned based on the need for information and research to complete FMPs or amendments in support of the Council's overall mission. Reports also identify research and data analysis needs, which can be used as a basis for short- and long-term programme planning by the NMFS and other agencies or organizations. The Council's annual reports satisfy the national standard requirement for a Stock Assessment and Fishery Evaluation (SAFE). Report recommendations also provide a reference for the Council to request programme funds so that high-priority research and data needs will be met rapidly.

2.4 Overview of the Bottomfish and Seamount Groundfish FMP and amendments

In addition to *Magnuson-Stevens Act* policies, the Council established objectives for managing bottomfish resources in the Western Pacific Region through promulgation of the FMP. These objectives are to:

- protect against overfishing and maintain the long-term productivity of bottomfish stocks
- improve the data base for future decisions through data reporting requirements and cooperative federal, state and territory data collection programmes
- provide for consistency in federal, state and territory bottomfish management to ensure effective management across the range of the fisheries
- protect bottomfish stocks and habitat from environmentally destructive fishing activities and enhance habitat if possible
- maintain existing opportunities for rewarding experiences by small-scale commercial, recreational, and subsistence fishermen, including native Pacific islanders

- maintain consistent availability of high quality products to consumers
- maintain a balance between harvest capacity and harvestable fishery stocks to prevent over-capitalization
- avoid the taking of protected species and minimize possible adverse modifications to their habitat and
- restore depleted groundfish stocks and to provide the opportunity for US fishermen to develop new domestic fisheries for seamount groundfish which will displace foreign fishing.

The *Bottomfish and Seamount Groundfish Fishery Management Plan* (Bottomfish FMP) was implemented in 1986. It prohibits certain destructive fishing techniques, including explosives, poisons, trawl nets and bottom-set gillnets. It established a moratorium on the commercial harvest of seamount groundfish stocks at the Hancock Seamounts and implements a permit system for fishing for bottomfish in the EEZ around the NWHI. The moratorium on the harvest of alfonsino and armourhead on the Hancock Seamounts, the only exploitable seamount habitat in the management area, was put in place (63 FR 35162, 29 June 1998) in an effort to rebuild the groundfish stocks. The moratorium will remain in effect until August 2010. The plan also established a management framework process that includes adjustments such as catch limits, size limits, area or seasonal closures, fishing effort limitation, fishing gear restrictions, access limitation, permit and, or, catch reporting requirements and a rules-related notice system.

	NWHI Regulatory Regime
I.	HOOMALU (7) LIMITED ENTRY PROGRAMME
II.	MAU (10) LIMITED ENTRY PROGRAMME
III.	NON-TRANSFERABLE FEDERAL PERMITS
IV.	LOG BOOK REPORTING
V.	VESSEL SIZE LIMITS OF 60 FEET
VI.	NEW ENTRY CRITERIA BASED ON WEIGHTED PAST FISHING ACTIVITY POINT SYSTEM
VII.	MANDATORY PROTECTED SPECIES WORKSHOP
VIII.	OBSERVER PLACEMENT REQUIREMENTS
IX.	PROHIBITION ON USE OF
-	BOTTOM TRAWLS
-	BOTTOM SET GILLNETS
-	POISONS
-	EXPLOSIVES
-	INTOXICATING SUBSTANCES
X.	MORATORIUM ON HARVEST OF SEAMOUNT GROUNDFISH ON HANCOCK SEAMOUNTS
XI.	FRAMEWORK REGULATORY PROCESS

The FMP has been amended seven times since 1986. Amendment 1 was implemented in 1987 and put in place, within the framework structure of the FMP, the ability to rapidly implement limited access programmes for bottomfish fisheries in the EEZ surrounding American Samoa and Guam if required. Amendment 2 in 1988 divided the EEZ around the NWHI into two management zones: the Hoomalu Zone to the northwest and the Mau Zone to the southeast. A limited access system was created for the Hoomalu Zone while the Mau Zone remained open through general permitting. Amendment 3 (1991) defined recruitment overfishing as a condition in which the ratio of the spawning stock biomass per recruit at the current level of fishing to the spawning stock biomass per recruit that would occur in the absence of fishing is equal to, or less than, 20 percent. Amendment 3 also delineates the process by which overfishing is monitored and evaluated. Amendment 4 (1990) requires vessel owners or operators to notify NMFS at least 72 hours before leaving port if they intend to fish in a 50 nm "protected species study zone" around the NWHI. This notification allows federal observers to be placed on board bottomfish vessels to record interactions with protected species if this action is deemed necessary. Amendment 5 (1999) established a limited access system for the Mau Zone. Amendment 6 (1999) identifies and describes essential fish habitat for managed species of bottomfish, discusses measures to minimize bycatch and bycatch mortality in the bottomfish fishery, provides criteria for identifying when overfishing has occurred in the fishery and describes fishing communities in the Council's Region. Amendment 6 was only partially approved. The provisions for bycatch, overfishing and fishing communities in Hawaii were disapproved. The disapproved provisions were revised and implemented through Amendment 7 in August 2003. Amendment 7 established new control rules to monitor for "overfished" and "overfishing" conditions of resources managed under the Council's FMPs. The new biomass based rules replaced the Spawning Potential Ratio (SPR) proxy which was implemented through Amendment 3.

3. FISHERY CHARACTERISTICS

3.1 Bottomfish management unit species

The Bottomfish FMP includes deep and shallow-water species found in Hawaii, American Samoa, Guam, the Northern Mariana Islands and other uninhabited US Pacific Islands. Bottomfish management unit species (BMUS) refer to the fishes listed in Table 1.

TABLE 1
Bottomfish management unit species

Common name	Local name	Scientific name
Snappers:		
Silver jaw jobfish	*Lehi* (H); *palu-gustusilvia* (S)	*Aphareus rutilans*
Grey jobfish	*Uku* (H); *asoama* (S)	*Aprion virescens*
Squirrelfish snapper	*Ehu* (H); *palu-malau* (S)	*Etelis carbunculus*
Longtail snapper	*Onaga*, *ulaula* (H); *palu-loa* (S)	*Etelis coruscans*
Blue stripe snapper	*Taape* (H); *savane* (S); *funai* (G)	*Lutjanus kasmira*
Yellowtail snapper	*Palu-I lusama* (S); yellowtail, *kalekale* (H)	*Pristipomoides auricilla*
Pink snapper	*Opakapaka* (H); *palu-tlenalena* (S); *gadao* (G)	*Pristipomoides filamentosus*
Yelloweye snapper	*Palusina* (S); yelloweye *Opakapaka*, *kalekale* (H)	*Pristipomoides flavipinnis*
Snapper	*Kalekale* (H)	*Pristipomoides sieboldii*
Snapper	*Gindai* (H,G): *palu-sega* (S)	*Pristipomoides zonatus*
Jacks:		
Giant trevally	White *ulua* (H); *tarakito* (G); *sapo-anae* (S)	*Caranx ignoblis*
Black jack	Black *ulua* (H); *tarakito* (G); *tafauli* (S)	*Caranx lugubris*
Thick lipped trevally	Pig *ulua*, *butaguchi* (H)	*Pseudocaranx dentex*
Amberjack	*Kohala* (H)	*Seriola dumerili*
Groupers:		
Blacktip grouper	*Fausi* (S); *gadau* (G)	*Epinephelus fasciatus*
Sea bass	*Hapuupuu* (H)	*Epinephelus quernus*
Lunartail grouper	*Papa* (S)	*Variola louti*
Emperor fishes:		
Ambon emperor	*Filoa-gutumumu* (S)	*Lethrinus amboinensis*
Redgill emperor	*Filoa-paloomumu* (S); *mafuti* (G)	*Lethrinus rubrioperculatus*
Seamount groundfish:		
Alfonsin		*Beryx splendens*
Ratfish/butterfish		*Hyperoglyphe japonica*
Armourhead		*Pseudopentaceros richardsoni*

G: Guam, H: Hawaii, S: American Samoa.

3.2 Life history

Relatively little is known about the reproduction and early life history of deepwater bottomfish in the region. Spawning occurs over a protracted period and peaks from July to September (Haight, Kobayshi and Kawamoto 1993). The eggs are released directly into the water column and hatch in three to four days. The planktonic larval phase is thought to last at least 25 days (Leis 1987). For some species this phase may be considerably longer. For example, the pelagic stage for *opakapaka* is thought to be as long as six months (Moffitt and Parish 1996). Larval advection simulation research indicates that larval exchange may occur throughout the Hawaiian archipelago and that the amount of larval exchange between the NWHI and the MHI is correlated with the duration of the larval phase, the highest larval exchange occurring with the longest larval phase durations (Kobayashi 1998). Data on actual exchange rates, however, are lacking. Preliminary genetic work on *onaga* and *ehu* corroborates the notion of single archipelago-wide stocks of bottomfish. However, more recent genetic work on *hapuupuu* suggests that more localized stocks of this endemic species may exist within the Hawaiian archipelago.

Little is known of the life history of the juvenile fish after they settle out of the plankton, but research indicates that *P. filamentosus* juveniles utilize nursery grounds well away from the adult habitat (Parish 1989). Most of the target species have a relatively high age at maturity, long life span, and slow growth rates. These factors, combined with considerable variation in larval recruitment make them highly susceptible to overfishing (Haight *et al.* 1993).

Robert Humphreys, Pacific islands Region Science Center, National Marine Fisheries Service, reports that armourhead undergo an initial 2+ year pre-recruit pelagic phase in surface waters of the temperate and subarctic North Pacific. During this pelagic phase, armourhead undergo somatic growth but remain non-reproductive. Armourhead return to the southern Emperor-northern Hawaiian Ridge (SE-NHR) seamounts (consisting of Koko, Yuryaku, North and South Kammu, Colahan, and C- H Seamounts outside the US EEZ and Northwest and Southeast Hancock Seamounts inside the US EEZ) and recruit to the summits and upper slopes of these seamounts. Recruitment to the bottom trawl fishery and to the seamounts are simultaneous; these full-size adults recruit to the seamounts primarily during late spring-early summer. After recruitment, armourhead cease somatic growth, develop reproductively and spawn annually at the seamounts during November-February. Post-recruit movement of armourhead between seamounts is considered unlikely. Population genetics studies indicate that armourhead consists of a single seamount-wide population. Armourhead may survive up to 4–5 years at the seamounts, however, individuals gradually become emaciated; undergoing an irreversible decline in somatic weight and body depth with age. Annual increases in armourhead biomass at these seamounts is therefore solely dependent on recruitment.

3.3 Habitat and ecology

Commercially-important deepwater bottomfish inhabit the slopes of island coasts and banks at depths of 100 to 400 m. Deepwater snappers are typically distributed in a clumped pattern throughout their spatial and depth range and are often associated with underwater headlands and areas of high relief. Although deepwater snappers are generally thought of as top-level predators, several snapper species in the Pacific are known to incorporate significant amounts of zooplankton in their diets (Haight *et al.* 1993).

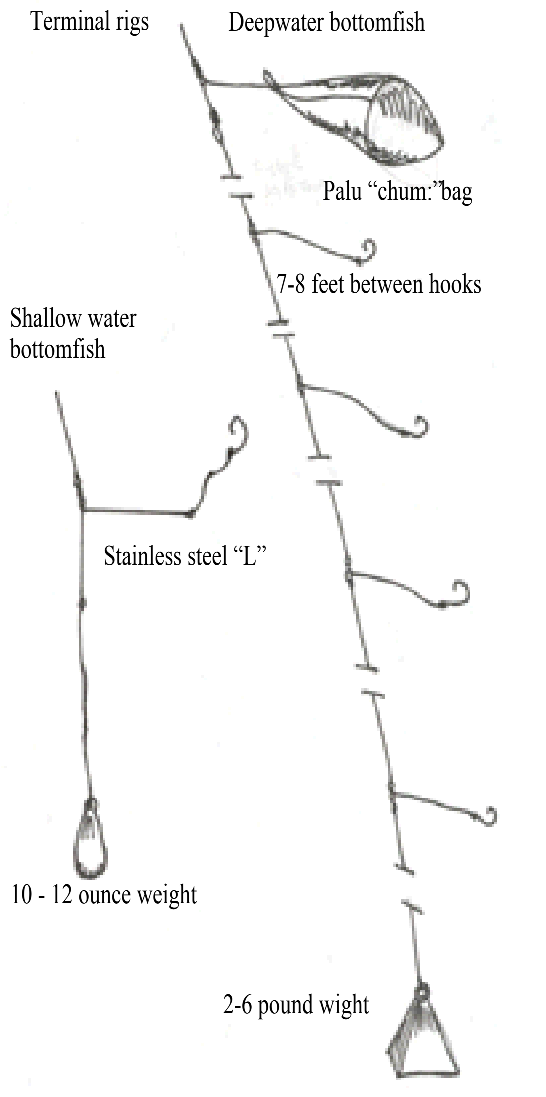
Three species of seamount groundfish are included as BMUS in the FMP. These deepwater species primarily occur at depths of 270–500 m at Hancock Seamount, which is located 2 800 km northwest of Honolulu. The seamount species generally occur at higher latitudes and below the depth range of the snapper-grouper bottomfish species complex. Armourhead and alfonsino spawn free-floating eggs, which are dispersed by the North-equatorial and Kuroshio currents. Juvenile fish remain in the pelagic environment for up to a year and then descend to seamount summits and begin a demersal existence. These species feed on species associated with the deep-scattering layer (euphausids, copepods, shrimps, myctophids, etc.) and make vertical migrations at night to follow their prey.

3.4 Fishery characteristics

3.4.1 Gear and methods

The basic design of the handline gear used in Hawaii's bottomfish fisheries has remained essentially unchanged from gear used by early native Hawaiians (Haight *et al.* 1993). The gear consists of a main line constructed of dacron or monofilament with a 2–4 kg weight attached to the end (Figure 3). Several 40–60 cm sidelines with circle hooks are attached above the weight at 0.5–1 m intervals. A chum bag containing chopped fish or squid may be suspended above the highest of these hooks. The gear is retrieved using hydraulic or electric reels after several fish are hooked.

FIGURE 3
Bottomfish terminal rig



Circle hooks are generally used for their self setting ability and their curved design with long inward-facing hook points that make it difficult for the fish to escape once they are embedded. Circle hooks used in the bottomfish fishery are typically flat by design. "Kirbed" hooks (bent or offset to the side) are also available but are not generally used. Flat circle hooks work well for fish that engulf and move off with bait in their mouth. As a fish moves off with the baited hook, the line will trail out of the corner of the fish's mouth. The hook is then drawn to the corner of the mouth where the motion of the fish in relation to the pull of the line will rotate the hook through the corner of the jaw. In addition, circle hooks are less prone to snag on rocky or hard substrate bottoms. This characteristic minimizes the loss of gear (Kawamoto, NMFS, Hawaii, pers. comm.).

All demersal fishermen in Hawaii target the same assemblage of bottomfish species. The ability to target particular species varies widely depending on the skill of each captain. Electronic navigation (GPS) and fish-finding equipment (sonar) greatly aid fishermen in returning to a particular fishing spot and catching desired species with little incidental catch (Haight *et al.* 1993).

3.4.2 Vessels

In contrast to the main Hawaiian island bottomfish fishery, fishing in the NWHI is conducted solely by part-time and full-time commercial fishermen. Vessels in the NWHI tend to be larger than those fishing around the MHI as the distance to fishing grounds is greater (Haight *et al.* 1993).

As the number of vessels participating in the NWHI fishery increased during the 1980s, the fleet characteristics of the fishery became more diverse. Pooley and Kawamoto (1990) divided the fleet into three groups based on size and mode of propulsion: motor sailors, medium-sized powered vessels and large-sized powered vessels. The motor sailors are 46 to 66 ft long and are more streamlined in hull design than the standard powered vessels. The sail can be used to save on fuel, but this limits the hold capacity compared with powered vessels of similar length. The powered vessels generally share one characteristic: a large working area on the aft deck. The medium-sized powered vessels are 42 to 49 ft long. Because their smaller size limits fishing range and hold capacity, they usually operate in the lower (southeastern) end of the NWHI or in the MHI. The larger powered vessels are 47 to 64 ft long. With an average fuel capacity of 1 500 gallons, the vessels have a maximum range (round-trip) of 1 800 miles. The average maximum hold capacity is 15 000 lb.

3.4.3 Fishing strategies

Many boats that fish in the Mau Zone participate in multiple fisheries. The majority of vessels fishing in the Mau Zone are generally active during a season, which extends from November to April.

A 1993 survey of participants in the NWHI fishery found that vessels fishing in the Mau Zone made on average 12.7 trips a year to the area to target bottomfish and 3.4 trips to target pelagic fish or a mixture of pelagic species and bottomfish (Hamilton 1994). In addition, during that year an average of 5.6 trips were made by these vessels to bottomfish fishing grounds around the MHI. Although bottomfish fishing in the Mau Zone is not the only activity of these boats, it may be vital to the successful year-round operations of some fishermen.

Fishing strategies and catches of vessels fishing in the Hoomalu Zone tend to be fairly uniform (Pan 1994). A 1993 survey found that all boats fishing in the Hoomalu Zone were engaged exclusively in commercial bottomfish fishing (Hamilton 1994). They averaged nine trips a year to the zone and the average trip length was about three weeks.

Popular fishing grounds in the Mau Zone include the waters around Nihoa Island and Necker Island. Especially productive fishing areas in the Hoomalu Zone are Brooks Bank, Laysan Island and Gardner Pinnacles. During rough sea conditions bottomfish fishing vessels that take refuge in the relatively sheltered waters around French Frigate Shoals may fish on relatively shallow (10—50 fm) banks (WPRFMC 2000a).

3.4.4 Landings

Virtually all of the bottomfish caught in the NWHI fishery are sold and therefore are required to be reported under State of Hawaii law (Table 2). NWHI bottomfish landings grew dramatically in the mid-1980s and then tailed off, stabilizing in the 1990s at a level slightly below the MHI bottomfish landings.

Beginning in the late 1960s, large catches of armourhead were made by foreign fishing vessels for about ten years until overfishing caused the fishery to collapse. There has never been a domestic seamount groundfish fishery in the US western Pacific region.

TABLE 2
Commercial bottomfish landings in NWHI, 1984-2001

(1 000 lbs = 453.59 kg)

Year	MAU		HO'OMALU		Total	
	lbs	kg	lbs	kg	lbs	Kg
1984	NA	NA	NA	NA	661	300
1985	NA	NA	NA	NA	922	418
1986	NA	NA	NA	NA	869	394
1987	NA	NA	NA	NA	1 015	460
1988	NA	NA	NA	NA	625	284
1989	118	54	184	83	303	137
1990	249	113	173	78	421	191
1991[1]	103	47	283	128	387	176
1992[1]	71	32	353	160	424	192
1993[1]	98	44	287	130	385	175
1994[1]	160	73	283	128	443	201
1995[1]	166	75	202	92	369	167
1996[1]	135	61	176	80	311	141
1997[1]	105	48	241	109	346	157
1998[1]	66	30	266	121	332	151
1999[2,3]	54	24	269	122	323	147
2000[2]	49	22	213	97	262	119
2001	50	23	236	107	286	130
mean	109.38	50	243.54	110	482.33	219
s.d.	57.5	26	53.18	24	234.5	106

3.4.5 Markets

A market for locally caught bottomfish was well-established in Hawaii by the late nineteenth century. Today, fresh bottomfish continue to be an important seafood for Hawaii residents and visitors. Nearly all bottomfish caught in the NWHI fishery are sold through the Honolulu fish auction. Prices received at the auction change daily and the value of a particular catch may even depend on the order in which it is placed on the floor for bidding (Hau 1984). Bottomfish sales have also occurred through less formal market channels, e.g. local restaurants, hotels, grocery stores and individual consumers are important buyers for some fishermen. However, due to new US Food and Drug Administration rules regarding seafood safety and handling, most sales are now primarily channeled through wholesale-type dealers. In addition to being sold, bottomfish are eaten by fishermen and their families, given to friends and relatives as gifts, and bartered in exchange for various goods and services.

Historically, the demand for bottomfish in Hawaii has been largely limited to fresh fish. Seventy years ago Hamamoto (1928) remarked that fish dealers in Honolulu refused to buy fish that had been harvested in the NWHI and frozen on-board because the demand for this product was so low. In the last few years the price differential between frozen and fresh product has narrowed for some species of bottomfish, but it remains substantial for *onaga* and *ehu*, the two highest priced fish. Until the market for frozen bottomfish develops, participants in the NWHI fishery will be caught in the same on-going dilemma – they must stay out long enough to cover trip expenses, but keep the trips short enough to deliver a readily saleable, high-quality product (Pan 1994). In the past, bottomfish catches from the MHI have tended to command higher aggregate prices than those caught in the NWHI, reflecting a larger proportion of preferred species and greater freshness. Bottomfish caught around the MHI are iced for only one to two days before being landed, whereas NWHI fresh catches may be packed in ice for ten days or more. By the late 1990s, however, the prices appeared to converge, perhaps due to the softness of the upscale part of the Hawaii market as the State's economic recession continued (WPRFMC 1999).

Catches of bottomfish around the MHI typically consist of plate-sized fish preferred by household consumers in Hawaii and by restaurants where fish are often served with the head on. Bottomfish caught around the NWHI tend to be the medium to large fish (> 5 lbs) preferred by the restaurant fillet market. Because the edible yield is high, handling costs per unit weight are lower and more uniform portions can be cut from the larger fish.

Pooley (1987) showed that Hawaii auction market prices increase when MHI landings drop. However, during the 1990s the relationship between price and volume faltered, perhaps due to an increase in imported fresh fish that competed in the market with locally-caught bottomfish (WPRFMC 1999). Since 1996, the average annual amount of fresh snapper imported into Honolulu has been 460 343 lbs (20 900 kg), with a free-alongside-ship value of $1 238 548 (NMFS Fisheries Statistics and Economics Division undated). Not only has the quantity of foreign-caught fresh fish increased during the last few years, but the number of countries exporting fresh fish to Hawaii has also increased. A decade ago, for example, fresh snapper was exported to Hawaii mainly from within the South Pacific region. In recent years, fresh snapper has also been received from nations as far away as Vietnam, China and Madagascar.

3.5 Historical participation

Bottomfish fishing was a part of the economy and culture of the indigenous people of Hawaii long before European explorers first visited the islands. Descriptions of traditional fishing practices indicate that native Hawaiians harvested the same deep-sea bottomfish species as the modern fishery and used some of the same specialized gear and techniques employed today (Iversen, Dye and Paul 1990). The *poo lawaia* (expert fishermen) within the community knew of dozens of specific *koa* (fishing areas) where bottomfish could be caught (Kahaulelio 1902). As Beckley (1883:10) noted, each *koa* could be precisely located:

> *"Every rocky protuberance from the bottom of the sea for miles out, in the waters surrounding the islands, was well known to the ancient fishermen, and so were the different kinds of rock fish likely to be met with on each separate rock….[They] took their bearing for the purpose of ascertaining the rock which was the habitat of the particular fish they were after, from the positions of the different mountain peaks."*

European colonization of the Hawaiian Islands during the early nineteenth century and the introduction of a cash economy led to the development of a local commercial fishery. As early as 1832, fish and other commodities were sold near the waterfront in Honolulu (Reynolds 1835). Other fish markets were established on the islands of Maui and Hawaii. John Cobb (1902), who investigated Hawaii's commercial fisheries in 1900 for the US Fish Commission, reported that the bottomfish ulaula, uku and ulua were three of the five fish taken commercially on all the Hawaiian Islands.

Initially, the commercial fishing industry in Hawaii was monopolized by native Hawaiians who supplied the local market with fish using canoes, nets, traps, spears and other traditional fishing devices (Jordan and Evermann 1902, Cobb 1902). However, the role that native Hawaiians played in Hawaii's fishing industry gradually diminished during the latter half of the nineteenth century as successive waves of immigrants arrived in Hawaii. Between 1872 and 1900, the non-indigenous population increased from 5 366 to 114 345 (OHA 1998). Kametaro Nishimura, credited by some to be the first Japanese immigrant to engage in commercial fishing in Hawaii, began his fishing career in the islands in 1885 harvesting bottomfish such as *opakapaka*, *ulua* and *uku* (Miyaski 1973). By the turn of the century, Japanese immigrants to Hawaii dominated the bottomfish fishery using wooden-hulled "sampans" propelled by sails or oars (Cobb 1902). The sampan was brought to Hawaii by Japanese immigrants during the late nineteenth century and over time Japanese boat-builders in Hawaii adapted the original design to specific fishing conditions found in Hawaii (Goto, Sinoto and Spehr 1983). The bottomfish fishing gear and techniques employed by the Japanese immigrants were imitations of those traditionally used by native Hawaiians with slight modifications (Konishi 1930).

During the early years of the commercial bottomfish fishery, vessels restricted their effort to areas around the MHI. Cobb (1902) records that some of the best fishing grounds were off the coasts of Molokai and notes that large sampans with crews of 4 to 6 men were employed in the fishery. Typically, the fleet would leave Honolulu for the fishing grounds on Monday and return on Friday or Saturday. The fishing range of the sampan fleet increased substantially after the introduction of motor powered vessels in 1905 (Carter 1962). Fishing activity was occurring around the NWHI at least as early as 1913, when one commentator recorded: "Fishing for *ulua* and *kohala* is most popular, using *bonito* for bait, fishermen seek this [sic] species in a 500 mile range toward Tori-Jima [NWHI]" (Japanese Consulate (1913), as cited in Yamamoto 1970:107). Within a few years more than a dozen sampans were fishing for bottomfish around the NWHI (Anon. 1924, Konishi 1930). Fishing trips to the NWHI typically lasted 15 days or more and the vessels carried seven to eight tons of ice to preserve their catch (Nakashima 1934). The number of sampans traveling to the more distant islands gradually declined due to the limited shelter the islands offered during rough weather and the difficulty of maintaining the quality of the catch during extended trips (Konishi 1930). However, during the 1930s at least five bottomfish fishing vessels ranging in size from 65 to 70 ft continued to operate in the waters around the NWHI (Hau 1984). In addition to catching bottomfish, the sampans harvested lobster, reef fish, turtles and other marine animals (Iversen *et al.* 1990).

During World War II the bottomfish fishery in Hawaii virtually ceased, but recommenced shortly after the war ended (Haight *et al.* 1993). The late 1940s saw as many as nine vessels fishing around the NWHI, but by the mid-1950s vessel losses and depressed fish prices resulting from large catches had reduced the number of fishery participants. During the 1960s, only one or two vessels operated around the NWHI.

There was renewed interest in harvesting the bottomfish resources of the NWHI in the late-1970s following a collaborative study of the marine resources of the region by state and federal agencies (Haight *et al.* 1993). The entry of several modern boats into the NWHI fishery and the resultant expanding supply of high-valued bottomfish such as *opakapaka* and *onaga* made possible the expansion of the tourism-linked restaurant market by providing a regular and consistent supply of relatively fresh fish (Pooley 1993a). Markets for Hawaii bottomfish further expanded after wholesale seafood dealers began sending fish to the US mainland. By 1987, 28 vessels were active in the NWHI bottomfish fishery, although only 12 fished for bottomfish full time (Table 4). Some of the part-time vessels also engaged in the pelagic or lobster fisheries (Iversen *et al.* 1990). In 1989, the Council developed regulations that divided the fishing grounds of the NWHI bottomfish fishery into the Hoomalu Zone and Mau Zone. Limited access programmes were established for the Hoomalu Zone and Mau Zone in 1988 and 1999, respectively, to avoid economic overfishing (Pooley 1993b, WPRFMC 1998).

TABLE 4
Number of vessels in the NWHI bottomfish fleet, Mau and Hoomalu zones

Year	Boats Mau	Hoomalu	Total[2]
1984	NA	NA	19
1985	NA	NA	23
1986	NA	NA	24
1987	NA	NA	28
1988	4	12	13
1989	5	5	10
1990	14	5	16
1991[1]	14	4	17
1992[1]	8	5	13
1993[1]	8	4	12
1994[1]	12	5	16
1995[1]	10	5	15
1996[3]	13	3	16
1997[3]	9	6	15
1998[2]	7	6	13
1999[3]	7	6	13
2000[3]	6	5	11
2001[3]	6	5	11
mean	8.79	5.43	15.83
s.d.	3.33	2.06	4.89

[1] Based on a combination NMFS and HDAR data set.
[2] Total may not match sum of areas due to vessel participation in multiple areas.
[3] Based on HDAR data.

Since the NWHI bottomfish fishing grounds were divided into the Mau Zone and Hoomalu Zone in 1988; the Mau Zone has generally seen a greater share of the fishing effort as access to the Hoomalu Zone was restricted under a limited access programme (WPRFMC 1999). Since 1989, 17 permits to fish in the Hoomalu Zone have been issued, of which 15 have been used. In comparison to the Mau Zone, the Hoomalu Zone exhibits more continuity in participation, but the turnover has still been fairly high. Only about half of the active vessels fished in the Hoomalu Zone for more than two years.

Only five vessels harvested bottomfish in the Mau Zone in 1989, but during the 1990s an average of ten vessels fished in the area. The amount of effort (fishing days) expended in the Mau Zone has fluctuated along with the number of active vessels. Mau Zone activity levels peaked in 1994 with a total of 594 fishing days as a result of a combination of a relatively large fleet size and intensive activity by each vessel.

Eighty-one permits to fish in the Mau Zone have been issued since 1989, but only 37 of the permits were used. The turn-over rate has been high, with only 38 percent of the 37 active vessels fishing in the Mau Zone for more than two years. A limited access programme was established for the Mau Zone in 1999 and currently ten vessels are allowed to fish in the area. Permits to fish in the Mau Zone are non-transferable and are subject to a'use-it-or-lose-it' requirement. At present, there is no procedure for issuance of new Mau Zone limited access permits. However, the Council approved a procedure based on historical participation in the MHI and NWHI fisheries and is preparing the final transmittal document for Secretarial review and approval.

4. PRESENT ISSUES AND FUTURE CHALLENGES

4.1 NWHI reserve and sanctuary designation

An area of controversy involves the relationship between fisheries in the Northwestern Hawaiian Islands managed under the Bottomfish FMP and restrictions on fishing imposed by the Presidential Executive Orders creating the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve. In May 2000, President William Clinton issued a Memorandum stating that it is time to implement the Coral Reef Task Force's recommendations to ensure the comprehensive protection of the coral reef ecosystem of the Northwestern Hawaiian Islands (NWHI)[1]. The Reserve was established by E.O. 13178 of 7 December 2000 and included certain conservation measures and Reserve Preservation Areas that are either completely closed to fishing or within areas where fishing is curtailed. Bottomfish conservation measures included grandfathering of existing permits holders as of December 2000, individual harvest limits and closed areas. The EO was revised and finalized by EO 13196, issued 18 January 2001. Further, the Secretary of Commerce was directed by the *National Marine Sanctuaries Act Amendments* of 2000 to initiate the process to designate the Reserve as a National Maine Sanctuary and, as required, has initiated this process. The National Marine Sanctuaries Office is in the process of developing management alternatives, including that for bottomfish, to be considered in the environmental impact statement for the designation of a NWHI Coral Reef Sanctuary.

4.2 Overfishing Control Rule

The final rule implementing new biomass-based Overfishing/Control rules for bottomfish resources under the Council's FMP was published in the Federal Register in August 2003. The Bottomfish Plan Team projected, based on existing estimates of catch per unit effort and maximum sustainable yield, that the "overfishing" threshold (effort component of the control rule) for the archipelagic bottomfish stocks may be exceeded. The Council is now working with the State of Hawaii and NMFS to validate current MSY estimates and refine and standardize catch per unit effort to reflect changes in fleet characteristics over time. In addition, the effects of recently established marine protected areas on how the status of stocks are evaluated must be assessed.

The Council will also be working with the Hawaii Institute of Marine Biology to conduct genetic studies on *onaga and ehu* to determine stock structure throughout the archipelago. A similar study was recently completed on *hapuupuu*, which suggested that genetic differences may exist along the Hawaiian archipelago. The Council is seeking funding to support the laboratory analysis component of the project and partners from agencies and industry to obtain fin clip samples from locations throughout the archipelago and other parts of the Pacific.

The Council, NMFS and State of Hawaii will host a stock assessment workshop on 13–16 January 2004 at the Council office to determine the status of Hawaii bottomfish stocks. The objective of the workshop is to develop a plan to improve data collection and assessment methodology to a point where reliable resource assessments can be obtained. Accordingly, the workshop will (a) evaluate existing biological, oceanographic and fisheries data as well as stock assessment systems relating to bottomfish resources in Hawaii and the other US island areas, (b) identify weaknesses and inadequacies in current assessment methods and supporting data, (c) review alternative approaches to modeling and stock assessments and (d), propose a course of action to improve stock assessment methods and associated data

[1] The President's directive coincided with Executive Order 13158, which requires federal agencies to establish a comprehensive national network of marine protected areas (MPAs) throughout US marine waters. The executive order calls for expansion of the nation's MPA system to include examples of all types of US marine ecosystems. According to the executive order, a MPA means any area of the marine environment that has been reserved by federal, state, territorial, tribal or local laws or has regulations to provide lasting protection for part or all of the natural and cultural resources therein.

4.3 Ecosystem-based management

4.3.1 Policy Directions

Integrating ecosystem principles into fishery management plans and developing ecosystem-based management regimes is identified as one of the highest priorities for the National Oceanographic and Atmospheric Administration (NOAA 2003). The Council has led the way in this effort by implementing the first ecosystem-based plan – the Coral Reef Ecosystem FMP. Efforts will now focus on integrating ecosystem principles into existing plans, such as the Bottomfish FMP. Efforts will focus on trophic level interactions, mitigating bycatch, reducing impacts to habitat and, in particular, avoiding protected species interactions.

4.3.2 Bycatch

The *Magnuson-Stevens Act* direct Councils, "to the extent practicable, (A) minimize bycatch and (B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch". Bycatch is defined as any fish that is returned to the sea – no matter if it is dead, alive or damaged. Given this definition, fishermen in the Pacific Ocean who return live fish or participate in conservation efforts, such as tag and release programmes, compromise National Standard 9, which is intended to reduce bycatch. This is not true for Atlantic Ocean fisheries, which are exempt from this standard. The Council is working with NMFS and Congress to correct this problem.

Being a hook and line rig, the gear used is relatively selective, with the ability to successfully target particular species groups dependant upon the skill of the fisher. Experienced vessel crews are able to catch the desired species with little bycatch, however, it is impossible to completely avoid non-target species.

Logbook data and research programmes conducted by the State of Hawaii and the NMFS indicate that bycatch accounts for approximately 8–19 percent of the total catch in bottomfish fisheries in the Hawaiian archipelago. Sharks, oilfish, snake mackerel, pufferfish and moray eels are the most numerous discard species and not kept by vessels because ther are unpalatable. Other reasons for discards include concerns for ciguatoxic poisoning, economic factors, product shelf-life and fish damage. The major discard species in the NWHI bottomfish fishery are given in Table 5.

TABLE 5
NMFS logbook estimates of discards in the NWHI deepwater bottomfish fishery, 1997

Scientific name	Common name	Number discarded
Seriola dumerilli	amberjack	2 120
Caranx ignobilis	black trevally	1 298
P. filamentosus	pink snapper	215
Charcarhinidae	misc. sharks	166
Epinephelus quernus	seabass	114
Etelis carbunculus	red snapper	98
P. zonatus	yellowband snapper	98
Aprion virescens	jobfish	87
Pristipomoides auricilla	yellowtail snapper	19
Carangidae	misc. jacks	7
Galeocerdo cuvier	Tiger shark	5
Aphareus rutilans	red snapper	2

The largest component of the releases is that of *kahala* (*Seriola* spp.). *Kahala* was once an important commercial species, but due to the presence of ciguatoxin in some fish it has not been sold for many years due to liability concerns. It is thought that since *kahala* are caught in such large numbers while fishing for the targeted species their population represent competition for food and habitat resources. Large kahala are also known to feed on the valuable bottomfish species, often stealing them off the hooks and thus contributing to the inefficiencies of the fishing operations. The fishermen release the majority of kahala they catch although they may from time to time use them as bait or chum. Releases can be either live or dead depending on the preference of the captain. The percentage of live releases to dead releases is unknown. Many of the NWHI captains voluntarily participate in the State of Hawaii's *ulua* tagging study and routinely tag many *kahala* and other *jacks*.

Conservation, or stock related releases, are another component of the release strategy employed by the fishermen. The NWHI fishermen have been releasing a low number of small-sized high-value BMUS species live such as *onaga, opakapaka, ehu* and *uku*. Large numbers of various commercially low-valued species (ie., *butaguchi, kalekale* and *white ulua*) are also released live to reduce and minimize waste of fishery resources.

4.3.3 Impacts of habitat

Bottomfish gear has limited impacts on fish habitat. Habitat damage may occur from deployment of anchors during deepwater fishing activities. However, impacts are highly localized as the targeted fishing habitat is focused primarily on the 200 m contour areas with high relief. Anchoring positions during such fishing operations would generally be at depths from 60–350 m (30 to 175 fm). Reef building corals are generally not found below 100 m, the lower extent of light attenuation. It is estimated that suitable bottomfish habitat where vessels might anchor represents approximately one percent of the total bank habitat. Shallow water bottomfish activities are conducted while drifting, therefore minimizing the potential for anchor damage.

The National Marine Fisheries Service, State of Hawaii Division of Aquatic Resources and Hawaii Undersea Research Laboratory have conducted a series of submersible dives on bottomfish habitat in the main and northwestern Hawaiian islands. Evidence of fishing related impacts on habitat in the NWHI has not been observed to any significant extent.

4.3.4 Protected species considerations

Concerns have been raised about the possible effect of the Northwestern Hawaiian Islands bottomfish fishery on populations of the Hawaiian monk seal through competition for bottomfish resources. Monk seals, which are listed as endangered under the US Endangered Species Act, are opportunistic feeders, consuming a wide variety of prey items. There does not appear to be any geographic correlation between areas heavily fished for bottomfish and declining monk seal populations. On the other hand, the relative importance of bottomfish in the monk seal diet is poorly understood. The NMFS is conducting research using fatty acid analysis to determine if, and to what extent, bottomfish is an important component in monk seals' diet.

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Assessment and management of snappers in the tropical Australasian region

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We review our experiences on biology, stock differentiation and commercial potential of snappers in three study areas:

i. an *Etelis carbunculus* fishery off the west coast of Australia
ii. shared snapper stocks (*Lutjanus malabaricus, L. erythropterus* and *Pristipomoides multidens*) between Indonesia and Australia and
iii. Etelis, *Pristipomoides* and *Lutjanus* spp. off Lihir Island, Papua New Guinea.

In some cases, we collected critical population dynamics information in order to undertake stock assessments. Even so, the information base for stock assessment was often weak. For example, ageing of these tropical species is difficult commercially, artisanal data in some regions are incomplete and juvenile animals were under-represented as their nursery grounds were difficult to identify. Although the general life-history parameters known for these species were found to be applicable, key population dynamic parameters described for the same species from elsewhere in the tropics were not transferable to the study areas. Growth rates and reproductive activity show significant regional variation. Further, the deep trenches between the Indonesian islands increase the potential for stock differentiation. Some of these species are unproductive. Based on these findings, the stock assessments confirmed that many of these fisheries are not able to maintain medium to large-scale fisheries and need to be carefully managed.

Ruby snapper (*Etelis carbunculus*) is a deepwater species, preferring continental shelf regions. In the northern part of Western Australia, it is targeted by a trawl fishery that from 1997 to 2001 showed strong declines in catch rates. A robust estimate of stock size and maximum sustainable yield could not be obtained with the available data through a biomass-dynamic model. Through a yield-per-recruit analysis, the optimal legal size at first capture was 56 cm. There was a lot of uncertainty associated with this figure. The main reason was the unreliability arising from using growth and natural mortality parameters from other parts of the world. Two very different growth curves for the same species exist from Hawaii and Vanuatu, which produce completely different sets of management recommendations.

The stocks of red and gold-band snappers that are exploited by Australia in the Australian zones of the Timor and Arafura Seas are shared with Indonesia (and East Timor). Indonesian fishers also exploit other genetically distinct stocks of these species. The genetic mtDNA studies demonstrated that there are two stocks of *L. malabaricus* in the region, two stocks of *L. erythropterus,* and at least six separate genetic stocks of *P. multidens*. Electrophoretic studies of allozymes supported the mtDNA studies, but suggest that the Arafura stock of *L. malabaricus* might be starting to differentiate. The results of the parasite studies and otolith microchemistry were consistent with those

of the electrophoretic and mtDNA studies and confirmed that there is relatively little mixing of *L. malabaricus* or *L. erythropterus* from different parts of the Arafura Sea.

Studies of the growth of *L. erythropterus* and *L. malabaricus* used the counts of annuli on both whole and sectioned otoliths as alternative proxies for age and thereby determined age compositions of the sampled fish and growth curves for these two species. Growth studies were undertaken on *P. multidens* using sectioned otoliths as a proxy for age to determine growth curvesand age composition for this species. Studies of reproductive biology demonstrated that *L. malabaricus* is a serial spawner that breeds throughout the year, but exhibits a peak in spawning activity between November and March, while *L. erythropterus* has a peak spawning activity which slightly precedes that of *L. malabaricus*. Both species mature at about 300 mm SL, i.e. at about 3 years of age. *P.multidens* is also a serial spawner. Size at maturity was around 295 mm SL. Prior to this study, juveniles of *L. erythropterus* and *L. malabaricus* had been misidentified. With the advantage of knowing the precise identity of each individual juvenile fish based on a genetic analysis, it is now possible to discriminate between the different species for fish > 30 mm SL using morphometric data. Juveniles of *L. erythropterus* were caught in sampling surveys using trawl fishing in depths of between 4 and 7 m in two bays near Darwin. The data suggest that the juveniles are associated with bottoms with rocks, coral rubble, sponges or gorgonians.

A socio-economic study formed part of the Australia-Indonesia snapper project and has resulted in improvements in the Indonesian licensing system for vessels greater than 30 gross tons. The study determined that the Indonesian snapper fishery comprises the following.

i. A small-scale artisanal fishery that uses bottom longlines, droplines and operates in waters down to 100–150 m depth within the 12 mile limit from the coastline.
ii. A semi-industrial or industrial-scale fishery of about 500–600 boats that fish using bottom longlines, droplines and lines in waters of 100–200 m depth or in areas of untrawlable bottom near the coastline.
iii. A much larger industrial-scale trawl fishery of around 700 boats that operate in the Arafura Sea and transfer frozen catches directly to export carrier ships. These vessels are often re-flagged Thai trawlers with Thai crews. The product from this fishery is shipped directly overseas without landing in Indonesia. Value adding occurs outside Indonesia. Thus, there is little economic return to Indonesia from the Indonesian trawl fleet.

The Australian snapper fishery is relatively small and comprises the Northern Territory fishery, which has moved towards the use of traps and a limited trawl fishery consisting of about four boats in the Gulf of Carpentaria.

The main objectives of this section of the study at Lihir Island in Papua New guinea were to, (a) determine the species composition and distribution of the deepwater fish around the Lihir Island group and identify species of commercial interest, (b) assess the suitability of using otoliths as a reliable method for ageing tropical fish around Lihir, (c) estimate age, growth and mortality for each species and (d), determine fish stock size and potential fishery yields.

Growth rates for the fish around the Lihir Island group were comparable to those found by other studies on these deepwater species. Total mortality estimates were low compared to other studies, but the natural mortality estimates were generally equal to, and in some instances, higher than our total estimated mortality from catch curve data, suggesting that the estimates of total mortality may be underestimated or that fish stocks around Lihir are only lightly exploited. However, results obtained from artisanal fishing surveys indicate that the deepwater fish stocks are already heavily exploited by the artisanal fishery.

We identified 17 species of deepwater fishes, many of them lutjanids, that would be suitable for commercial fishing around the Lihir Island group, but catch rates for these species were low compared to commercial and exploratory fishing catches in other tropical regions. Catch rates around the islands were also highly variable and few species showed consistent catches over even short fishing durations. The Lihir Island group has limited deep-slope habitats and are relatively isolated with few alternative fishing grounds in close vicinity, so there is little opportunity to rotate to other fishing grounds when one area becomes overexploited. Therefore, these deepwater species are highly susceptible to overfishing by even only moderate commercial fishing effort. Fish biomass was estimated by extrapolating mean catch rates and estimated 'effective fished area' to the total habitat area around these islands. For comparison with our results, we also applied the Polovina and Ralston method. The two methods resulted in different biomass estimates of 121 tonnes and 17.5 tonnes respectively for all commercial species. This generated widely variable sustainable yields for the commercial fish stocks. We consider that the Polovina and Ralston method more accurately describes the true stock size of these deepwater fishes around Lihir and indicates a conservative annual sustainable yield of only 965 kg.

Azorean deepwater fishery: ecosystem, species, fisheries and management approach aspects

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1. INTRODUCTION

"Deepwater species" is a new term describing species caught at great depths. The definition does not rely on fisheries but on the frontier between demersal and deepwater species and is not well defined. For example, the FAO has defined "deepwater" as species caught off-shelf and deeper than 200 m and ICES, from greater than 400 m in depth. The term "deepwater fishery" is usually used in the context of the new, industrial fisheries of the developed countries such as that for orange roughy (*Hoplostethus atlanticus*). However, deepwater species cover a huge number of species, which include species caught by traditional large-scale fisheries on slope areas, e.g. Greenland halibut (*Reinhardtius hippoglossoides*) and redfish (*Sebastes* spp.) and species caught on the continental shelf but whose distribution extends to deeper waters, e.g. anglerfish and megrim caught by the traditional small-scale fisheries in island regions such as the Azores, Madeira and Canaries – where there is no shelf.

Interest in deepwater species in the Atlantic has arisen recently because of the declines in the more traditional fisheries and the consequent increasing exploitation of fish stocks in deeper waters. Concerns exist because experience in other parts of the world has shown that new fisheries can develop rapidly and the resources are vulnerable to overfishing. Assessments of the most important commercial deepwater species in the North Atlantic are made by the ICES Working Group on Biology and Assessment of Deep-sea Fisheries Resources (WGDEEP) (ICES 2004). However, some traditional species, which may be considered as deepwater, are also subject to assessment by other ICES working groups.

Management measures for these resources have been recently introduced by the European Community under the Common Fishery Policy. However, conflicting management options arise related to the interaction between fisheries (shelf, slope and deep species definition), fishing areas (European Union versus international fleets) and resource access under the context of the traditional large-scale versus small-scale fisheries options.

In this paper we attempt to describe the deepwater fishery of the Azores Archipelago as a case study of a North Atlantic small-scale deepwater fishery where the problems described above arise.

2. THE AZOREAN ECOSYSTEM

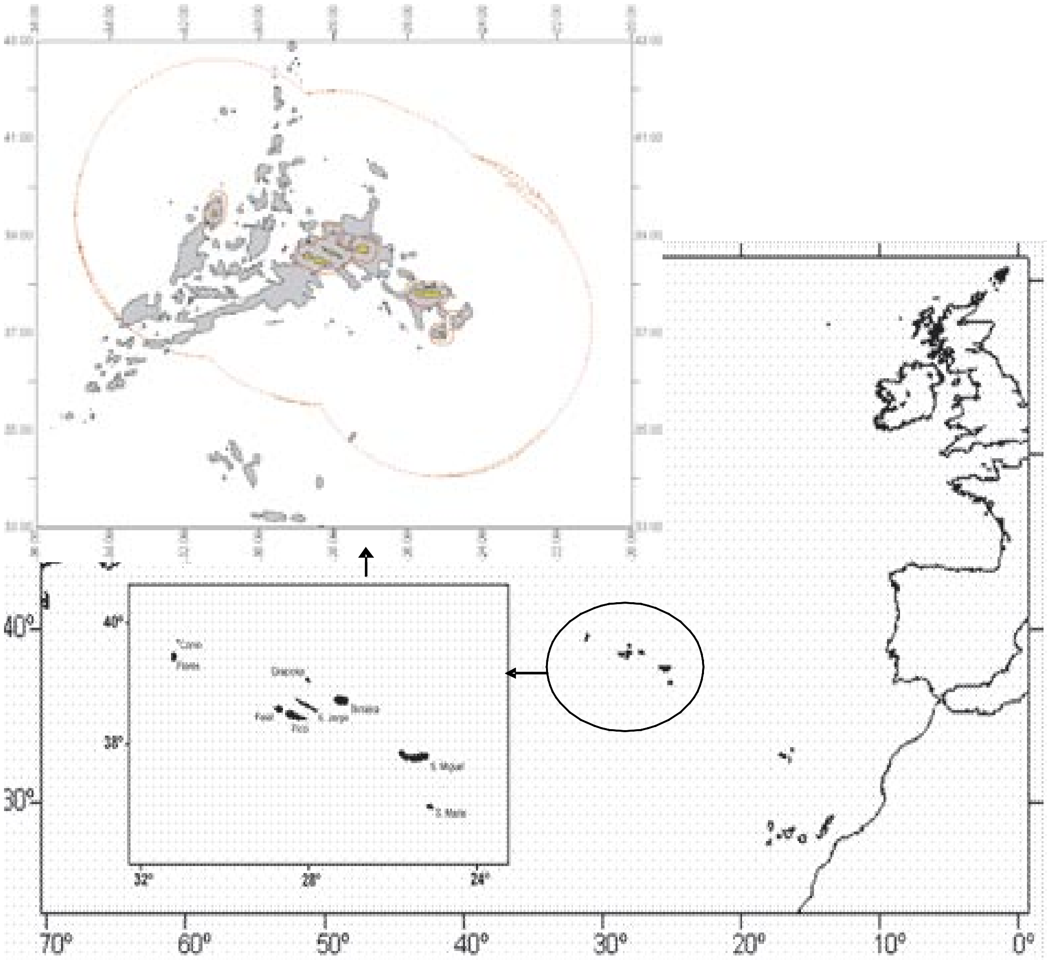
The Azores archipelago is located on the mid-Atlantic ridge at the juncture of three main tectonic plates. The archipelago consists of nine volcanic islands forming three groups, running from WNW-ESE between 37° and 40° N latitude, 25° and 32° W longitude (Figure 1).

The land area of the archipelago is 2 344 km² and the marine exclusive economic zone (EEZ) is 948 439 km² (Instituto Hidrográfico 1981). The marine topography is highly variable, characterized mainly by rocky bottoms where there is no continental shelf and sedimentary areas are scarce (Figure 1) (Martins 1986, 1987). Compared to other archipelagos, the Azores have a fairly recent origin in geological terms having, therefore, small or thin sea bottoms and steep sea floors around the islands. These impose great limitations to the distribution of the marine organisms that live in the more productive and shallower areas.

FIGURE 1

The Azores archipelago showing potential fishing areas

Grey areas represent the 1 500 m contour and the red lines the 12 miles and 200 miles zones.



The Azores have been classified as a temperate warm or subtropical region (Gorshkov 1978). Ocean circulation around the Azores is complex and not well understood (Juliano 1989, 1994, Alves 1990, Santos *et al.* 1995). The surface is dominated by the Gulf Stream water mass flowing from the west, approximately at 40° N which then splits into the North Atlantic current and the Azores current. Each of these currents divides into two further branches. The actual system is more complex because it may change during the year affected by the complex bottom topography of the Azores (see Juliano 1994, Santos *et al.* 1995). Overall, the general current flow is west to east.

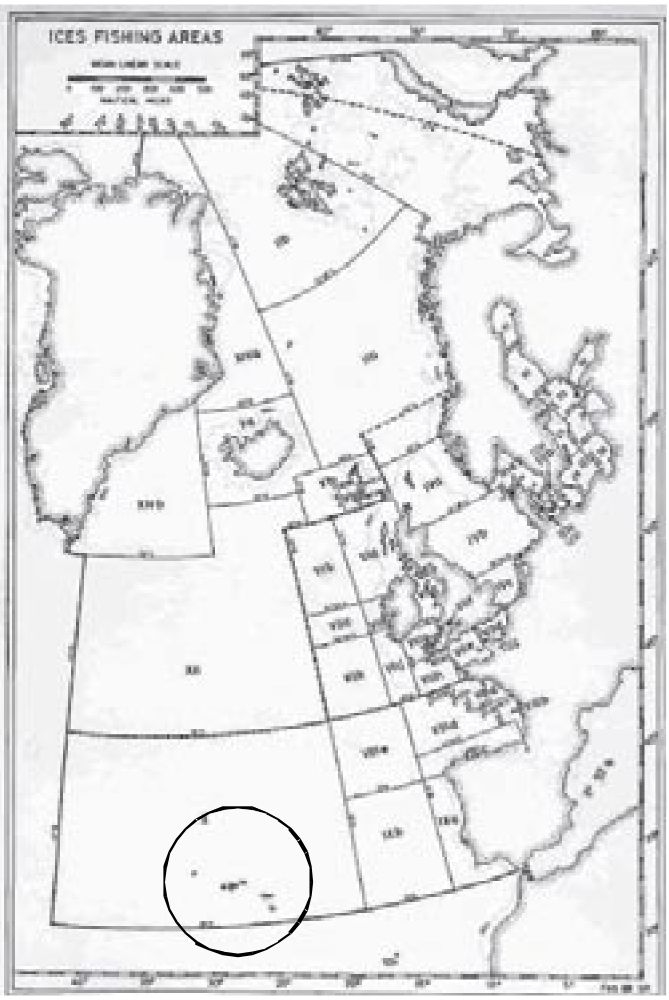
However, despite the dominance of the oceanic system from the west, marine littoral flora and fauna have more affinities with the Eastern Atlantic (Santos *et al.* 1995), showing the complexity of the Azorean ecosystem. About 460 fish species have been identified as occurring in the Azores, (Santos, Porteiro and Barreiros 1997) but endemic fish species are almost absent. Thus, the Azores region has been described as a “cross-road” where fauna and flora from different origins meet and serves as a “stepping-stones” area for dispersion of organisms.

The marine Azores environment is considered to be a deepwater fisheries area characterized by narrow island coastal areas (the strata from 0 to 1 000 m represents about one percent of the total EEZ area); seamount (including knolls, hills or guyots) areas (strata from 0 to 1 000 m) represent about two percent of the total EEZ (Martins 1986, Isidro 1996, Menezes 2003, Pinho 2003). Areas down to 1 000 m, considered as less productive for fisheries, represents about 97 percent of the total EEZ. The interactions between coastal areas and the different seamounts are not yet well understood.

This deepwater ecosystem is complex because of the particular features and interactions of the different dynamic areas. The dynamics of some areas, such as seamounts, are in general poorly known (Rogers 1994).

The Azores is at the limit of the ICES statistical area, ICES Area X (Figure 2), which corresponds to an area of environmental and faunal transition in the Atlantic North (40°–50° N) and therefore are close to the limits of the distribution (North and, or, South) of many species, such as tunas and some demersal and deepwater species. The ecosystem is even more complex when the Azores is considered in the context of the Mid-Atlantic Ridge (MAR) and North Atlantic ecosystems.

FIGURE 2
ICES statistical areas
The Azores archipelago (ICES area X) is marked on the map.



3. STRUCTURE OF DEEPWATER SPECIES

Here, deepwater species are defined as those species occurring below 200 m though ICES defines them as those species occurring below 400 m. In the Azores it is quite difficult to use this definition because some important fishery species are distributed through all strata, as is the case for the important commercial species, blackspot bream (*Pagellus bogaraveo*). Further, because the archipelago is a natural deepwater ecosystem all “demersal species” may be considered a deepwater fishery.

In the Azores area most of the commercial species are found to 1 200 m. Three main species assemblages have been identified for the deepwater community according depth: shallow (0–200 m), intermediate (200–600) and deep (600–1 200) (Menezes 1996, 2003) (Table 1).

4. STRUCTURE OF THE FISHERY

In the Azores one finds, in general, four main fisheries: (a) Small pelagic (for *Trachurus picturatus* and *Scomber japonicus*) using small open-deck vessels less than 12 m operating with small nets (Fernandes 1994, Isidro 1996, Pinho, Pereira and Rosa 1995); (b) a tuna fishery using pole-and-line operating on bait boats (>18 m) from March to October (Pereira 1995); (c) a "demersal and deepwater" fishery using hook gears (hand lines and deep longlines) operating from small open-deck vessels (<12 m) and closed-deck vessels (>12 m) (Menezes 1996, Pinho 2003). More recently (1987) a fishery for swordfish (*Xiphias gladius*) has developed using surface longlines and operating from open- (<12 m) or closed-deck vessels (>12 m) (Simões 1995, Silva and Pereira 1999).

Other small fisheries can be defined such as those targeting squids and octopi using traps (Porteiro 1994, Carreira 2000), kitefin shark (*Dalatias licha*) using gillnets and hand lines (Aires da Silva and Pinho 2003), a crustacean fishery using traps and targeting lobsters (*Palinurus elephas*, *Scylarides latus*), crabs (*Cancer bellianus*, *Chaceon affinis*) and shrimps (*Plesionika* sp. and *Heterocarpus* sp.) (Pinho *et al.* 2001a, b, c) and other littoral fisheries such as for limpets (*Patella* sp.) (Ferraz *et al.* 1999) and seaweeds.

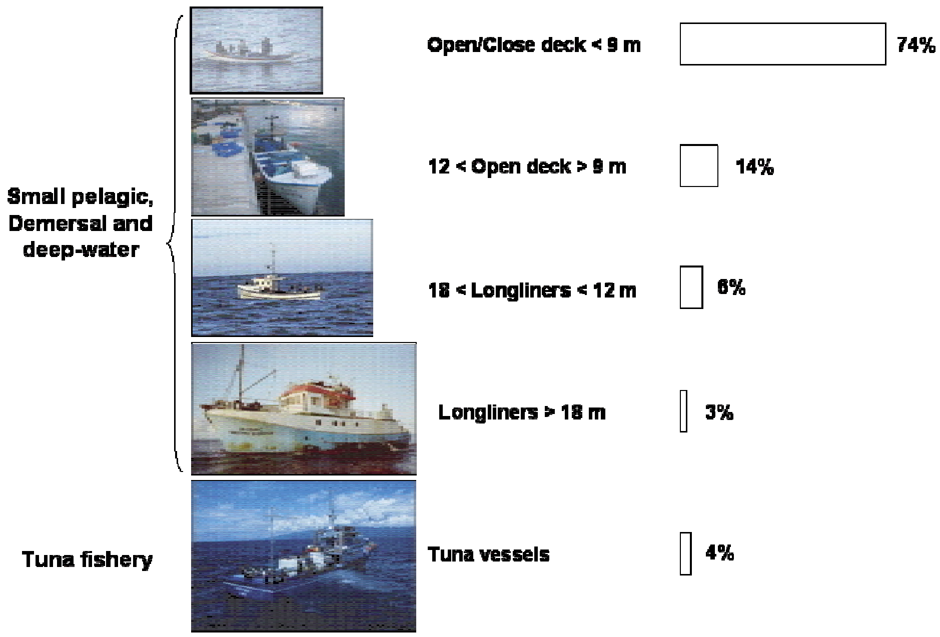
This division is subjective and must be considered flexible because vessels can be classified into more than one gear component. Vessels are in general licensed for more than one gear. For example some demersal deepwater vessels also target swordfish during autumn. Tuna vessels also catch small pelagic and demersal fishes for bait and crustacean vessels operate in the demersal fishery during the winter (the closed season for crustaceans). Thus, in this sense almost all of the Azorean fleet can be considered as a deepwater fishery.

In the Azorean fleet we can identify three main components: (a) artisanal open-deck vessels, characterized by a mean length less than 12 m and a gross registered tonnage (GRT) <50 ton, (b) artisanal closed-deck vessels, with mean lengths less than 18 m and a GRT <50 ton and (c), the industrial vessels with mean lengths greater than 18 m and a GRT >50 ton (Figure 3).

The operational regime of each vessel type varies considerably. Small open-deck vessels usually operate in areas near the coast, using mainly hand lines. They make daily trips and target mainly shallow (<200 m) and intermediate (200–600 m) depth species (see Table 1). Some open-deck vessels (9–12 m) based in St Miguel Island operate in a larger area including banks near the coast (to 50 nm). Small closed-deck vessels are considered the main component of the fleet targeting deepwater species and cover almost all areas and strata. They use mainly deep longlines and hand lines, operating in areas near the coast and in the banks and seamounts. These vessels operate in all strata but preferentially target species from 200–600 m strata, making on average three-day fishing trips, with one set a day, though occasionally more using from eigth to ten thousands hooks a set. Industrial vessels operate mainly on banks and seamounts, using deep longlines. They usually fish in the intermediate and deepwater strata. These vessels make trips, on average of seven days, with one (or more) sets a day of about 14 000 hooks.

The fleet has developed over time with significant changes in their operational regime and fishing effort due to the construction of the new vessels since the 1980s and the introduction of deep longlines (Figure 4). During the year the operational regime of the fleet changes among vessels, fishing areas and gears, and targeting of different groups of species. The target species of the "demersal-deepwater" fishery is the blackspot seabream, and the fleets' operations change throughout the year according to the distribution of this species in time and space.

FIGURE 3
Structure of the Azorean fleet
Classification by size of the vessels and proportion of each component is presented.



5. LANDINGS

The demersal deepwater species are the second most important fishery of the Azores after the tuna fishery and recently have been the most important fishery in terms of weight (Figure 5). Total landings increased until the 1993, with a decadal rate of increase of about 1 000 t, decreasing thereafter. Globally the demersal/deepwater fishery generated an ex-vessel income of about € 12.5 millions.

The Azorean demersal deepwater fishery includes more than 20 families. Blackspot seabream is the main target species, dominating landings by weight and value (Figure 6). Other species are also commercially important and caught simultaneously. The ten top species fished during 1990–2003 were bluemouth (*Helicolenus dactylopterus*), conger eel (*Conger conger*), wreckfish (*Polyprion americanus*), forkbeard (*Phycis phycis*), alfonsinos (*Beryx* sp.), red porgy (*Pagrus pagrus*) and silver scabardfish (*Lepidopus caudatus*).

Landings increased until 1990–93 with a greater increase in the intermediate (200–600 m) and deep (>600 m) strata species, i.e. for conger eel, bluemouth, wreckfish, alfonsinos and mora. Landings of the traditional coastal species, e.g. forkbeard or red porgy, maintained the same level or decreased significantly during this period. A short-time exponential increase of silver scabbardfish during the 1990s was followed by a dramatic fall. Landings of deep-strata species, e.g. mora, deepwater sharks (*Centrophorus* sp. and *Deania* sp.) and black scabbard fish (*Aphanopus carbo*) started to increase slowly recently, indicating that the fishery is expanding to deeper waters. The same trend is observed in landings by value, i.e. they increased until 1993 and were stable or decreased thereafter. Thus prices increased as the landings in weight decreased.

TABLE 1
Deepwater species assemblage

Roman numbers means a defined depth assemblage. "A", "B" and "C" refer to a more homogeneous assemblage, defined for example by common habitat type. Only species that occur regularly on the annual Azorean spring long line survey where used on the analysis.

Assemblage	Species	Common name		Strata*
		(English)	(Portuguese)	
I A	*Pagellus acarne*	Axillary sea-bream	Besugo	Shallow
	Pagrus pagrus	Red porgy	Pargo	Shallow
	Serranus atricauda	Blacktail comber	Garoupa	Shallow
	Galeorhinus galeus	Tope	Cação	Shallow
I B	*Phycis phycis*	Forkbeard	Abrótea	Shallow
	Muraena helena	Moray eel	Moreia	Shallow
	Aspitrigla cuculus	Red gurnard	Ruivo (cabrinha)	Shallow
	Raja clavata	Thornback ray	Raia lenga	Shallow
I C	*Trachurus picturatus*	Jack mackerel	Chicharro	Shallow
	Scomber japonicius	Chub mackerel	Cavala	Shallow
-	*Scorpaena scrofa*	Red scorpion-fish	Rocaz	Shallow
	Boops boops	Bogue	Boga	Shallow
	Diplodus sargus cadenati	White sea bream	Sargo	Shallow
II A	*Pagelus bagaraveo*	Blackspot seabream	Goraz	Intermidean
	Pontinus kuhlii	Offshore rockfish	Bagre	Intermidean
	Lepidopus caudatus	Silver scabbardfish	Pexe espada branco	Intermidean
	Conger conger	Conger eel	Congro	Intermidean
IIB	*Helicolenus dactylopterus*	Bluemouth	Boca negra	Intermidean
	Deryx decadactylus	Alfonsino	Imperador	Intermidean
II C	*Phycis blennoides*	Greater forkbeard	Abrótea do alto	Intermidean
	Coelorhynchus coelorhynchus	Black spot grenadier	Rato bicudo	Intermidean
	Beryx splendens	Golden eye perch	Alfonsim	Intermidean
	Nezumia aequalis	Smooth grenadier	Rato redondo	Intermidean
-	*Polyprion americanus*	Wreckfish	Cherne	Intermidean
III A	*Synaphobrancus kaupi*	Kaup´s arrowtooh eel	Congrinho	Deep
	Mora moro	Mora	Melga	Deep
	Deania calceus	Shovel nosed shark	Sapata	Deep
	Daenia profundorum		Sapata	Deep
III B	*Etmopterus spinax*	Velvet belly	Lixinha da fundura	Deep
	Etmopterus pusilus	Smooth lantershark	Lixinha da fundura	Deep
-	*Epigonus telescopus*	Deep-sea cardinal fish	Escamuda	Deep
	Molva dipterygia macrophthalma	Blue ling	Pescada	Deep
	Serranus cabrilla	Comber	Garoupa do alto	Deep
	Aphanopus carbo	Black scabbard fish	Peixe espada preto	Deep

* Shallow <200 m; 200 m < Intermidean <600 m; Deep >600 m

FIGURE 4
Annual proportion of species by strata (shallow, intermediate and deep) landed by the bottom longliners
Graphs constructed selecting, from DOP database, only landings by vessel with more than 50% of target species considered as demersal/deepwater.

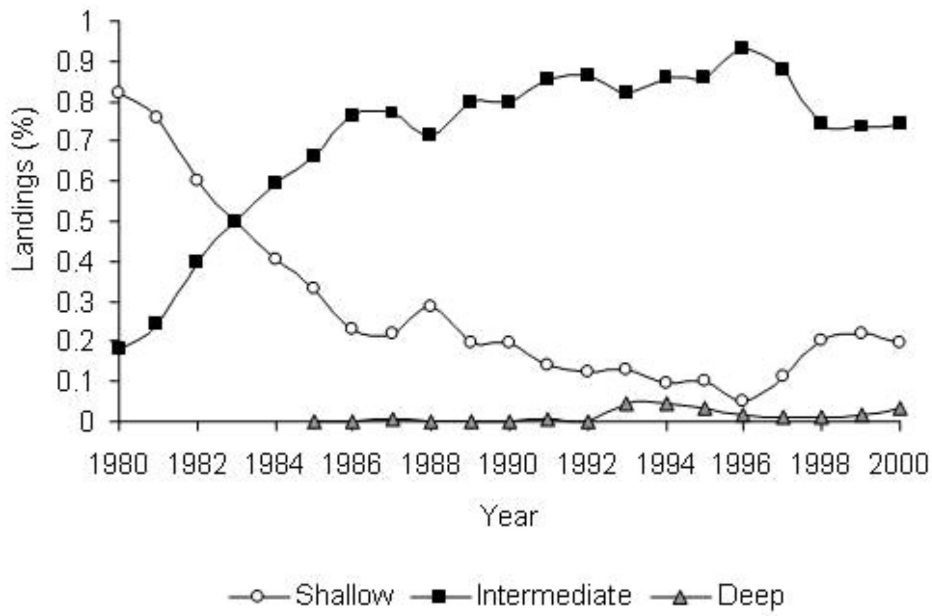


FIGURE 5
Landings in weight by the Azorean fleet

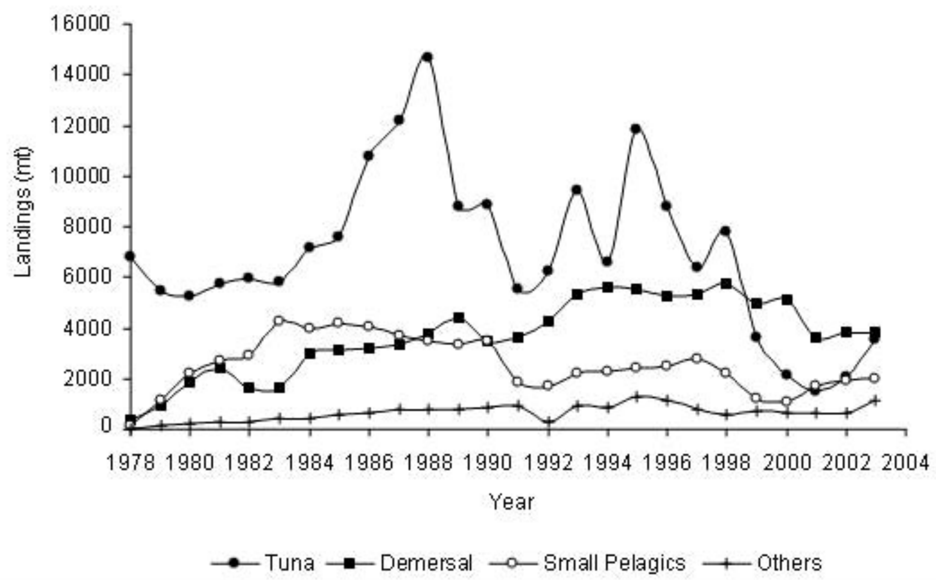
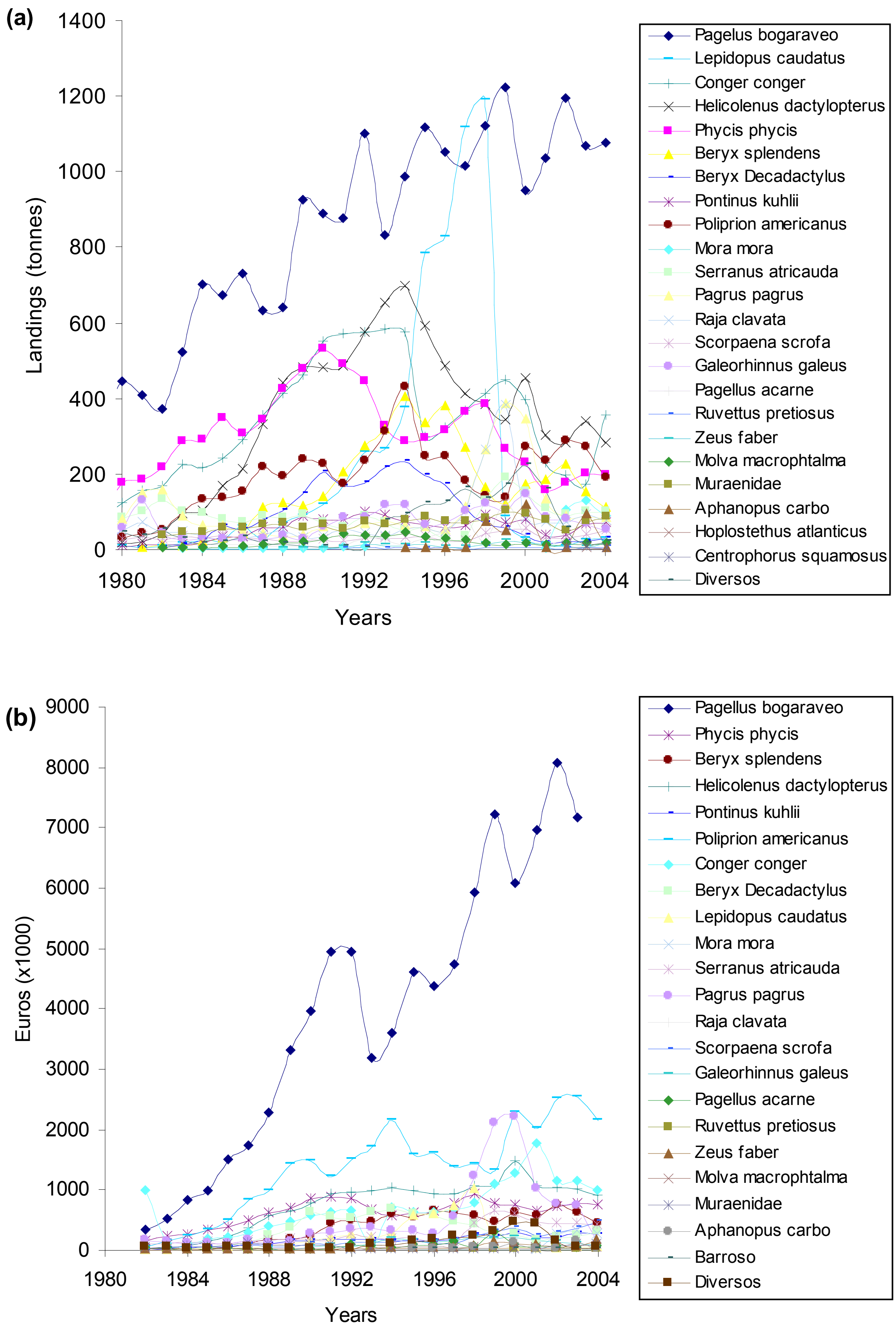


FIGURE 6
Landings of demersal deepwater species from the Azores (ICES Area X).
Weight (a); Value (b)



Landings seem to show a decreasing pattern for almost all the important commercial species of the Azores. However, the trend in the landings may not indicate a real change on the abundance of the stocks because the multigear and multispecies character of the fishery results in a change in the dynamics of the fishery over time. For example, Pinho, Menezes and Krug (1999) suggested that the decrease of some of the littoral species such as blacktail comber and red porgy may be related more with changes in exploitation patterns than a real change in the stock abundance. Species such as conger eel and wreckfish that seem to maintain the same relative proportion in the landings may reflect specific targeted fishing by some components of the fleet. Nevertheless, the continuous decrease in landings of the main target species such as forkbeard, blackspot seabream, bluemouth and alfonsinos must be of concern because it seems to suggest a high level of exploitation or overexploitation.

6. DATA COLLECTION

Landings by species, vessel, island and port are collected at the time of first sale by auction. Data are detailed and of high quality since 1993. Length compositions of the landings are collected at the main ports through the Regional Biological Port Sampling Programme. In addition, effort data are recorded during the biological sampling programme. Logbooks are not available for most of the fleet. Since 2002 the sampling programme is running under the supervision of the European Union through the "Minimum Sampling Programme for Fisheries Data" project <*http:/fish.jrc.cec.eu.int/fisheries/stecf/meetings/sgrn/november2004/2005/portugal.pdf* >.

Abundance data, independent of the fishery, are collected annually from the Azorean spring bottom longline survey (Pinho 2003). Biological data, including maturation ogives, sex ratio and age composition, are collected annually for the assessment purposes. Despite the effort and high costs associated with the data collection programme, some problems occur in the quality of data for assessments, related to the use of commercial catch per unit effort (CPUE) estimates as an abundance index and problems in ageing fish, etc. Geo-referenced data and data disaggregated by gears for the analysis of the dynamics of the fleets by areas are not yet available.

7. STATE OF THE STOCKS

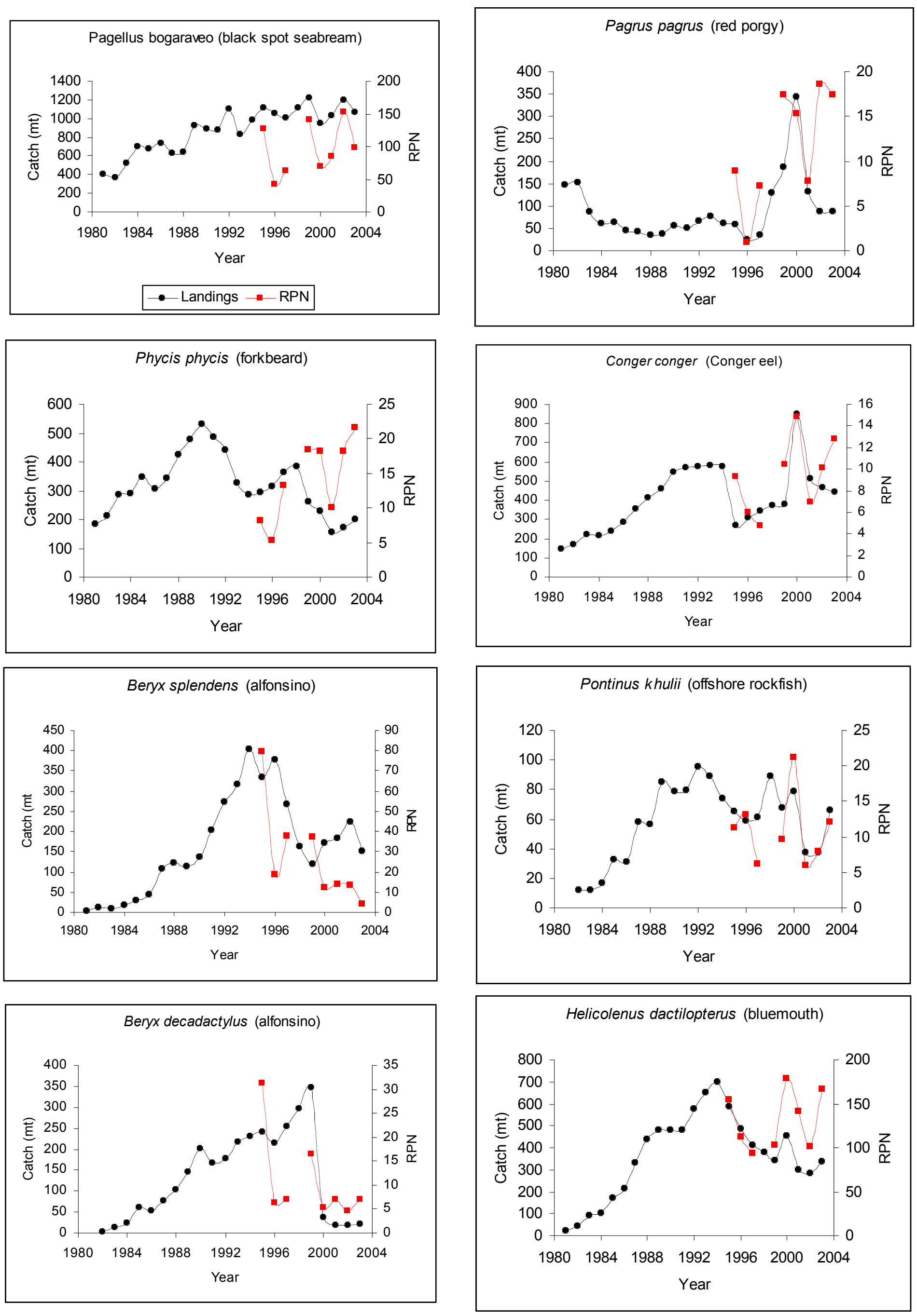
The Azorean demersal deepwater fishery is a multispecies fishery. Results from diet studies show that predation among demersal species is not observed, which means that predator–prey relationships are a less important factor for assessments than are technological interactions (Gomes *et al.* 1998). However, there is no simple theoretical approach to assessing and managing the stocks in a multispecies context. For the Azores case, it has been assumed that changes in abundance of blackspot seabream, the main target species, reflect the dynamics of the other species.

Stock assessments of blackspot seabream have been done and presented to the fishery community since 1987 (Silva 1987, Krug and Silva 1988, Krug 1994, Silva, Krug and Menzes 1994, Pinho, Menezes and Krug 1999, Pinho 2003). Until 1992 demersal resources were considered moderately exploited, but by 1994 the assessments showed that resources were intensively exploited. Recent assessments suggest that the stock of blackspot seabream may be overexploited (Pinho 2003). However, it has been suggested that models used in the assessment may not accurately capture the dynamics of the species and the fishery. For example, stock identity is not yet defined for most of the species even by areas in the Azores ecosystem (coastal island areas, banks and seamounts). The interaction between all these areas is not yet understood but some local depletion has been observed, e.g. on the Condor bank and in the coastal areas off St Miguel Island.

Analysis of survey abundance data suggests that some of the traditionally commercially important demersal and deepwater species, such as alfonsinos and bluemouth, are intensively exploited (Pinho 2003) (Figure 7). However, survey results also show a high annual variability in the abundance indices, which cannot be explained only by fishing effects, indicating a high degree of complexity of the Azorean ecosystem. Particular concern must be paid to the consequences of the pattern of exploitation of the fishery on the sustainability of the less abundant species when harvest decisions are based on a target species. Pinho (2003) discusses this concern for the Azorean multi-species fishery.

FIGURE 7

Annual landings and abundance indices (RPN – Relative Population Number from the Azorean Spring bottom longline survey) of some commercially demersal deepwater species



8. MANAGEMENT

Until 1992 demersal resources were considered moderately exploited and no management action was taken. Since then several recommendations, e.g. TACs, have been made to the regional government to reduce fishing effort and mortality but none were implemented. During 1998 and 2000 some technical measures were implemented, including restrictions on licences based on a minimum threshold landing in value, hook size limit and fishing area restrictions by vessel size and gear type. Minimum lengths are also in force for a limited number of species.

Coastal Marine Protected Areas have been proposed and implemented under the E.U Natura 2000 network and offshore MPAs has been proposed under Annex V of the OSPAR convention (Afonso and Santos 2004).

As a consequence of the intense fishing of traditional species, exploitation of new deepwater species such as mora (*Mora mora*) and black scabbard fish have been encouraged. However there is no local market for these species and so development of these fisheries has been slow.

Under the European Community's Common Fishery Policy, management measures were taken with the introduction of TACs for some of the deepwater species (black scabbard fish, orange roughy and blackspot seabream) and effort restrictions (licensing of deepwater vessels based on a threshold tonnage). An additional and exceptional measure was introduced in the Azores (ICES Area X) with the creation for a temporary period of a buffer area of 100 nautical miles where only Azorean vessels can operate. However, conflicts between traditional artisanal fishery developments versus industrial fisheries have been observed under the governance process of the Common Fishery Policy. The management measures that were introduced are poorly understood by locals and they seem to rely more on political agreements than on effective conservation measures for protection of fisheries and for thei0r ecosystems. For example, it is not realistic to promote open access to resources on the Azores area (ICES Area X) letting many industrial vessels from northern EU countries to fish species when local fishermen see resource depletions or when severe declining trends of landings and abundance indices are observed (as is the case for alfonsinos)! There is also a general lack of scientific knowledge of the ecosystem on different scales and a lack of political flexibility of the Common Fishery Policy to choose the regional option of small versus large-scale fisheries based on the local economic and social importance of fishing, physical restrictions of available fishing areas and limited commercial resources available (if the objective is to exploit resources on the sustainable basis).

After 2004 fisheries governance will be the exclusive responsibility of the European Union under the Common Fishery Policy and so all the management procedures, including data collection and assessment process of the EU, will be completely adopted.

9. CONCLUSIONS

The Azores is a natural deepwater environment where ecosystems (coastal areas, banks and seamounts) can be defined at different scales (regional coastal areas, seamounts, Mid-Atlantic Ridge and North Atlantic). The dynamics and interactions between areas of different ecosystems are poorly known. The fishing areas available are scarce due to limited habitats where most of the commercial important species may occur. The resources are generally modest in size and exhibit a wide variety of life histories including long-lived and slow-growing strategies. Some fisheries occur on spawning aggregations around coastal areas or on underwater features, which make them particularly vulnerable to overexploitation. As a consequence the Azores option has been to develop small-scale fisheries to provide possible sustainable economic (export) and social (employment) benefits.

The Fisheries are multispecies and multigear (hook gears). Stock structures indicate that populations or subpopulations can be defined at local (e.g. shallow coastal areas or seamounts), regional (EEZ), and most probably, broader (North Atlantic) scales.

Data collection costs the same as for large-scale fisheries and the level of accuracy has been improved considerably recently.

Traditional resources seem to be intensively exploited and probably some less abundant species are overexploited. Efforts to develop new deepwater resources are underway with the objective of decreasing effort on traditional resources. However technological and market aspects, as well as size of the stocks and resource access policy have constrained the expected growth of new fisheries.

Management is complex and works at the regional, national and European Community level, resulting in conflicting managing objectives. From 2004 management will be the exclusive responsibility of the EC under the Fishery Common Policy and so all the procedures of EU will be applied, including those for data collection. Harvest decisions have been made for target species but have been criticized in favour of adopting more risk-adverse management approaches. Several other management tools, such as marine protected areas and co-management process, as well as a ecological management approach (Menezes 2003) and precautionary approach, have been used or proposed. Precautionary TACs are set annually for some species under the Common Fishery Policy because analytical results from the assessments are not available for most of the stocks.

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Workshop on the Conservation and Management of Deep-Sea Chondrichthyan Fishes

Synopsis

This meeting examined the ecology, taxonomy, stock status and conservation threats to deep-sea chondrichthyans. It was noted that few studies on deepwater chondrichthyans exist and the majority deal with squaloids, reflecting their greater commercial importance. Deepwater chondrichthyans form a large bycatch in many fisheries though fisheries targeting deepwater chondrichthyans are also becoming more important. Chondrichthyans are particularly vulnerable to fishing owing to their slow growth, late sexual maturity and low reproductive output. Data on deepwater chondrichthyan catches are sparse and usually uninformative as landings data rarely provide accurate species composition information. To use landings data for assessments species must be known, which requires species to have been described taxonomically. The 2004 *IUCN Red List of Threatened Species*™ assessment of deepwater chondrichthyans followed the Workshop.

Presentations on chondrichthyan life history noted that sharks especially are apex predators, and that their depth distributions may be linked to surface water primary production as shark numbers are highest in the deeper waters areas where surface water primary production is highest. Age estimates were reported for the deepwater species *Centroscymnus crepidater* with maturity occurring at 9–15 years. It was noted that knowledge of the status of most deep-sea chondrichthyans is limited, if not 'data deficient' and that several deep-sea chondrichthyans are critically endangered.

Case studies on Namibia and Australia demonstrated that a small number of vessels can quickly deplete unexploited stocks whose recovery is likely to be extremely slow because of the sharks' life history characteristics. Indonesian chondrichthyan landings were noted as high and largely unreported. In areas where baseline data exists, mean relative catch rates have severely declined. Abundance measures were reported for three chondricthyans in the Mediterranean Sea.

Deepwater chondrichthyans do not require unique management measures but their management is more complex as the available stock and sustainable yield is lower, especially for the unproductive deepwater species. The depth and spatial segregation that often occurs within a chondrichthyan population may make different components of the population available to the fishery and thus it can be relatively easy to remove an entire component of a population. Reliable catch information is rarely available and landing of processed animals makes it extremely difficult to identify the species composition of the catch. Lamentably, catch statistics for many species are often reported as "shark various", "black shark", "skate", "ray", etc. Regulations should require the retention of heads, fins and tails and prohibit the landing of fins, skate wings and livers without the accompanying carcass.

The need for better identification keys and guides to identify species and stock distributions and genetic techniques to separate sympatric species was noted. While knowledge of longevity and age-at-maturity estimates is needed for stock assessments, ageing techniques tried for squaloids, chimaeras and rajids have not yet been validated. Age validation may require radiocarbon dating or radiometric isotope analysis.

Knowledge of trophic levels would allow definition of community structure and provide data for ecosystem modelling. Consumption rates, interspecies dynamics, energy partitioning between co-occurring species and ontogenetic regional and seasonal variations are largely overlooked and unrecorded. Information on basic metabolic physiology is also required.

Knowledge of reproductive biology, duration of development, inter-breeding intervals and natural mortality are required and reproductive cycles remain undefined. Research is needed on the survival of discards of juveniles of larger species as the smaller individuals are usually discarded. Different fishing methods result in different discard mortalities. Analysis of catches taken in shorter tows in cooler waters show that a high proportion of dogfishes landed are alive and assessments are required of the survivability of these animals if they are released quickly.

Biology of exploited deepwater sharks west of Ireland and Scotland

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1. INTRODUCTION

In the northeast Atlantic, deepwater elasmobranchs are taken in several deepwater fisheries. Most deepwater fishing activity occurs west and north of Ireland. Two species of sharks are routinely landed for their flesh and livers, the leafscale gulper shark (*Centrophorus squamosus*) and the Portuguese dogfish (*Centroscymnus coelolepis*). These species are collectively called "siki" in French fishery records though they are also marketed elsewhere under this name. French vessels catch these species in the mixed-species trawl fishery. Spanish longliners target deepwater sharks (Pineiro, Casas and Banon 2001), but it is difficult to quantify landings as separate statistics for deepwater shark species are not collected from these vessels. In addition, fleets of UK and German registered longliners and gillnetters have been targeting deepwater sharks since the mid 1990s, though their catches are reported only as generic sharks or dogfish. More recently, longliners from Norway and Ireland and trawlers from Scotland and Ireland are catching these species. Other, smaller, species of deepwater sharks are now being landed, or in some cases livers or fins are retained and the carcasses discarded. In addition to trawl and longline, there are fisheries for deepwater sharks using gillnets and tangle nets, but there are no catch or effort data available for these gear types. Smaller species include *Deania calceus, Centroscyllium fabricii* and *Centroscymnus crepidater*, though these are mainly discarded. Some progress has been made by some countries in collecting deepwater shark data, though data are still incomplete. The process of collating landings data began in 2000, but ICES has not yet been able to produce a reliable set of data for deepwater sharks. This is due to the use, by many countries, of generic reporting categories. It is also due to the low priority assigned to this task by many states. It is hoped that ICES will have a reliable dataset available by 2005 when the next stock assessments are planned.

Relatively few studies on deepwater elasmobranchs have been reported in the scientific literature. The majority deal with members of the Squalidae, but little attention has focussed on the impacts of fisheries on these species, despite their commercial importance in several regions of the world. This paper presents an overview of studies conducted in Ireland on deepwater elasmobranchs biology and fisheries.

2. MATERIALS AND METHODS

The present study is based on three trawl and three longline surveys undertaken during 1993–2000 on the Rockall Trough and Porcupine Bank, between 50° N and 59° N in the depth range from 500 to 2 000 m. Fishing was carried out in eight fixed areas (Figure 1) of the continental slope from 500 m to 1 300 m. Some deeper settings were made during longline surveys. Commercial fishing gears were used in these surveys. Trawl surveys used a "bobbin" trawl (Gundry's© Ltd.) with a 105-mm mesh cod-end and 25-mm small-mesh liner. The foot-rope length was 23 m with rubber discs of 40 cm. The bridles were comprised of 92 m of single warp and 46 m of double wires. Trawl hauls ranged in duration from 135 to 380 minutes. Longline surveys used the "Autoline" system with main lines of 9 mm or 11.5 mm diameter, with Mustad© size 13/O EZ and smaller numbers of size 7/O EZ hooks. Snoods were 40–70 cm in length attached to the main line at 1.4 m intervals. Bait consisted of squid (60 percent) and mackerel (40 percent).

Dorsal spines were used for age estimation of *Centrophorus squamosus* and *Deania calceus*. The spines were cleaned in a 4 percent hypochlorite solution for up to 12 hours, washed in running tap water and air-dried. Spines were sectioned using a Buehler© low speed jewellers saw with a diamond blade. Sections were taken at a thickness of 500 µm at intervals of 2000 µm along the length of the external spine in order to make comparative counts. All bands (consisting of one translucent and opaque zone) present in the inner trunk layer (*sensu* Maisey 1979) were included in age estimates. Maximum band count was found in those sections immediately proximal to the constriction of the central cavity, therefore age estimation was based on this region of the spine. Sections were cleared in xylene, air-dried before mounting on glass slides using resin C. Spine sections were read using a Wild Heerbrugge© binocular microscope using x 50 magnification and transmitted light. The dentinal layers were differentiated using a Leitz Biomed© compound microscope at x 40 magnification with transmitted light.

The von Bertalanffy growth model was fitted to the combined data from the present study and that of Machado and Figueiredo (2000). The von Bertalanffy growth function can be represented as

$$L_t = L_\infty \left(1\text{-exp}^{-K(t-t_0)} \right)$$

where

L_t = length at time t

L_∞ = asymptotic length, or mean maximum length

K = a rate constant with units of reciprocal time (years $^{-1}$) and

t_o = age of the fish at theoretical zero length.

The von Bertalanffy growth function was fitted to length at estimated age for males and females separately by means of the Levenberg-Marquardt algorithm using the non-linear regression routine in SPSS *v*. 9.1 (SPSS 1999).

Length-frequency distributions (5-cm groups), separated by sex, for *Centrophorus squamosus, Centroscymnus coelolepis* and *Deania calceus* were pooled by gear type (trawl, longline). The Kolmogorov–Smirnov Two Sample Test (Sokal and Rohlf 1995) was used to test for significant differences between length frequencies from trawl and longline catches in 1997 trawl and longline survey data.

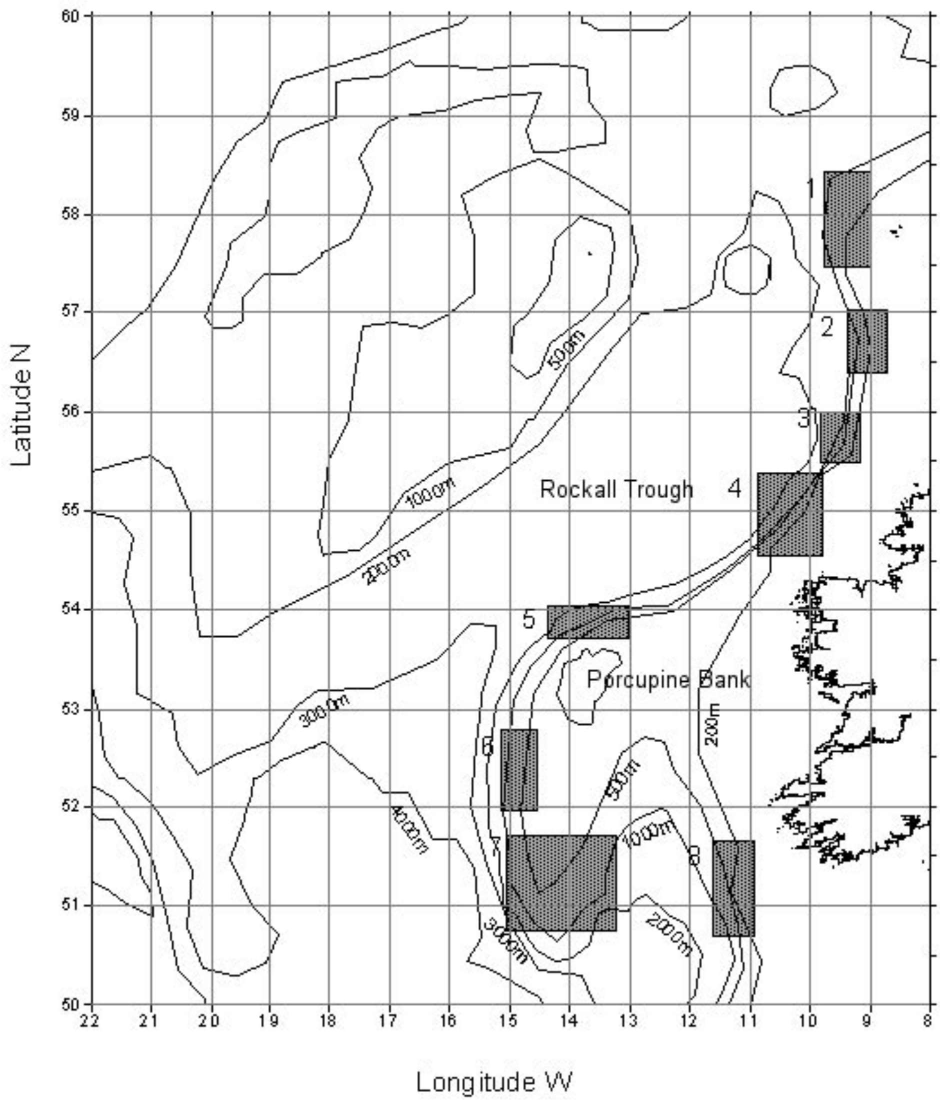
Comparative selectivity ogives for trawls and longlines were constructed for *Deania calceus, Centrophorus squamosus* and *Centroscymnus coelolepis*. Selectivity ogives were estimated using the method of Sparre, Ursin and Venema (1989) where the descending limb of a catch curve is extrapolated backwards to achieve an estimate of the non-fully selected age groups. The difference between these expected catch numbers and the observed values provide an estimate of the combined effect of recruitment and selectivity of the gear for these age groups. The logistic model was assumed to describe the selectivity pattern for each species. Input data for *D. calceus* were age-based catch curves from the August 1997 trawl survey and the December 1999 longline survey. Initial runs displayed little difference between ogives for males and females, so data by sex were combined.

It was not possible to produce a catch curve for *Centroscymnus coelolepis* or *Centrophorus squamosus* because von Bertalanffy growth parameters were not available. To simulate a selectivity ogive, length-frequency distributions from the

FIGURE 1

The eight areas where stations were completed and shark sampling carried out

Areas 1-5 were in the Rockall Trough, and areas 6-8 were in the Porcupine Bank area.



1997 trawl and longline surveys were used to produce length converted catch curves (Pauly 1984). In the absence of parameters for the von Bertalanffy growth function, the following hypothetical parameters were chosen:

C. coelolepis: K = 0.09, t_0 = 0, L_∞ = 115 cm

C. squamosus: K = 0.09, t_0 = 0, L_∞ = 136 cm.

3. RESULTS

The depth distribution of three species is illustrated by catch rates in kg per 1 000 hooks from longline surveys (Figure 2). The habitual depth range (300 m – 1 800 m) of each species was sampled. *Centrophorus squamosus* and *Deania calceus* were most abundant between 700 m and 900 m. *Centroscymnus coleolepis* was more abundant in deeper water (1 300 m). Table 1 shows the relative proportions of elasmobranchs and teleosts in trawl and longline catches in each area (Figure 1). In longline catches, the elasmobranchs outnumber teleosts in all areas, except Area 4, where shallower hauls took the dominant species (ling and tusk) shallower than 500 m. In trawl catches elasmobranchs were still well represented, but the ratio favoured teleosts. Clearly, the number of species is greater in trawls, and though elasmobranchs are present, they are a less important component of the catch. In longline catches, elasmobranchs dominate. There is also a trend for greater numbers of species in catches the more further southwards.

FIGURE 2
Catch rates (kg/1 000 hooks) from longline surveys 1995–2000
Each 100 m interval indicated by its lower value.

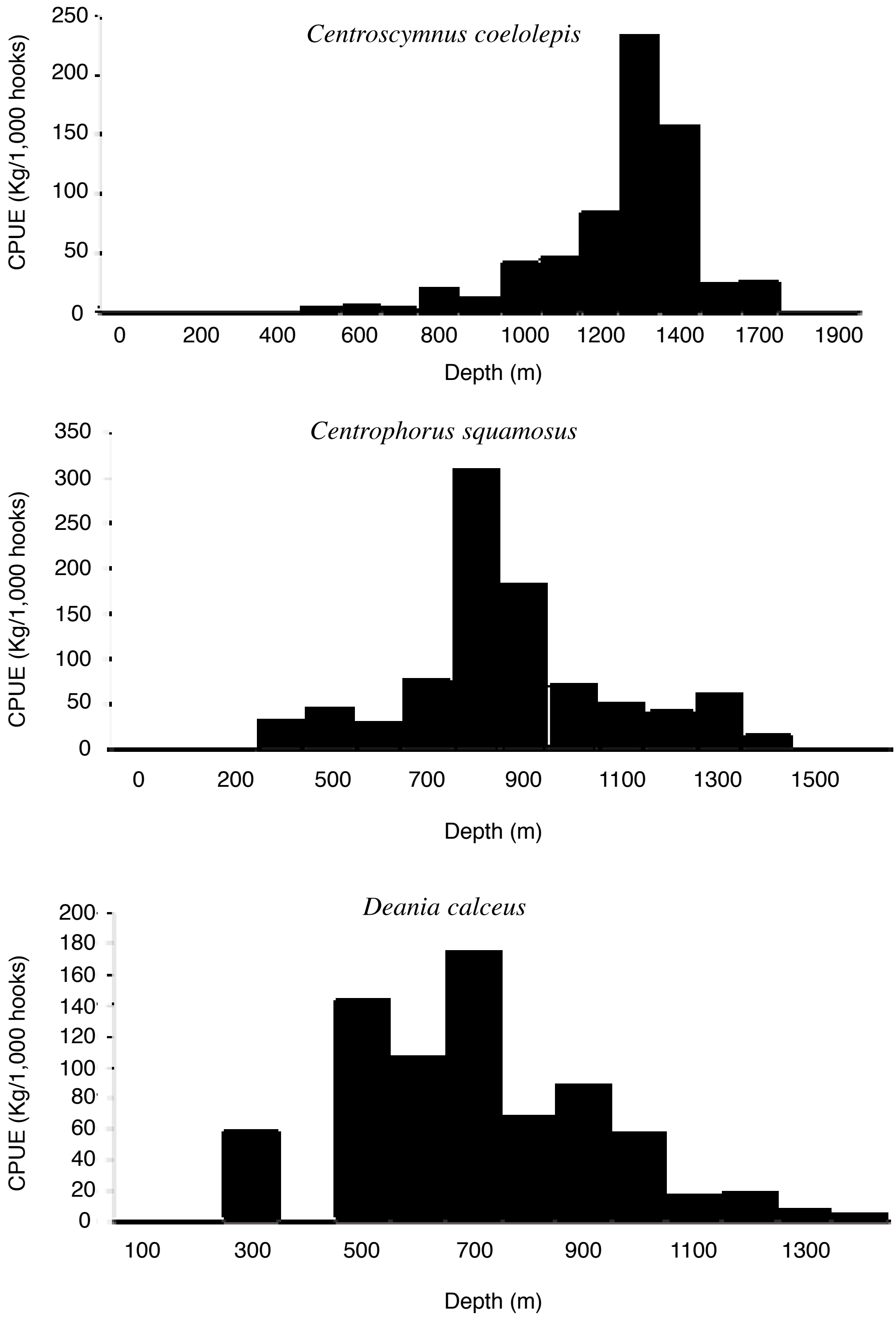


TABLE 1

Relative numbers of elasmobranchs and teleosts from trawl and longline surveys of the same areas of the eastern and southern slopes of the Rockall Trough in 1997

Gear	Area	No. hauls	Depth	No. elasmobranchs	No. teleosts	Ratio elasmobranchs: teleosts
Longline	1	4	691–1 350	9	3	3.0
	2	4	684–1 166	10	8	1.3
	3	4	775–1 401	11	9	1.2
	4	9	353–1 357	12	13	0.9
	5	7	637–1 418	15	7	2.1
Trawl	1	4	654–1 159	5	14	0.4
	2	3	880–1 105	6	18	0.3
	3	4	550–1 150	7	28	0.3
	4	7	520–1 100	7	34	0.2
	5	3	1100–1 174	8	20	0.4

Figure 3 shows the percentage catch composition by species from comparable trawl and longline surveys of the continental slopes of the Rockall Trough in 1997. Squalid sharks dominate longline catches deeper than 500 m in this area. Elasmobranch dominance increases with depth with catches deeper than 1 300 m almost totally composed of squalid sharks (98 percent). The non-commercial species *Deania calceus* is the largest component of the catch between 500 and 700 m and squalids are the dominant species at all depths in longline catches. In contrast, trawl catches display a greater diversity of species with less dominance. The roundnose grenadier (*Coryphae noides rupestris*), a teleost, dominated at depths greater than 700 m, but the remainder of catches at these depths comprised a variety of species both chondrichthyan and teleost. The large commercial squalids – *Centrophorus squamosus* and *Centroscymnus coelolepis* – were the most abundant in trawl catches. Whereas teleosts comprise a higher component of trawl catches than elasmobranchs, it is clear that the latter group is well represented in catches from towed gears. The percentage species composition of longline catches on the continental slopes of the Porcupine Bank is illustrated in Figure 4. The differing species composition in this more southern region is evident. *D. calceus* is dominant over a range of depths here, comprising more than 60 percent of the catch between 700 and 900 m.

The spines of *Deania calceus* (Plate 1) and *Centrophorus squamosus* (Plate 2) displayed the same morphology as those described by Maisey (1979) and by Gullart (1998) for *Centrophorus granulosus*. While the cap tissues cover the anterior-lateral faces of the spines of *Squalus acanthias*, they are reduced to one or more ribs in the species in the present study and in other deepwater squalids *Centrophorus granulosus* (Gullart 1998) and *Etmopterus spinax* (Maisey 1979). Estimates of 21–70 years (*Centrophorus squamosus*) and 11-35 years (*Deania calceus*) were obtained from cross-sections of first dorsal spines. Agreement for the first and second spines within one year was found for more than 93 percent of *Deania calceus* and 88 percent of *Centrophorus squamosus*. The present data for *Deania calceus* were combined with published data for small specimens of this species (Machado and Figueiredo 2000) and allowed the construction of von Bertalanffy growth models (Table 2 and Figure 5).

Length frequencies show the absence of smaller specimens of these species from the study area (Figure 5). These are based on trawl and longline surveys spanning all the areas. Trawls and longlines selected for significantly different (Kolmogorov-Smirnov two-sample test, $p < 0.05$) for size ranges of *Centroscymnus coelolepis* and *Deania calceus*, though not *Centrophorus squamosus*. Large female *D. calceus* were well represented in longline catches, but less well represented in trawls, indicating that large, mature females can avoid these nets.

FIGURE 3

Percentage composition of total catch by species in trawl and longline catches from the continental slopes of the Rockall Trough

Percentages rounded to nearest integer and presented by 200 m depth interval

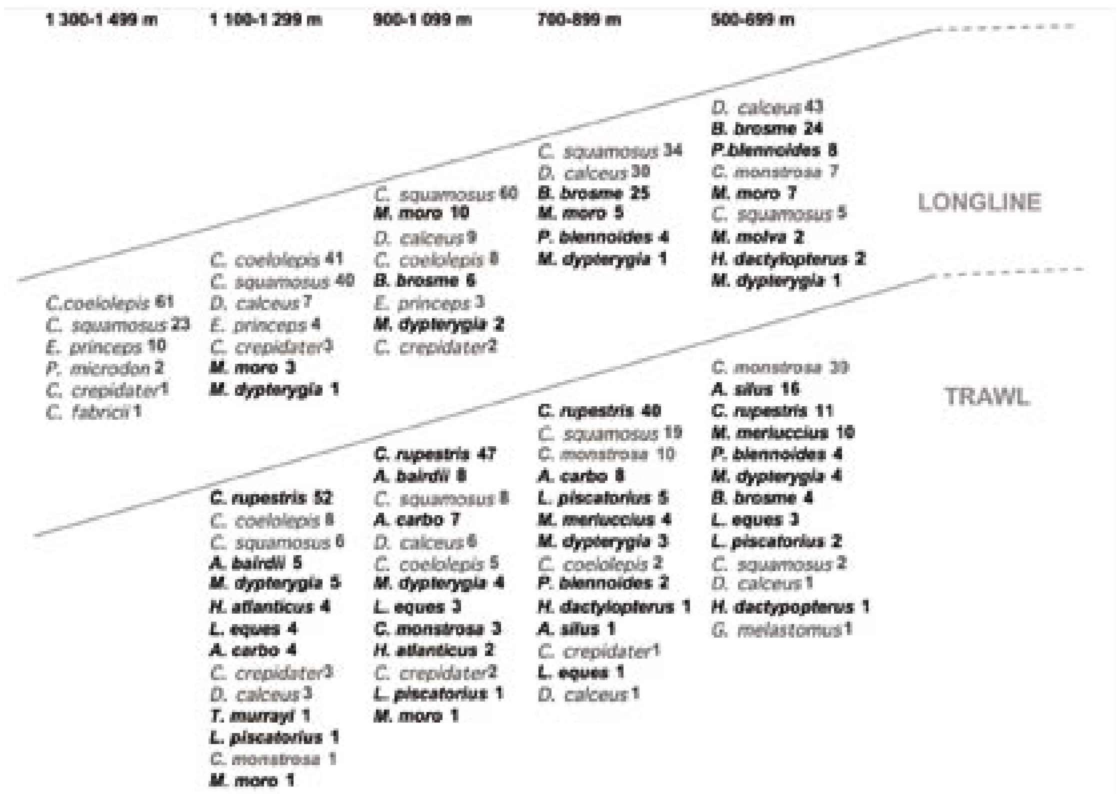


FIGURE 4

Percentage composition of total catch by species longline catches from the continental slopes of the Porcupine Bank

Percentages rounded to nearest integer and presented by 200 m depth interval

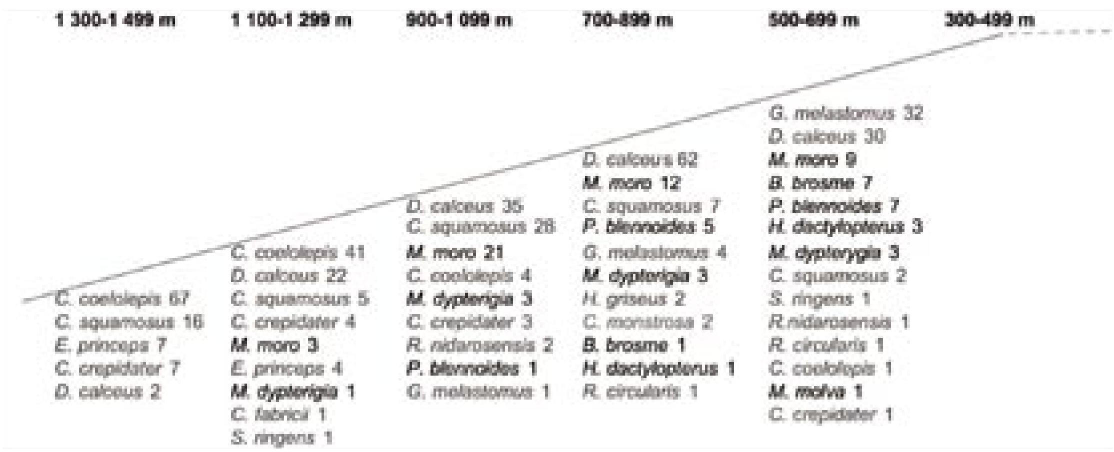


TABLE 2

Estimates of the parameters of the von Bertalanffy growth model for *Deania calceus* based on age estimation data from the first dorsal spine in the present study and from empirical growth data presented by Machado and Figueiredo (2000)

Sex	Estimate	S.E.	95 % confidence limits	
Females				
K	0.077	0.0126	0.052	0.102
t_0	-0.933	0.6809	-2.289	0.422
L_∞	119.303	6.6700	106.024	132.582
Males				
K	0.135	0.0190	0.098	0.173
t_0	0.165	0.5433	-0.917	1.247
L_∞	93.516	2.8231	87.895	99.138

An important finding is the absence of smaller specimens of these species from the study area (Figure 3). The length range for *Centrophorus squamosus* was 71–122 cm for males and 74–145 cm for females. The range for *Deania calceus* was 55–109 (males) and 52–117 for females, whilst for *Centroscymnus coleolepis* the range was 68–118 cm (males) and 70–121 for females. Small (7/0 EZ) hooks were deployed during the long-line surveys in 1997 and 1999 in an attempt to target small sharks but no smaller specimens were taken. Interestingly, the modal lengths for male and female *Centroscymnus coleolepis* were widely separated though those for *Centrophorus squamosus* were not, even though there was an obvious tendency for females to grow larger in both cases. Gravid female *Centrophorus squamosus* were entirely absent from the study area in contrast to *Centroscymnus coleolepis* where all maturity stages occurred. Evidently, larger mature *Centrophorus squamosus* are mainly absent from the study area.

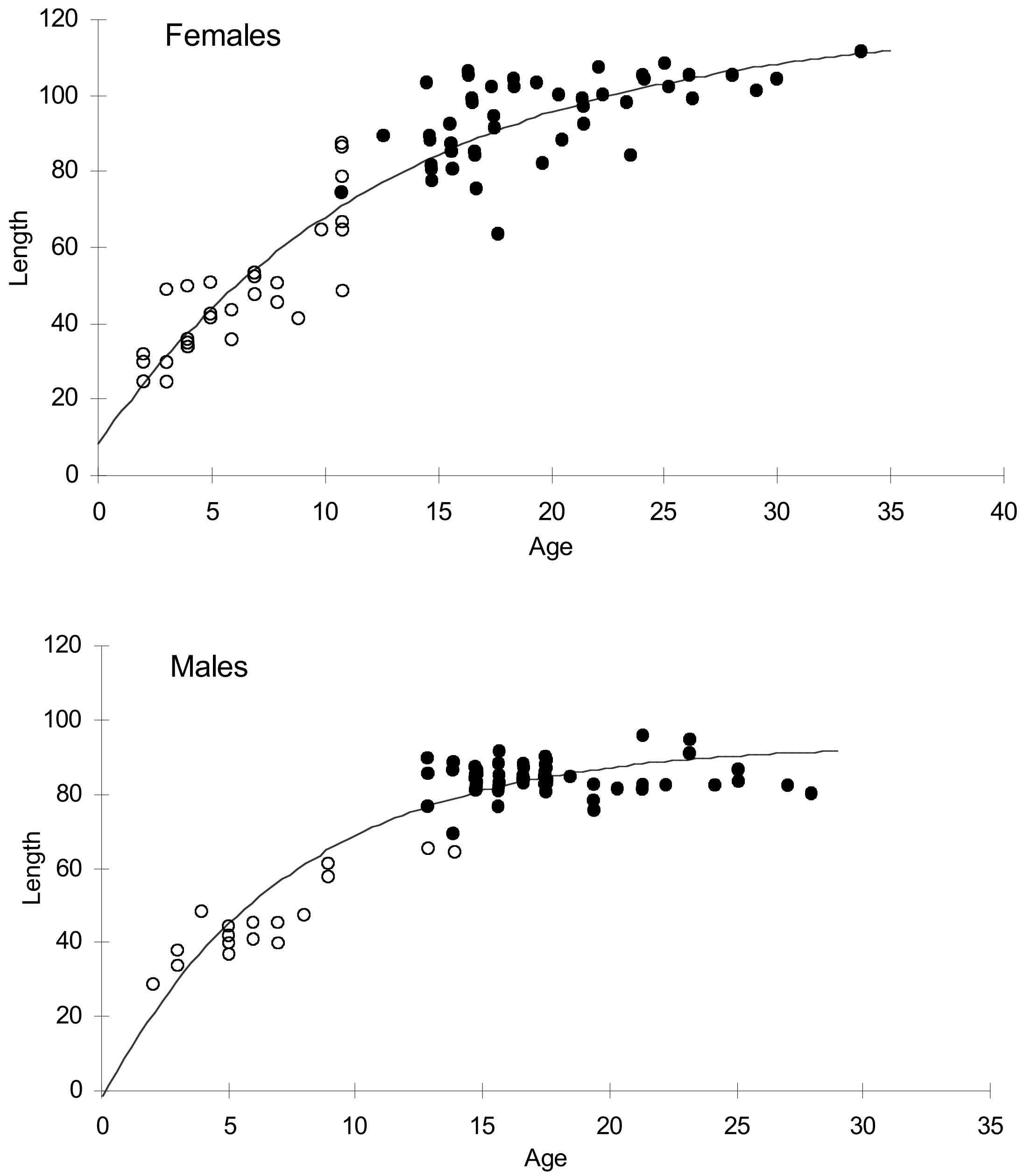
Selectivity ogives for *Deania calceus* (Figure 7) display similar shapes for both gears and sexes. The model predicts that longlines select for older (larger) sharks than trawls. Age_{50} was estimated at 11 years for trawls and 15 years for longlines. Results of the simulated ogive analysis for *Centroscymnus coelolepis* (Figure 8) suggest different selectivity patterns between trawl and longline. For females, longlines appear to be less selective than trawls for younger (smaller) sharks. The ogive for longline-caught females displayed a lower Age_{50} and only slight increases in proportions selected with increasing age. In contrast the trawl ogive for females displayed a sudden increase in proportion selected around age 25. This suggests that longlines are less selective for female *C. coelolepis* than males and take a higher proportion of smaller sharks. This effect is also illustrated in the comparative length frequencies (Figure 5), smaller females being selected by hooks, but are absent in the catches of the towed gear. There is less difference in the ogives for male *C. coelolepis* for which longlines did not take greater numbers (Figure 5). When combined for both sexes, the differences were masked, however the longline ogive is slightly less steep than that of the trawl. For *C. squamosus,* trawls selected smaller individuals than longlines (Figure 9). The shapes of the selectivity ogives are however similar.

4. DISCUSSION

There are important differences between trawls and longlines with respect to catches of deepwater elasmobranchs. Clearly, the catch composition of deepwater sharks is depth dependent, as has been found by Gordon (1999). The present data show the composition of elasmobranch species in the total catch for commercial gears by depth. Of the two commercial species, *Centrophorus squamosus* has a shallower distribution between 800 and 1 000 m and *Centroscymnus coelolepis* is a deeper, and the dominant species in longline catches deeper than 1 100 m. *Deania calceus* is not commercially exploited, but dominates longline catches in intermediate depths on the slopes of the Porcupine Bank; it is a slightly less important component further north in the Rockall Trough. Because this species tends to occupy hooks that could otherwise attract commercially valuable species, longline fishermen tend to avoid these depths. Therefore two completely separate longline fisheries can be defined in this area, one on the upper slopes targeting ling (*Molva molva*) and tusk (*Brosme brosme*) with bycatches of greater forkbeard (*Phycis blennoides*), mora (*Mora moro*) and blue ling (*Molva dypterygia*). Deeper than 1 000 m there is a target fishery mainly for the two commercially important large sharks, *C. squamosus* and *C. coelolepis*.

FIGURE 5

Von Bertalanffy growth models for *Deania calceus* based on age estimate data from the current study – closed circles – and from published work by Machado and Figueiredo (2000) – open circles



Trawl catches are not dominated by elasmobranchs. On the slopes of the Rockall Trough, roundnose grenadier dominates trawl catches from 700 m and deeper. However, after this teleost deepwater sharks are the next most important species in terms of weight. Discards from trawling in this region are high and are composed of up to 30 different species, while the species diversity of discards from longlining is lower and is dominated by sharks. Trawl discards are composed of small individuals of commercial species such as *Coryphaenoides rupestris, Molva dypterygia* and *Phycis blennoides*. Some teleost species, notably *M. moro* and *B. brosme*, are taken mainly on longline and are mainly absent from trawl catches. Small specimens of the squalid sharks are not present in this region (see below). Trawl discards are also composed of a large range of non-commercial species, such as blue antimora (*Lepidion eques*), Murray's longsnout grenadier (*Trachyrhynchus murrayi*) and Baird's smoothhead (*Alepocephalus bairdii*). In contrast, longline fishery discards are mainly composed of non-commercial shark species such as blackmouth dogfish (*Galeus melastomus*), greater lanternshark (*Etmopterus princeps*), *Deania calceus* and *Centroscymnus crepidater.* Longlines take many small shark species, and smaller specimens of some of the larger species of shark than the trawls.

FIGURE 6

Comparison of length frequencies from trawl and longline surveys of the Rockall Trough in 1997

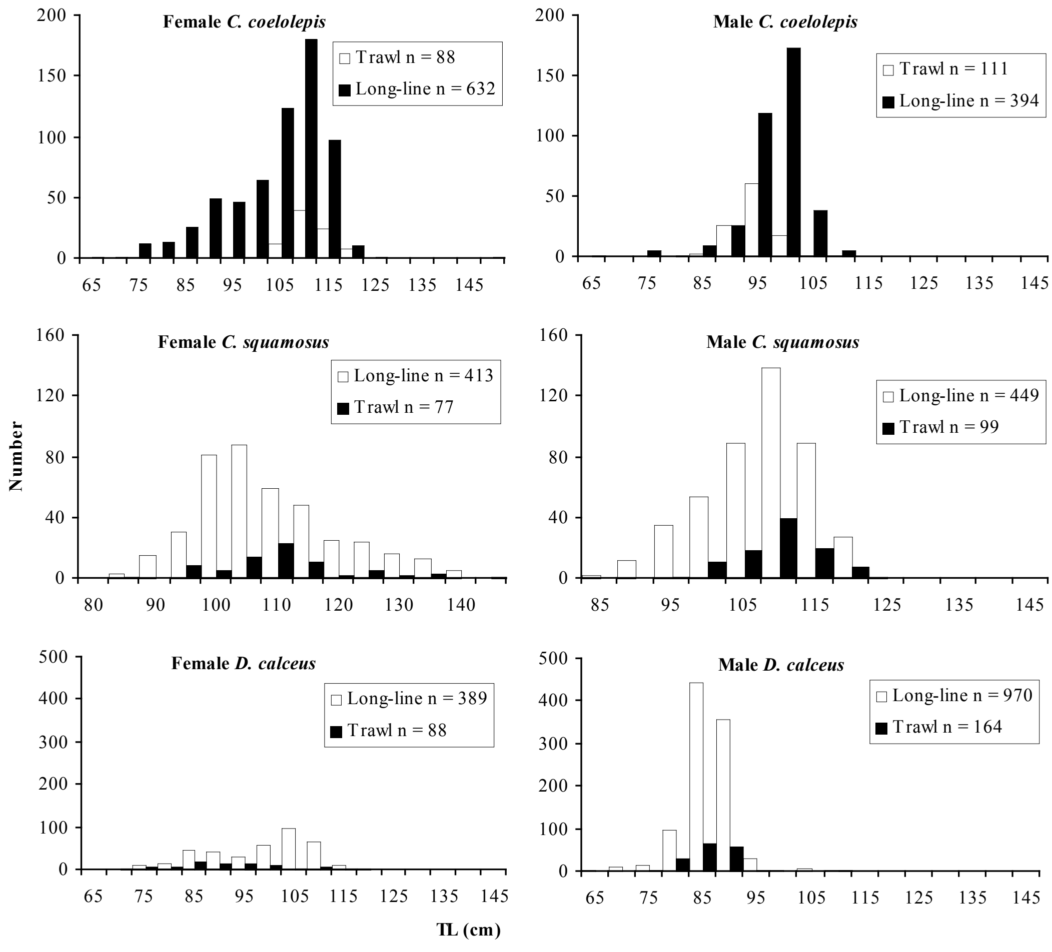
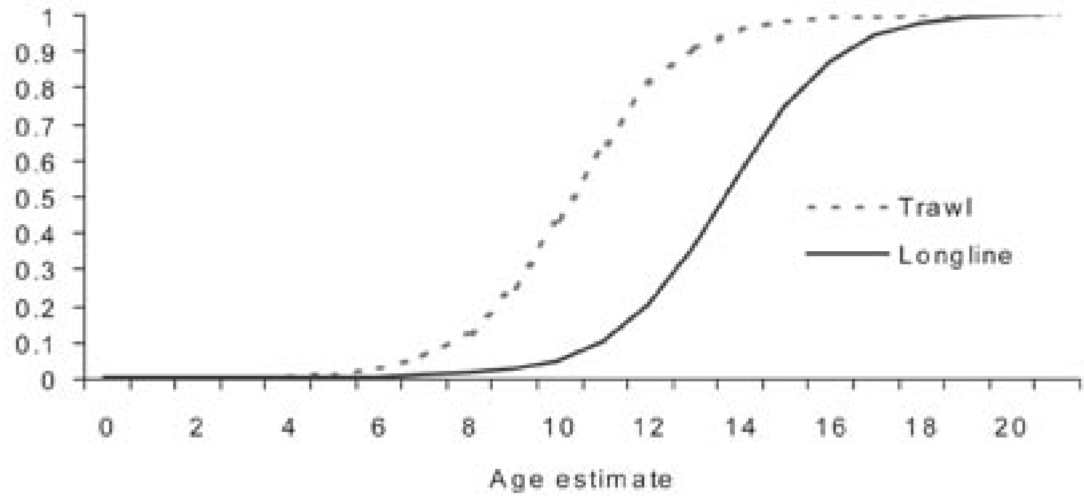


FIGURE 7
Estimated selectivity ogives for *Deania calceus*, sexes combined, derived from catch curve analyses
Estimated age 50 (trawl) = 11 and age 50 (longline) = 15



Clarke, Connolly and Bracken (2002b) estimate that 533 t of *Deania calceus* was discarded during trawling operations in the Rockall Trough and slopes of the Porcupine Bank in 1996 (corresponding to ICES Sub-areas VI and VII). It is more difficult to estimate discarding levels from longlining because landings data are less complete. However, from the species composition data it can be seen that non-commercial sharks will dominate the discards. In shallower longline settings the main species taken are *D. calceus* and *Galeus melastomus*, whereas in the deepest settings (commercial viability decreases below 1 500 m) *Centroscymnus crepidater* and *Etmopterus princeps* are most important. Markets for *D. calceus* and other non-commercial species are becoming available, which would lead to increased exploitation of these sharks.

The biological data presented above, concerning age, growth and maturity are dealt with in more detail in Clarke, Connolly and Bracken (2001, 2002a, 2002b). These studies along with other biological work on deepwater sharks suggests that these species are particularly vulnerable to overexploitation. Of all the species caught in the deepwater fisheries in the northeast Atlantic, deepwater sharks will have the lowest resilience to fishing pressure and the slowest replacement rates (Clarke, Connolly and Molloy 2003). It can be seen from Figure 10 that sharks are taken in both the demersal trawl and longline fisheries of the region. Therefore, they are an especially vulnerable group to commercial fishing pressure. Some of these sharks are highly migratory as is evident by the absence of certain life history stages in certain areas. This might ameliorate the effects of heavy exploitation if this is confined to small portions of their overall range. However, for species such as *Centroscymnus coelolepis*, where all reproductive stages are present in the main fishing area (west of Ireland and UK) the effects on the population are likely to be severe.

Trawls and long-lines are fundamentally different fishing methods. Trawls herd fish into the opening of the net, but fish are attracted to long-lines by the smell of the bait. This results in both size and species selection (Hareide 1995). Long-lines tend to select for larger teleost fish (Hareide 1995, Jørgensen 1995). The present study shows that longlines selected for size ranges of *Centroscymnus coleolepis* and *Deania calceus* not taken on trawl. These results show that long-lines are not size-selective for squalid sharks and demonstrate that commercial longline gear selects for the entire free-swimming size-range of these exploited squalid sharks in the NE Atlantic.

FIGURE 8

Estimated selectivity ogives for *Centroscymnus coelolepis*, derived from length-converted catch curves developed with hypothetical von Bertalanffy growth parameters

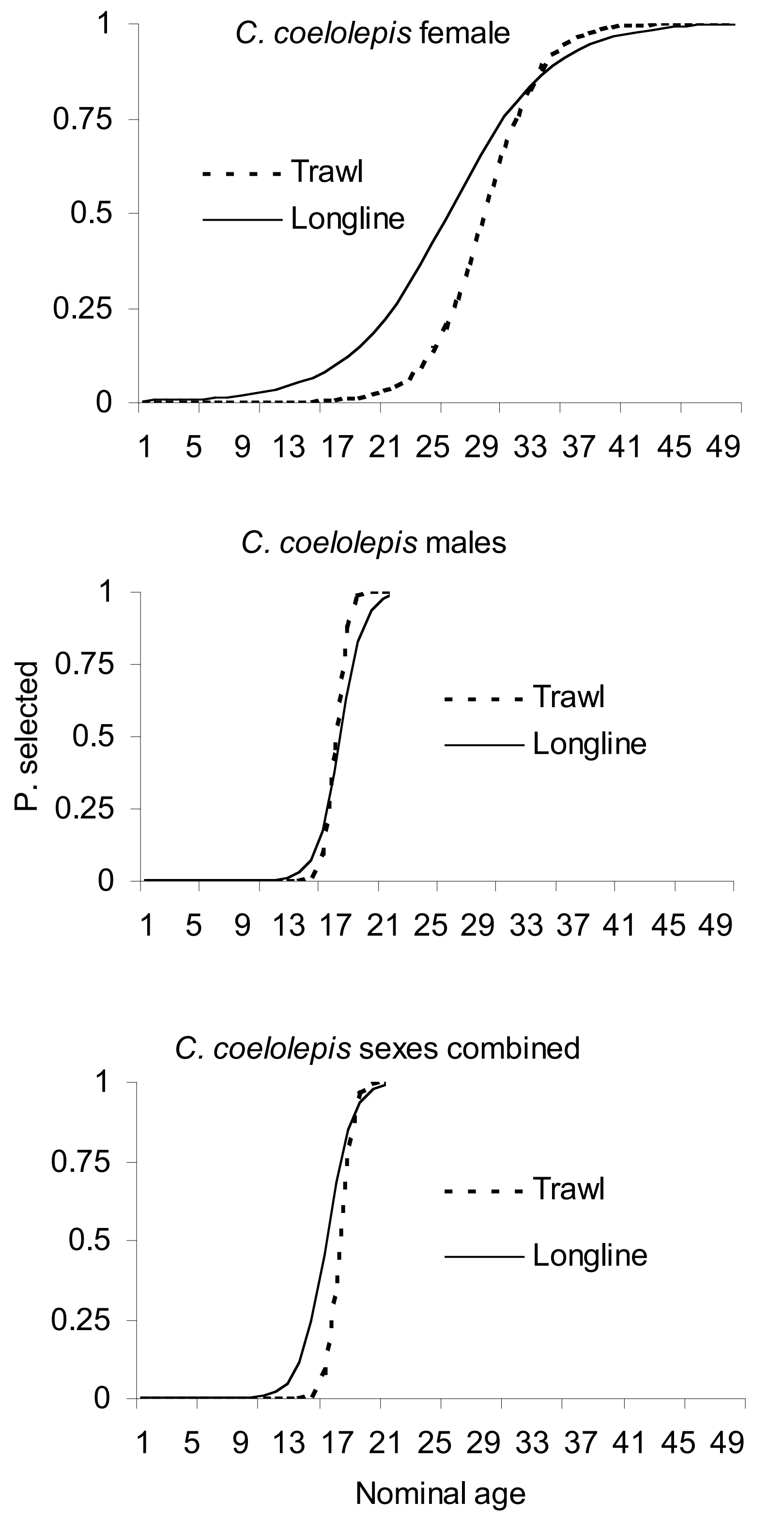


FIGURE 9

Estimated selectivity ogives for *Centrophorus squamosus*, derived from length-converted catch curves developed with hypothetical von Bertalanffy growth parameters

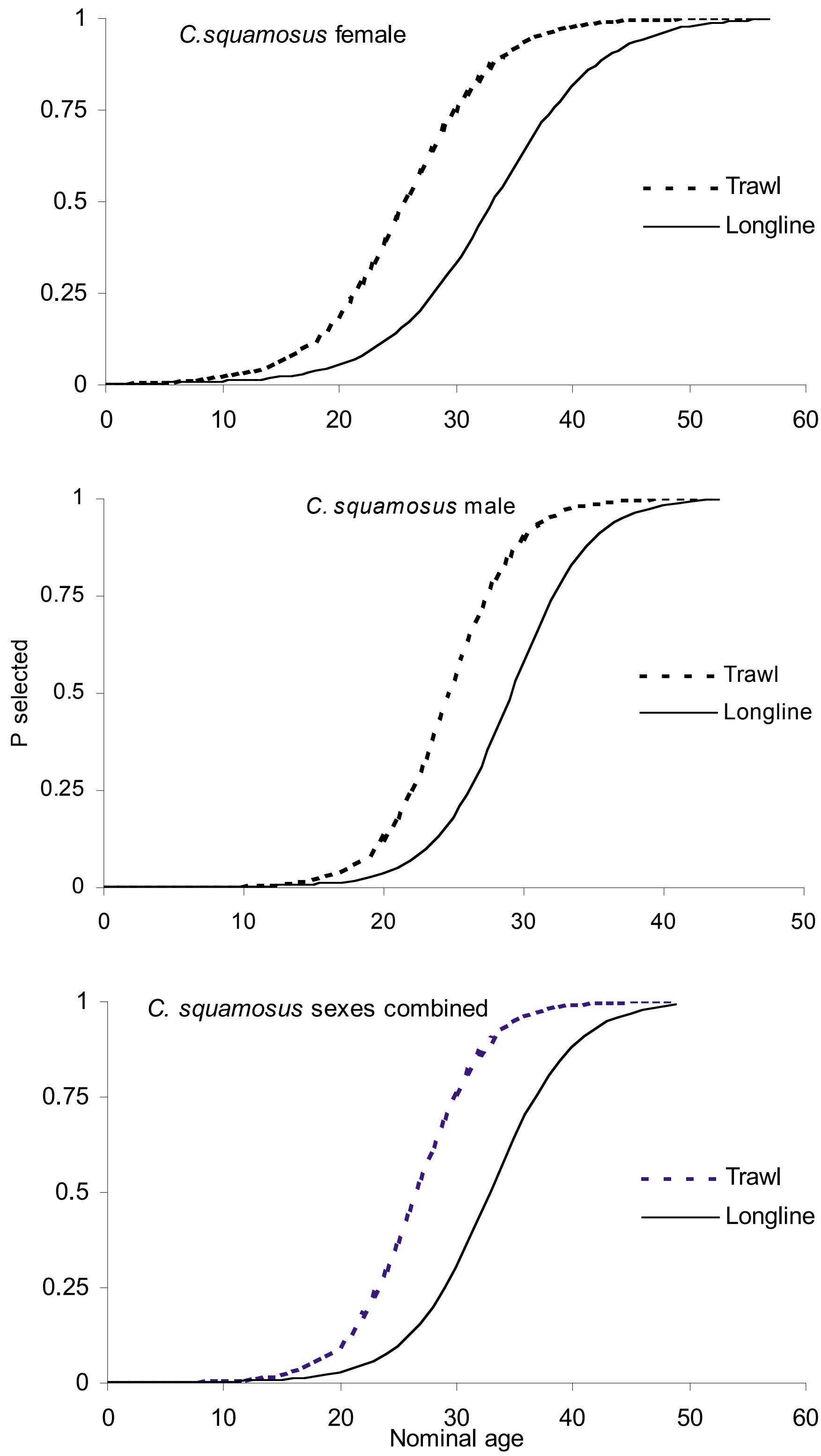
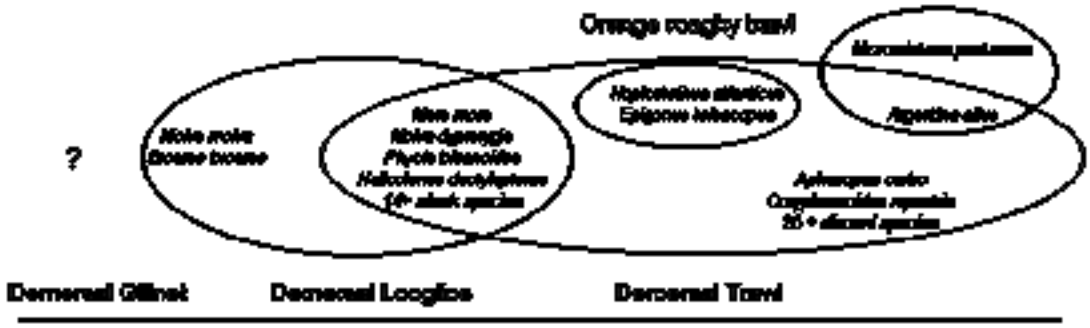


FIGURE 10

Schematic representation of the interactions between the main deepwater fishing gear types in the area west of Ireland and Britain

Some species are caught by more than one gear. Data on bycatch in the pelagic trawl fishery for greater Argentine *Argentina silus* are lacking. No data are available for gillnet fisheries.



More detailed analysis of selectivity in deepwater sharks is provided by Clarke, Borges and Officer (2005). The results show that longlines select for larger *Deania calceus* and *Centrophorus squamosus* than trawls. These results are in agreement with those found for many teleosts. However, results of the simulations for female *Centroscymnus coelolepis* suggest that longlines are not always more selective that trawl. Indeed, trawl catches displayed almost "knife-edge" selectivity for females of this species. These differences highlight an important property of longlining. This method can capture fish from a wider area than trawls, resulting in differing size distributions. This simulation predicts that exploitation of a stock of *C. coelolepis* by longlines will involve the removal of greater numbers of smaller females than exploitation by trawl. This suggests that longlines may be less size-selective for some deepwater sharks. This effect would suggest that a fishery for deepwater sharks, prosecuted solely by longline could result in greater removals of younger sharks, which is the opposite to what has been observed for teleosts.

Longlines are more effective at catching sharks and shark species dominate in longline catches deeper than 500 m. Small elasmobranchs dominate the discarded fraction of the catch from longlines, but not trawls. Therefore, in general, elasmobranchs are more vulnerable to longlines than to trawls. For some species, longline selects larger specimens. In theory, this means that exploitation of these species by longline will result in more of the biomass being left in the sea. However, for *Centroscymnus coelolepis*, longlines actually select for smaller females. This implies that targeting of this species by longline will remove more of the spawning stock than trawling. Therefore, *C. coelolepis* is especially vulnerable to exploitation in the area west and north of Ireland because all stages of its reproductive cycle are found in this area. In contrast, mature and gravid *Centrophorus squamosus* are totally absent, and those stages of *Deania calceus* are largely absent. This implies that these two species are somewhat less vulnerable to fishing in this area.

Until recently, fisheries taking deepwater sharks in the NE Atlantic were unregulated. However, in 2003, the European Community introduced a management regime for deepwater fisheries in Community waters and by Community vessels (Clarke and Patterson 2003). No TACs for sharks were implemented because there were no data upon which to base fishing quotas rights. However, a restriction on the amount of effort that can be expended on fishing any of the main deepwater elasmobranchs was put in place. Management of deepwater fisheries in the Northeast Atlantic Fisheries Commission (NEAFC) regulatory area is now being negotiated. This area corresponds to the international part of ICES waters. Though NEAFC has set an interim freeze on effort that can be expended in catching deepwater species, including sharks, it is not clear how effective this measure is.

Another important consideration for deepwater sharks in the northeast Atlantic is the FAO International Plan of Action for Elasmobranchs (IPOA-Sharks). The European Community intends to produce such a plan in 2004. This plan should pay particular attention to deepwater elasmobranchs because of their widespread occurrence in deepwater fisheries of Europe. Other coastal states have yet to implement national plans.

The current paper presents some biological and technical information on fisheries for deepwater elasmobranchs in the Northeast Atlantic. Much more work is still required. In particular, it will be necessary to have better assessments of the status of the stocks. Some progress has been achieved, though much remains to be done (Clarke *et al.* 2002). The main impediment is the lack of species-specific landings data or even data at a level sufficient to identify deepwater sharks separately from pelagic or shelf-dwelling taxa. The ICES Working Group on Elasmobranch Fishes is attempting to collate and refine catch data for deepwater and other sharks. A particular problem is the absence of information from the gillnet fleets that target deepwater sharks.

In conclusion, deepwater elasmobranchs are vulnerable species with low resilience to fishing and slow replacement rates. Heavy fishing pressure may be offset by the fact that it is concentrated in small portions of the overall range of these highly-migratory species. Assessments have been hampered by lack of data. However, the biological information available, along with the selectivity and technical data allow for some informed management advice to be provided. As stated in FAO texts on the Precautionary Approach to fisheries management, lack of data should not be used as an excuse for postponing management actions. This statement is particularly relevant for deepwater elasmobranchs.

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Utilization of deepwater dogfishes in Australia

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1. INTRODUCTION

In Australia, deepwater dogfishes are a major bycatch and, or, byproduct of commercial trawlers targeting orange roughy (*Hoplostethus atlanticus*) and drop and longliners targeting blue-eye trevalla (*Hyperoglyphe antarctica*) and pink ling (*Genypterus blacodes*).

Fishers are now targeting dogfishes to supplement their income outside the quota system with the flesh and liver oil of at least 11 species being marketed (Table 1).

TABLE 1
Marketed products of deepwater dogfishes by species

Species	Liver oil	Flesh
Centrophorus uyato	√	√
C. harrissoni	√	√
C. moluccensis	√	√
C. squamosus		√
Centroscymnus crepidater	√	√
C. owstoni	√	√
C. coelolepis	√	√
C. plunketi		√
Deania calcea	√	√
D. quadrispinosa	√	√
Etmopterus baxteri	√	

2. PRODUCTS

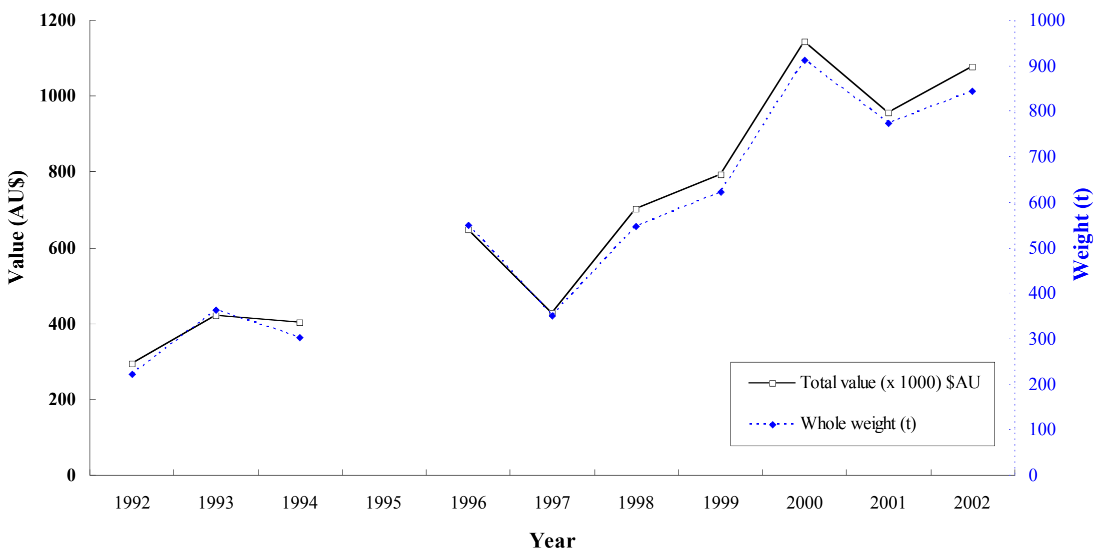
2.1 Flesh

Quantifying the market sales of dogfish is difficult as carcasses are sold at wholesale markets as:

- pearl/black shark
- (black) roughskin and
- endeavour shark (*Centrophorus* spp.).

The annual whole weight of dogfishes sold at the Melbourne and Sydney markets has increased from 221 t in 1992 to 844 t in 2002. The value has increased from $A292 000 in 1992 to $A1 080 000 in 2002 (Figure 1).

FIGURE 1
Annual whole weight and value of deepwater dogfish sold in Australia



In Sydney, the mean price of black roughskin shark has increased from $A1.77/kg in 1992 to $A4.23/kg in 2002, while the price of endeavour shark has remained between $A3.10 and $A3.90/kg over the same period. Retail outlets sell long and thin dogfish fillets as flake and prices are generally over $10/kg.

2.2 Liver oil

Livers from most *Centrophorus* spp. are higher in squalene and are therefore more valuable than livers from other dogfishes. Fishers are paid about $A6/kg for *Centrophorus* spp. livers while *Deania* spp. and *Centroscymnus* spp. livers are worth $A3/kg. *Etmopterus* spp. livers are worth less than $A2.80/kg.

3. MANAGEMENT

Fishers are permitted to take up to 150 kg of *Centrophorus* spp. a day of which only 30 kg can be of *C. harrissoni*. There are currently no regulations governing the catching of mid-slope dogfishes although fishers collecting livers must also land the associated carcasses.

4. DISCUSSION

It is well documented that chondrichthyans are vulnerable to overfishing and serious declines in upper-slope dogfish (*Centrophorus* spp.) stocks off southeastern Australia have already been documented (Graham, Andrew and Hodgson 2001). As mid-slope dogfish products become more marketable there is increasing scrutiny with respect to their management and conservation.

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The conservation status of deep-sea chondrichthyan fishes

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1. INTRODUCTION

1.1 Background

Deep-sea species are widely recognized as relatively unproductive, highly vulnerable to overfishing and potentially slow to recover from the effects of overexploitation. In the face of rapidly expanding deep-sea fisheries and lack of effective management, of particular concern is the impact, either through targeted fishing or bycatch, on deep-sea chondrichthyan[1] fishes, an extremely vulnerable taxonomic group (Lack, Short and Willock 2003). Despite this concern, knowledge regarding such impacts and the conservation status of most of the deep-sea chondrichthyans is seriously limited. This paper summarizes the outcomes of a series of the IUCN Shark Specialist Group's Red List workshops for the assessment of the conservation status of chondrichthyans, focusing on case studies of deep-sea species and discussing some of the problems faced due to lack of data and taxonomic uncertainty.

1.2 Deep-sea chondrichthyans

Chondrichthyans are an evolutionarily conservative group that has functioned successfully in diverse ecosystems for 400 million years. Despite their evolutionary success, some populations may now be threatened with extinction as a result of human activities and the conservative life–history traits of this group of fishes: slow growth, late maturity, low fecundity and low natural mortality. These characteristics result in low rates of potential population increase with little capacity to recover from overfishing (either direct or indirect) and other threats such as pollution and habitat destruction (Holden 1974, Pratt and Casey 1990).

Nearly 35 percent of chondrichthyan species are confined to deepwater (defined here as >200 m), although the number of chondrichthyans known to spend all or part of their lifecycle below 200 m depth includes at least half of the >1 100 living species. The fauna of most deep-sea areas is poorly known and new deepwater chondrichthyan species are regularly recorded and described worldwide. For example, exploratory deep-sea fishery surveys resulted in the discovery of six-gilled stingrays (Hexatrygonidae) in the Pacific in the mid-1990s, as well as new skates and undescribed chimaeras in the South Atlantic (L.J.V. Compagno, South African Museum, pers. comm.) and in 2003 a

[1] The cartilaginous fishes: sharks, skates, rays and chimaeras.

research cruise on the seamounts and abyssal plains around Lord Howe and Norfolk Islands in the western Pacific also resulted in the discovery of new species and new records of deep-sea chondrichthyans <*http://www.oceans.gov.au/norfanz/*>.

Deep-sea chondrichthyans are considered to be less resilient to fishing pressures than coastal and epipelagic oceanic species (Gordon 1999). This is due to the characteristically limited reproductive capacity of cartilaginous fishes (usually even lower in deep-sea species) combined with a lower population biomass compared to shelf species and the limited productivity and geographic constraints that characterize cold, deep environments. Many deep-sea species are widely (albeit often disjunctly) distributed, while others are endemic, restricted to small areas such as isolated seamounts, submarine ridges, or the deep slopes off a single country (Compagno and Musick 2005).

There is increasing commercial development of new deep-sea fisheries (Gordon 1999, Lack, Short and Willock 2003) as traditional pelagic and inshore demersal stocks decline and fleets move further offshore and into deeper water in attempts to sustain or increase catch levels. The development and wide-scale deployment of non-selective deep fishing gear means that fisheries are becoming far less selective, wider ranging, and entering environments that have not yet been surveyed. Deep-sea chondrichthyans will increasingly be caught as bycatch, at least in the early phases of fisheries when they are still well represented in the zonal fauna. In the few deep-sea areas that have been surveyed, evidence shows that some chondrichthyan populations have suffered serious, perhaps even irreversible, damage while the fisheries are still removing a sufficient biomass of bony fishes and invertebrates (Graham, Andrew and Hodgson 2001). It is possible that deep-sea fisheries could drive some bathyal chondrichthyans (particularly endemics) to extinction before management can be implemented, and possibly even before a species has been seen and described by researchers.

The availability of trade data for deep-sea chondrichthyans is sparse. While many species have little or no commercial value and are discarded, others are valued for their liver oil (rich in squalene) and flesh (Irvine, Laurenson and Stevens 2005). The commercial value of these products, together with declining catches of other deep-sea resources, has seen an increase in targeted fishing effort towards these species in some regions (Lack, Short and Willock 2003).

1.3 IUCN Red List of Threatened Species™

The *IUCN Red List of Threatened Species™* is widely recognized as the most comprehensive source of information on the global conservation status of plant and animal species used worldwide for focusing attention on species of conservation concern as a basis to enable management priorities to be targeted, and for monitoring the long-term success of conservation and management initiatives. Although the Red List is not a legal instrument, it is used by government agencies, non-governmental organizations, natural resource planners, educational institutions and others to promote improvements in management and the research necessary to deliver successful management.

Historically, marine species have been little considered for inclusion in the Red List. However, the IUCN Species Survival Commission (SSC), custodian of the *IUCN Red List of Threatened Species™*, plans a major effort over the next 5-10 years to address

[2] The IUCN (World Conservation Union) comprises >7 000 scientists, government officials and conservationists from 188 countries and provides advice to governments, international conventions and conservation groups throughout the world. It comprises several Commissions, one of which is the Species Survival Commission (SSC). The SSC established the Shark Specialist Group (SSG) in 1991, in response to growing awareness and concern of the severe impact of fisheries on chondrichthyan populations around the world. With >170 members around the world, this network provides leadership for the conservation of threatened species and populations of all chondrichthyan fishes and aims to at promote promoting their sustainable use, wise management and conservation.

this. This initiative includes ongoing efforts by the IUCN SSC Shark Specialist Group (SSG)[2] – the Red List Authority for chondrichthyans – to complete a global assessment of the >1 100 species by 2006. Comprehensive assessment of all chondrichthyans will establish a baseline against which to monitor future changes in the global and regional status of chondrichthyans and improvements in our scientific knowledge of this group. This information will promote improvements in the fisheries management of these biologically vulnerable species. In the case of deep-sea chondrichthyans, the need is particularly urgent given the sparse information available on stock sizes and distribution, unresolved taxonomic issues and the low management priority afforded them.

This 'Global Chondrichthyan Assessment' is being undertaken through a series of regional expert workshops to facilitate discussions and sharing of knowledge. Although only partially complete, this process is already highlighting the serious plight of this extremely vulnerable group of fishes (close to 20 percent of the 377 species assessed thus far have been classified as 'threatened'). In addition to identifying threatened species and elucidating the causative factors, this programme is documenting the distribution, life histories and other key parameters of the species assessed including trade and fisheries information, thus increasing our knowledge and creating an easy-accessed centralized dataset. This is already providing the international conservation community, treaties such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and agencies such as the UN Food and Agriculture Organization (FAO)[3], with a powerful tool for setting programme priorities.

2. METHODOLOGY

For more than 40 years the IUCN SSC has been evaluating the conservation status of species and subspecies on a global scale for IUCN Red Books on individual taxonomic groups and, more recently, for the *IUCN Red List of Threatened Species™*. A major advancement was the adoption in 1994 of a new system of Red List Categories and Criteria, which includes explicit quantitative criteria as the basis for extinction risk assessment. The most recently revised Categories and Criteria (Version 3.1) came into use in 2001 (Hilton-Taylor 2000, IUCN 2001).

Red List assessments evaluate the conservation status of individual species, identify threatening processes affecting them and, if necessary, propose recovery objectives for their populations. There are nine categories in the Red List system: Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern, Data Deficient and Not Evaluated. Classification into the categories for threatened species (Vulnerable, Endangered and Critically Endangered) is through a set of five quantitative criteria based on biological factors related to extinction risk including: rate of decline, population size, area of geographic distribution, and degree of population and distribution fragmentation. Table 1 lists definitions of the categories and Appendix I a summary of the criteria. For more details see the Red List Categories and Criteria Version 3.1 (IUCN 2001) available at <*http://www.redlist.org*>.

The series of regional workshops, which bring together international experts and national scientists and fisheries staff, compile and analyze species data. All assessments produced at these workshops are circulated for comment to the entire SSG network before being adopted by consensus and submitted to the Red List Programme for inclusion in the Red List (Table 2).

[3] The FAO International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) recommends that States adopt a National Plan of Action for chondrichthyan stocks whether catches occur as a result of directed or non-directed fisheries.

3. RESULTS AND DISCUSSION

3.1 Assessment status

To date the SSG has assessed the global threatened status of 377 chondrichthyan species (including those of deep-sea species), plus a further 67 assessments at the regional and subpopulation level. Sixty-five species are globally threatened (Critically Endangered, Endangered and Vulnerable), together with a further 27 subpopulations assessed as threatened at the regional level. Further Red List assessments for additional species have been undertaken recently, for which the review process is currently underway.

Of all chondrichthyan species assessed thus far (not only deep-sea species), 17.2 percent are threatened (Critically Endangered, Endangered or Vulnerable), 18.6 percent are Near Threatened, i.e. considered close to meeting the criteria for a threatened category, 25.7 percent are Least Concern and 38.2 percent are Data Deficient (note, one species was assessed as Conservation Dependent in 2000, this category is no longer in use by IUCN). Regarding deep-sea results, 109 species occurring only at depths of >200 m have been assessed to date, and of these 4.6 percent are threatened, 7.4 percent Near Threatened, 18.3 percent Least Concern and 69.7 percent Data Deficient. If species occurring at a wider depth range (i.e. species which occur >200 m, but also occur shallower) are included, of 216 assessed, 6.9 percent are threatened, 14.4 percent Near Threatened, 23.1 percent Least Concern and 55.6 percent Data Deficient, together with a further 5.6 percent threatened at the regional or subpopulation level. A detailed analysis will be published by the IUCN SSG on completion of the global programme.

TABLE 1
Red List categories (IUCN 2001)

Category	Definition
Extinct (EX)	A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known ~~and/or~~and, or, expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Extinct in the Wild (EW)	A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturali~~sed~~zed population (or populations) well outside the past range. A taxon is presumed Extinct in the Wild when exhaustive surveys in known ~~and/or~~and, or, expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Critically Endangered (CR)	A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered, and it is therefore considered to be facing an extremely high risk of extinction in the wild.
Endangered (EN)	A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered, and it is therefore considered to be facing a very high risk of extinction in the wild.
Vulnerable (VU)	A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable, and it is therefore considered to be facing a high risk of extinction in the wild.
Near Threatened (NT)	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Least Concern (LC)	A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

Data Deficient (DD)	A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and, or, population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and, or, distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate. It is important to make positive use of whatever data are available. In many cases great care should be exerczed in choosing between DD and a threatened status. If the range of a taxon is suspected to be relatively circumscribed, and a considerable period of time has elapsed since the last record of the taxon, threatened status may well be justified.
Not Evaluated (NE)	A taxon is Not Evaluated when it has not yet been evaluated against the criteria.

TABLE 2
Regional Red List workshops

Region	Species assessed[4]	Outcomes
Australia and Oceania	175	Regional and, or, global assessments for 175 species submitted to 2003 Red List and a workshop report published in hardcopy and as pdf on the web (Cavanagh *et al.* 2003).
South America	129	Regional and, or, global assessments for 50 species submitted to 2004 Red List. Remainder undergoing consultation process and will be submitted to 2005 Red List.
Southern Africa	130	Regional and, or, global assessments for 33 species submitted to 2004 Red List. Remainder undergoing consultation process and will be submitted to 2005 Red List.
Mediterranean	68	Initial consultation underway. Will be submitted to 2005 Red List.
Deep-sea species[5]	30	Global assessments for 30 species submitted to 2004 Red List.

3.2 Case Studies: Deep-sea Chondrichthyans on the Red List

A review of the assessments undertaken to date indicate that the taxa at highest extinction risk include commercially exploited species of deep-sea sharks. However, many deep-sea species are categorized as Data Deficient due to insufficient data to make a valid assessment of their status, even though some of these are likely to be threatened. Case studies of deep-sea species assessments to illustrate some of the trends are presented here.

i. Harrisson's dogfish (*Centrophorus harrissoni* – McCulloch 1915)

Red List assessment

Global (endemic to Australia) Critically Endangered A2bd+3d+4bd[6]

Notes: Endemic to Australia (New South Wales, Victoria and Tasmania). A demersal species occurring mainly at depths of 220–790 m, but also known from as deep as 1 050 m (Daley, Stevens and Graham 2002). Low fecundity (1–2 pups, every 1–2 years), high longevity (closely related species live for at least 46 years) (Fenton 2001) and probable late age at maturity.

This species provides a good example of documented declines over time (in the majority of cases for deep-sea chondrichthyans such fishery-independent data are

[4] Note that Some of the wider ranging species have been assessed at more than one workshop for different regional subpopulations.
[5] Thematic Undertaken by a thematic workshop held in conjunction with the Deep Sea 2003 Conference.
[6] See Appendix.

unavailable). The basis for this assessment was a study by Graham, Andrew and Hodgson (2001). Documented declines of over 99 percent were recorded between 1976–77 and 1996–97 between Newcastle (central New South Wales (NSW)) and the Eden-Gabo Island area (southern NSW/northern Victoria) by a fishery-independent trawl research survey. The relatively narrow continental slope habitat of this species (which is fished throughout its entire depth range) suggests that it may now only be present in significant numbers in areas that are non-trawlable. However, as dropline fishers also harvest this species off NSW, further pressure may be placed on it in such areas. As with other deepwater sharks, particularly this genus, the low fecundity, high longevity and probable late age at first maturity of this species not only result in extremely rapid population depletion in fisheries, but prevent it from quick recovery after such depletion (Pogonoski and Pollard 2003).

The demersal multi-species trawl fishery operating on the continental slope off south-eastern Australia studied by Graham, Andrew and Hodgson (2001) illustrates the difficulties of sustainably harvesting deep-sea chondrichthyans, particularly when they form a relatively minor component of a multi-species catch and the fishery continues after the severe decline of the sharks and rays. In addition to *C. harrissoni*, other species seriously affected by this fishery include the southern dogfish *C. uyato* (Critically Endangered in Australia), Endeavour dogfish *C. moluccensis* (Endangered in Australia) and several *Squalus* species (Graham, Andrew and Hodgson 2001, Cavanagh *et al.* 2003). Catches are now limited and *C. harrissoni*, *C. uyato* and *C. moluccensis* have been nominated for listing on the Australian Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. These deep-sea dogfishes also highlight taxonomic problems which further compound the difficulties in assessing and managing these species. For *C. moluccensis, C. uyato* and others, taxonomic uncertainties make it impossible to assess their threatened status on a wider geographical basis until species complexes are resolved and distribution better defined.

ii. Barndoor skate (*Dipturus laevis* – [Mitchell 1817])

Red List assessment

Global (endemic to Canada and USA): Endangered A1bcd

Notes: Restricted to the Northwest Atlantic continental shelf and slope of Canada and the USA (Kulka, Frank and Simon 2002). Found as shallow as the tideline (Bigelow and Schroeder 1953) down to 1 400 m (Kulka, Frank & Simon 2002). Longevity has been estimated as 13–18 years, and age at maturity 8–11 years (Frisk, Miller and Fogarty 2001). Egg production estimated as 47 a year (Casey and Myers 1998).

This Red List case study illustrates a situation where deep-sea areas can provide a refuge for species already vulnerable to exploitation in shallower shelf regions. The barndoor skate is highly vulnerable to exploitation because of its slow growth rate, late maturity, low fecundity and large body size. Although never directly targeted, it was a byproduct of multi-species trawl fisheries on the Georges Bank, Scotian Shelf, Grand Banks and Labrador Shelf and is also taken on longlines. Catch rates of barndoor skates in USA waters <400 m within the centre of its latitudinal range on the southern shelf (<43° N) declined by 96–99 percent from the mid-1960s to the 1990s. While the severity of this decline would theoretically be considered grounds for listing as Critically Endangered (directly applying the IUCN Categories and Criteria), there are several reasons for the lower Endangered listing: fishing effort on the shelf area has declined in the last decade, the latitudinal and depth range of this species is considerably wider than previously thought, and numbers of juveniles now appear to be increasing not only in no-take zones on Georges Bank and the Southern New England shelf but also in adjacent areas to the north and south and elsewhere. However, it is possible that in the event of opening the no-take areas, the subsequent increasing fishing effort would lead to the decline of the barndoor skate in these areas (Dulvy in press). A review of this Red List assessment is currently underway, particularly due to recovery of the population south of the Scotian Shelf (Gedamke and Kulka in prep).

The barndoor skate appears to be rare on the shallower continental shelf, and the main part of the population is now known to occur in shelf channels and along the continental shelf edge in waters >450 m deep (Kulka 1999, Anon. 2000). Further little fishing occurs at depths greater than 200 m. Strict precaution must be exercized as any increases in trawl fishing effort at depth will likely lead to the decline of the barndoor skate in these areas. Any development of fisheries into such areas requires strong management control to ensure the decline of this, and similarly vulnerable species occurring in deep-sea refugia, is prevented from the outset.

iii. Leafscale Gulper Shark (*Centrophorus squamosus* – [Bonnaterre 1788])

Red List assessment[7]

Global: Vulnerable A2bd+3bd+4bd

Notes: Wide but patchy global distribution in the Atlantic, Indian and Pacific Oceans. A demersal species occurring mainly in depths of 230–2 400 m, also pelagic in the upper 1 250 m of oceanic water in depths to 4 000 m (Compagno and Niem 1998). Fecundity 5–8 pups (Last and Stevens 1994), high longevity with varying age estimates of 21–70 years (Clarke, Connolly and Bracken 2002), and probable late age at maturity.

This example illustrates the case of a targeted Vulnerable deep-sea shark for which fisheries are increasing in some areas and where CPUE data are combined with similar species. *Centrophorus squamosus* has been exploited commercially for many years and is an important component of deepwater longline and trawl fisheries in certain areas within its range, such as the eastern Atlantic off Ireland, Spain, Portugal and France. It was targeted heavily by the Portuguese deepwater longline fishery for which exploitation peaked in 1986 but has been steadily declining since then (Correia and Smith in prep.). In Japan exploitation peaked during World War II, because of the high percentage of squalene in its liver, but quickly declined due to decreasing catches. Significant declines have been documented (ranging from 20–69 percent in one year to 80–90 percent in three years) in parts of the Northeast Atlantic, but these are based on CPUE for *C. squamosus* and *Centroscymnus coelolepis* combined for only part of the distribution area and cannot be related to fishing effort. It is extremely important that landings for this species are reported separately and no longer combined with *C. coelolepis*. However, these declines together with the acute vulnerability to exploitation of *Centrophorus* species as shown from NSW fishery-independent surveys (Graham, Andrew and Hodgson 2001), and the knowledge that *C. squamosus* has limiting life history characteristics, led to this species being assessed as Vulnerable as a precautionary measure. Due to the apparently long lifespan of this species, the recovery of a heavily fished population would require a long period of time (White 2003, Hareide in prep.).

Further studies are required to determine this species' life history characteristics and other parameters necessary for management. There is an intention to analyse historic French landing data with the purpose of separating landings and CPUE for the two species and this assessment should then be revisited. The level of fishing pressure needs to be further examined in the various populations within its range to establish

[7] This assessment is being updated due to more recent information from Europe. Red List assessments are continually updated as new information is obtained. For this reason, readers are urged always to consult the current Red List (<*www.redlist.org*>), updated annually, to obtain the most recent assessments.

whether separate regional assessments are more appropriate. It should be noted that a Vulnerable assessment may be applicable to many other poorly-known deep-sea species that are currently being exploited by unmanaged expanding fisheries.

iv. Lizard catshark (*Schroederichthys saurisqualus* – Soto 2001)

Red List assessment

Global (endemic to Southern Brazil): Vulnerable B1ab (iii, v)

Notes: Known from Paraná State to Rio Grande do Sul State (25 °S to 30 °S), Southern Brazil in depths of 250–500 m on the upper continental slope and sporadically on the outer edge of the continental shelf. Oviparous. It uses patches of deep-sea corals for egg-laying.

Currently known from a restricted area off Southern Brazil, the status of this deep-sea species is of concern due to the destruction of vital habitat through fisheries activities. It appears that the distribution of coral patches used for egg-laying determines the distribution of *Schroederichthys saurisqualus*. These coral patches seem to be naturally scarce, are of small size and are vulnerable to destruction by demersal trawling operating in the area. Trawl surveys of areas that have previously captured egg-laying females on stony coral have revealed that once the coral patch is gone so are the catsharks. Given the low temperatures (~5 – 8 °C) at the depths of coral occurrence, recovery from destruction is expected to be extremely long. It is possible that important coral habitat is more widespread in areas with rough bottom, not surveyed by trawling, and so the preferred habitat of this species may be more widespread than currently known, however, further surveys are required to confirm this. At present , this species is considered to face a high risk of extinction due to its restricted range, low density and loss of habitat through fishing activities. While further survey work is required to accurately determine the range of this species, the exclusion of fishing from breeding habitat or the creation of marine protected areas may prove essential for the conservation of the species (Vooren and Soto 2004).

v. Deepwater catsharks (*Apristurus* sp. A-G [Last & Stevens 1994])

Red List assessment

Global (endemic to Australia and New Zealand): Data Deficient

Notes: Uncertain distributions in the Western Pacific and Eastern Indian around Australia and New Zealand, although some species may be more widespread. These species have been variably recorded from depths of 590–1 500 m (Last and Stevens 1994). Virtually nothing is known of their biology.

There is great concern that some deep-sea fisheries are taking sharks for which there is little information and indeed some that are not yet taxonomically described, such as the poorly known deep-sea catsharks of the *Apristurus* genus. Their range is uncertain due to misidentification, although they are known to occur within some heavily fished areas, for example, some species from this genus are known to be taken as bycatch in orange roughy fisheries in both Australian and New Zealand waters (Lack, Short and Willock 2003). They are thought to be quite rare and there is concern regarding potential future expansion of deepwater demersal trawl fisheries. Although little is known about their biology, assuming they have life history characteristics similar to related species, they may not be sufficiently productive to withstand current and, or, future exploitation pressure (Cavanagh *et al.* 2003).

Despite the knowledge that they are likely to have limiting life history characteristics similar to better-studied deep-sea *Squalus* species, the lack of data on biology, extent of occurrence, population size or any indicator of population trends of some Australasian *Squalus* species results in their being given a Data Deficient listing (Cavanagh *et al.* 2003).

Case studies show that knowledge of the status of many deep-sea chondrichthyans is extremely limited. Consequently the Data Deficient category was often assigned, despite concerns that chondrichthyans appear to be among the most vulnerable of deep-sea species. Although efforts were made to avoid this category by using all data available, around 50 percent of deep-sea species are currently listed as Data Deficient, with inadequate information available on their distribution and, or, abundance to make a direct or indirect assessment of their extinction risk. It is clear that Data Deficient species are some of those most in need of urgent action. It is vital to direct funding for research efforts on these species as well as those in the threatened categories.

vi. Lined Lantern Shark (*Etmopterus dislineatus* – Last, Burgess & Séret 2002)

Red List assessment
Global (endemic to Australia): Least Concern

Notes: Endemic to a limited area in the central Coral Sea off Australia. Known from depths of 590–700 m on or near the bottom of the continental slope (Last and Stevens 1994). Little is known of their biology.

This example of a Least Concern species illustrates the situation when, despite little available information, there is enough evidence to assume there are no current or potential threats. There are presently no major fishing activities in the known area of occurrence and depth range of this small (to 45 cm total length) deep-sea lantern shark, which has no commercial value. The same applies to the similar species *E. caudistigmus, E. dianthus, E. evansi* and *E. fusus.* Overall, approximately a third of the deep-sea species assessed to date fall into the Least Concern category, usually for the same reasons as these lantern sharks. However, given the vulnerability of deep-sea species in general, it is essential that a precautionary approach be adopted to ensure they are protected. Many assessments incorporate a precautionary note that indicates the need to monitor the situation should deepwater trawling develop within their range (Kyne and Cavanagh 2003).

vii. Pale Ghostshark (*Hydrolagus bemisi* – Didier 2002)

Red List assessment
Global (endemic to New Zealand): Least Concern

Notes: Widespread on the upper and mid continental slope around New Zealand, it is recorded from depths of 86–1 410 m, but is most abundant at depths of 500–900 m. Is is an oviparous species of unknown productivity, but this may be low.

This species illustrates an example of an exploited chondrichthyan species that is managed through a quota system and is assessed as Least Concern. This species is widespread around New Zealand with a wide depth range. It is a bycatch of trawling for hoki and other deepwater species with landings of around 1 700t a year (Francis 2003a). Catches of this species together with the dark ghostshark (*H. novaezealandiae*) are regulated by the Quota Management System (QMS) through individual transferable quotas (ITQs) since 1998. Prior to 1998 there was no regulation and records of the catch were incomplete. Fishers are now required to report catches of the two species separately (Francis *et al.* 1998).

While biomass indices for this species are variable depending on location and depth, the overall population of *H. bemisi* is considered to be relatively stable and can support the current level of exploitation. For example, on the Chatham Rise, to the east of New Zealand's South Island, biomass indices show stability in the 200–800 m depth range, but are declining in the 750–1 500 m depth range. The 200–800 m range encompasses the main depth range for the species (500–900 m) (Francis 2003a). For *H. novaezealandiae*, also assessed as Least Concern, biomass indices are variable, but are possibly increasing in some areas (Francis 2003b). By setting appropriate output controls through the QMS these two species should continue to be sustainably harvested. The value of fisheries research and monitoring to produce biomass indices is highlighted by this case study.

4. SUMMARY

4.1 Taxonomic uncertainty and the lack of baseline data

The lack of species-specific reporting is a widespread problem in fisheries management. However, this is exacerbated in poorly studied deep-sea environments where taxonomic uncertainty may also be problematic. It is evident that knowledge of the taxonomy, stock structure, status and biology of most deep-sea chondrichthyan fishes is seriously limited. The lack of species-specificity of recorded data in many regions and the uncertainty surrounding the sustainability of current levels of fishing are issues in urgent need of attention. The Data Deficient category is often unavoidably assigned, despite concerns that deep-sea chondrichthyans are among the most vulnerable of species. This issue urgently needs to be addressed with research funding directed towards these species. There is a need for more fishery-independent data and research into the survivability of species caught by different fishing methods at various depths if they are released after capture. There are some important targeted deepwater chondrichthyan fisheries, some of which are driven by international demand for their products, particularly liver oil (Irvine 2005), and more data and regulation are required to better monitor and manage this trade.

4.2 Multi-species fisheries and bycatch

Many assessments highlight concern for species caught as bycatch. Most deep-sea chondrichthyans are taken in multi-species fisheries or as bycatch in fisheries targeting more abundant, valuable teleosts and crustaceans. A number of threatened deep-sea species have been discussed that raise complex management considerations for species such as *C. harrissoni*, which could go extinct while more fecund and resilient species continue to support the fishery. Seriously threatened species include *C. harrissoni* and the southern dogfish (*C. uyato*), which have suffered dramatic declines as a result of commercial fishing. These declines emphasize the importance of obtaining baseline data prior to the development of new deepwater fisheries in previously unexploited areas, and continued research and monitoring of the bycatch of chondrichthyans in non-target fisheries is vital. Such drastic declines in species with low productivity are highly unlikely to be reversible in the short to medium term. It may be that closed areas as a fisheries management tool that provide refuges for stock recovery are the only management solution. Marine protected areas are another tool to restore, safeguard and halt negative impacts on the biodiversity of the oceans, including deep-sea regions (Gjerde and Breide 2003).

This paper has discussed some of the main issues and trends highlighted by the IUCN SSG's Red List assessments, which indicate that commercially exploited species of deep-sea sharks are among the marine taxa at highest risk of extinction, a trend inextricably linked to their restricting life history characteristics and sometimes restricted distributions. Comprehensive assessment and regular re-assessment of chondrichthyans using IUCN's Red List system is one of the SSG's most important tasks. The status of species assigned to a threatened category must be monitored closely, and research conducted without delay to better understand their biology, threats and conservation needs, and to implement management and recovery plans where necessary. More resources need to be directed towards species that are assessed as Data Deficient, yet are potentially threatened. Moreover, since data collection in the deep-sea environment is so difficult, it is important to take note of the evidence available and manage with the precautionary approach (Irvine 2005). Few marine animals have a lower international management priority than deep-sea chondrichthyans and commercial development of new deep-sea fisheries, which threaten them, is increasing. In many cases it is unclear whether current levels of catch are sustainable and any increases in fishing effort, particularly if unregulated, are an obvious cause for concern for chondrichthyans that, as a taxonomic group, are considered to have little capacity to sustain, or recover from, fishing pressure (Lack, Short and Willock 2003).

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APPENDIX

The 2001 IUCN Red List Criteria (Ver. 3.1) for Critically Endangered, Endangered and Vulnerable

	Critically Endangered (CR)	Endangered (EN)	Vulnerable (V)
A. Reduction in population size based on any of the following:			
A1. An observed, estimated, inferred or suspected population size reduction of: over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are: clearly reversible AND understood AND ceased, based on (and specifying) any of the following a–e:	≥90%	≥70%	≥50%
A2. An observed, estimated, inferred or suspected population size reduction of: over the last 10 years or three generations, whichever is the longer, where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of the following a–e:	≥80%	≥50%	≥30%
A3. A population size reduction of: projected or suspected to be met within the next 10 years or three generations whichever is the longer (up to maximum of 100 years), based on (and specifying) any of the following b–e:	≥80%	≥50%	≥30%
A4. An observed, estimated, inferred, projected or suspected population size reduction of: over any period of 10 years or three generations whichever is longer (up to a maximum of 100 years), where the time period includes both the past and the future, and where the decline or its causes may not have ceased OR may not be understood OR may not be reversible, based on (and specifying) any of the following a–e: a) direct observation b) an index of abundance appropriate for the taxon c) a decline in area of occupancy, extent of occurrence and, or, quality of habitat d) actual or potential levels of exploitation e) the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.	≥80%	≥50%	≥30%
B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy) OR both:			
B1. Extent of occurrence estimated to be (km²): and estimates indicating any two of a–c:	≥100%	≥5 000%	≥20 000%
B2. Area of occupancy estimated to be (km²): and estimates indicating any two of a–c:	≥10%	≥500%	≥2 000%
a. Severely fragmented or know to exist at” b. Continuing decline, observed, inferred or projected, in any of the following: i) extent of occurrence			

	Critically Endangered (CR)	Endangered (EN)	Vulnerable (V)
ii) area of occupancy iii) area, extent and, or, quality of habitat iv) number of locations or subpopulations v) number of mature individuals. c. Extreme fluctuations in any of the following: i) extent of occurrence ii) area of occupancy iii) number of locations or subpopulations iv) number of mature individuals.			
C. Population small and declining Estimated to number fewer than(mature individuals) and either	<250	<2 500	<10 000
C1. An estimated continuing decline of at least			
in	25%	20%	10%
or	3 years	5 years	10 years
whichever is longer (up to a maximum of 100 years in the future)	1 generation	2 generations	3 generations
OR			
C2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals AND at least one of the following:			
a) Population structure in the form of one of:			
i) no subpopulation estimated to contain more than	50	250	1 000
(mature individuals), OR	90%	95%	All (100%)
ii) at least:			
of mature individuals are in one subpopulation			
b) Extreme fluctuations in number of mature individuals.			
D. Population size			
D1. Population size estimated to number fewer than: (mature individuals) OR	<50	<250	<1 000
D2. Population with a very restricted area of occupancy (typically less than 20 km2) or number of locations (typically five or less) such that it is prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and is thus capable of becoming Critically Endangered or even Extinct in a very short time period.	n/a	n/a	VU only
E. Quantitative analysis			
showing the probability of extinction in the wild is at least	50%	20%	10%
within	10 years	20 years	100 years
or	3 generations	5 generations	n/a
whichever is the longer (up to a maximum of 100 years)			

Preliminary investigation of artisanal deep-sea chondrichthyan fisheries in Eastern Indonesia

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1. INTRODUCTION

Indonesia has one of the richest elasmobranch faunas and the largest chondrichthyan fishery in the world, with an estimated 87 138 t and 100 000 t landed in 1993 and 1996, respectively (Bonfil 1994, Monintja and Poernomo 2000, Widodo 2000). However, there are few data on the species or size composition of these landings. The only information available on the catches of individual species is that provided by pelagic tuna fishers, who estimated that in 1999 they landed 5 217 tonnes of mako sharks (*Isurus paucus* and *I. oxyrinchus*) and 47 079 tonnes of other species (Priyono 2000). The high diversity of the elasmobranch fauna in Indonesia has been well documented by Gloerfelt-Tarp and Kailola (1984), Last and Stevens (1994) and Carpenter and Niem (1998, 1999). These authors highlighted the need for research in certain areas and in particular the acquisition of sound taxonomic data so that the various species could be readily identified and reliable data could be obtained for the geographical distribution and biology of many of the species.

All of the body parts of landed elasmobranchs are used. The flesh, which is often dried, is used for local consumption whereas the fins are dried and exported to other Asian countries where they are highly valued (Chen 1996). Squalene oil from the livers of some shark species (mainly squaloids) is also commonly exported with several companies in Indonesia exporting as much as 48 000 kg of liver oil annually (Chen 1996). Other exported shark products include the dried cartilage of larger individuals and there is a growing demand for specialist products at particular locations, such as the gill rakers of mobulid rays. The flesh of shark and rays are typically salted and dried and used for human consumption within Indonesia or exported.

The first detailed assessment of the compositions and relative abundances of species of chondrichthyans in the target and non-target fisheries of eastern Indonesia was conducted between April 2001 and December 2003. This project, which was funded by the Australian Centre for International Agricultural Research (ACIAR), involved staff at Murdoch University and the CSIRO Marine Research laboratories in Australia and the Indonesian Institute of Sciences (LIPI) and Research Institute of Marine Fisheries (RIMF) in Indonesia.

2. METHODS

A total of nine survey trips were undertaken between April 2001 and February 2003 in eastern Indonesia. Ten sites were surveyed on at least one occasion and six sites were surveyed on more than one occasion on most trips (Figure 1). The catches of deep-sea chondrichthyan fisheries were observed at four landing sites, i.e. Palabuhanratu (West Java), Cilacap (Central Java), Kedonganan (Bali) and Tanjung Luar (Lombok).

FIGURE 1
Distribution of survey sites in Indonesia

The initial focus was on determining which chondrichthyan species were present in the landings present on that day. The species were identified using the keys and, or, illustrations in Carpenter and Niem (1998, 1999), Compagno (1984) and Last and Stevens (1994). However, when a species was not recorded in the above keys, it was assigned to its appropriate genus and provided with an appropriate temporary name. Whenever possible, those species that could not be accurately identified using the above references were purchased and stored in plastic holding tanks containing 10 percent formalin for subsequent identification. Information on the gear characteristics and the duration and location of each fishing trip was also collected.

3. RESULTS

Summary of results of overall survey data

A total of 19 573 individual chondrichthyan were recorded throughout the project, representing 139 chondrichthyan species, of which 78 were sharks belonging to 16 families, 60 were rays belonging to 11 families and one species of chimaera. As many as 20 of these species appear to be undescribed. A reference collection of approximately 540 specimens representing 106 of the 139 species recorded was established during the project and these are currently stored in Jakarta, Indonesia or Hobart, Australia.

Target chondrichthyan fisheries, which are mainly artisanal, use a variety of fishing methods, such as gillnets, trammel nets, purse seines, longlines and droplines. The fisheries that land substantial catches of elasmobranchs as a bycatch include the prawn and fish fishery exploited by commercial trawlers and pelagic tuna fisheries. Deep-sea longlining for chondrichthyans primarily targets squaloids.

Deepwater longlining for squaloids

The length of the lines used in this fishery vary among the four sites with fishers at Kedonganan using short lines (~200 m in length) and those at Tanjung Luar using much longer lines (~5000 m in length). The longlines are set in depths of 150 to 600 m, with the majority of fishing occurring in depths of less than 300 m. No fishing occurring in depths greater than 600 m. The duration of the fishing trips also varies, with boats in Palabuhanratu spending only one or two days at sea while those in Tanjung Luar spend 7-14 days at sea. The number of boats involved in this fishery is low, i.e. two or three at Kedonganan and Palabuhanratu and about 5-10 in Tanjung Luar and Cilacap. These boats are all less than 15 m in length and usually have poor, if any, depth-sounding equipment (Figure 2).

FIGURE 2
Typical fishing boats at the landing site and market of Kedonganan, Jimbaran Bay in the south of Bali

The fishery for squaloids appears to be highly seasonal, peaking in January to March at Kedonganan and in March to July at the other three sites. At both Cilacap and Tanjung Luar, there is significantly less fishing effort in the off season while in Palabuhanratu and Kedonganan, there is similar fishing effort all year round.

Deepwater chondricthyan species composition

A total of 717 individual deepwater chondrichthyans were recorded, which represents only about 3.8 percent of all chondrichthyans observed during the project. A total of 22 species were recorded, consisting of 19 shark species representing six families, two ray species representing two families and a single chimaera species (see Table 1). The Squalidae and Centrophoridae were the most speciose and abundant families in the catches. The most abundant species by far was *Squalus* sp. 3 (short snout, v-shaped D2), which comprised ~51 percent of the total number of deepwater chondrichthyans recorded. The next most abundant species were *Centrophorus* cf *acus* (11 percent), *Hydrolagus* sp. 1 (9 percent) and *Squalus* sp. 1 (8 percent) (Figure 3).

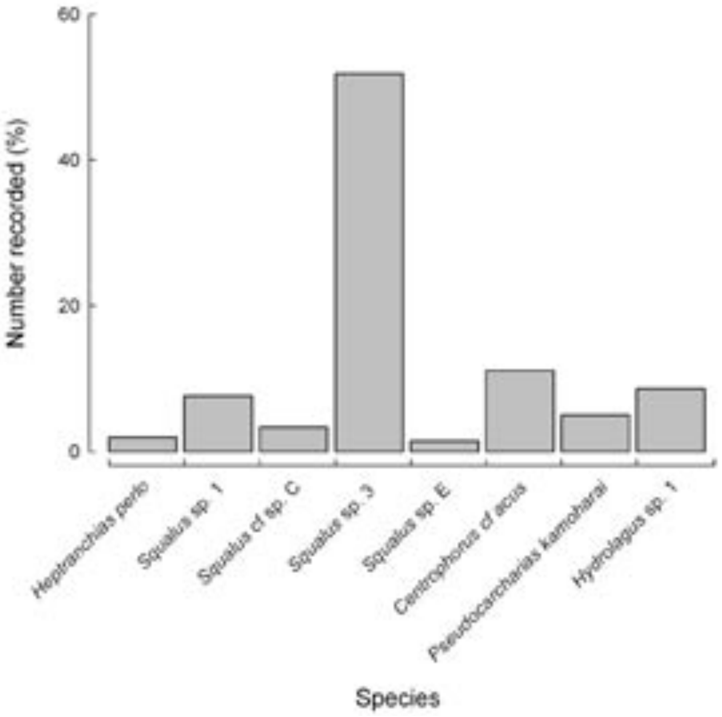
TABLE 1
Numbers and minimum and maximum sizes of all chondrichthyans recorded in the catches of the artisanal deep-sea longline fishery in eastern Indonesia between April 2001 and February 2003

Size refers to total length unless otherwise noted as disc width, i.e. DW.

Family	Species	Number recorded	*Minimum size* (mm)	*Maximum size* (mm)
Hexanchidae	*Heptranchias perlo*	14	750	980
	Hexanchus griseus	7	2190	3750
	Hexanchus nakamurai	2	950	1070
Squalidae	*Cirrhigaleus barbife*	2	800	995
	Squalus sp. 1	56	450	945

	Squalus sp. 3	373	420	780
	Squalus cf sp. C [Last & Stevens, 1994]	24	520	870
	Squalus sp. E [Last & Stevens, 1994]	10	460	600
Centrophoridae	*Centrophorus* cf *acus*	80	540	1640
	Centrophorus cf *atromarginatus*	7	600	802
	Centrophorus cf *lusitanicus*	5	840	930
	Centrophorus cf *moluccensis*	8	540	1070
	Centrophorus sp. (brown, longnose)	4	970	1010
	Centrophorus sp. (big eye)	7	600	750
	Centrophorus sp. 1 (longnose)	4	520	850
Pseudocarchariidae	*Pseudocarcharias kamoharai*	36	514	1060
Scyliorhinidae	*Cephaloscyllium* sp. E [FAO, WCP]	4	605	670
	Parmaturus cf *melanobranchias*	photo only	-	-
Triakidae	*Iago garricki*	1	650	650
Rajidae	*Dipturus* cf sp. I [Last & Stevens, 1994]	4	770 DW	1190 DW
Plesiobatidae	*Plesiobatis daviesi*	7	287 DW	1170 DW
Chimaeridae	*Hydrolagus* sp. 1	62	530	880

FIGURE 3
Frequency distribution of species recorded



Taxonomic related issues

One or more variants of a number of species, e.g. *Centrophorus* and *Squalus*, need to be examined in more detail in order to obtain more accurate species composition data. A number of species also appear to be undescribed, but these need to be compared with other closely-related species to confirm if they are undescribed. This work highlights the need to obtain accurate species composition data for a region. For example, *Centrophorus squamosus* is thought to be widely distributed, but closer examination of material identified as this species from Indonesia and Australia indicates that a species complex most likely exists for this species.

Preliminary reproductive data from squaloids

A single pregnant female each of *Centrophorus* sp. brown, longnose, *Centrophorus* cf *atromarginatus* and *Centrophorus* cf *moluccensis* were collected in March 2002. Each possessed only two embryos. The embryos in the former species were early term (~86 mm TL), while those in the latter two species were mid-late term embryos (170–210 mm TL). In contrast, several pregnant females of *Squalus* sp. 3 collected in

July 2001 contained 6–8 mid-late term embryos (~150 mm TL).

Processing of deepwater sharks
The most sought after produce of deepwater sharks is the valuable squalene oil of their livers and mainly derived from squalids and centrophorids. The livers are usually removed immediately on landing the shark (Figure 4) and are either dried or cooked to obtain the oil. This oil is bottled and exported or distributed within Indonesia depending on its quality. The fins are dried but are only considered of moderate quality in comparison to other shark fins, e.g. those from carcharhinids. The flesh of larger sharks is sliced into manageable pieces and salted in tanks after which it is dried on bamboo racks before distribution (Figure 5). Smaller sharks are typically sliced in half dorsolaterally, salted and then dried in a "butterfly" manner (Figure 6). The flesh from the large *Hexanchus griseus* is highly regarded and fetches a much higher price than that of other deepwater chondrichthyans. The vertebral columns of the larger squaloids are also dried and are typically exported either whole or powdered for there supposed medicinal properties. At Palabuhanratu, the enlarged yolked ova from *Centrophorus* species are considered a delicacy and are removed immediately upon landing (Figure 7).

FIGURE 4
Large *Centrophorus* cf *acus* with livers being excised immediately upon landing at Palabuhanratu in West Java

Figure 5
Drying of shark flesh on racks

Figure 6
Dried shark showing cut used to open body

4. FUTURE CONSIDERATIONS

Although waters greater than 600 m in depth are not currently exploited by deep-sea fishers, this is unlikely to be the case for much longer. Moreover, in the future, new fishing methods

Figure 7
Yolked ova of *Centrophorus* is a delicacy in Indonesia

(e.g. trawling) may be adopted, especially if foreign fishing vessels are allowed access to Indonesian waters, which have the potential to rapidly deplete the vulnerable deepwater chondrich-thyan fauna. Future expansion of this fishery in Indonesia is highly likely and protocols for managing such an expansion need to be developed in the near future. These management strategies need to be included into the National Plan of Action for sharks in Indonesia with the aim of preventing any significant expansion to deep-sea fishing in this country. Some anecdotal evidence suggests that squaloid catches from deep-sea longlining at one landing site, i.e. Cilacap, have declined rapidly in the last ten or more years despite it being only a relatively restricted fishery. This may be a result of localized depletion but further investigation is required since the fishers may have just begun using the nearby landing site at Sentolo kawat. Deep-sea longlining based at the landing sites of Kedonganan and Tanjung Luar appears to be a relatively new fishery. Thus, regular surveys of these ports are required to assess to what extent the catch compositions change over the years.

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Contribution to the knowledge of the biology of *Etmopterus spinax* (Linnaeus 1758) (Chondrichthyes, Etmopteridae)

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1. INTRODUCTION

The velvet belly (*Etmopterus spinax*) is a small shark of the Etmopteridae family (*sensu* Mould 1998) common in all Italian seas where it lives on mud and clay bathial bottoms, usually between 200 and 500 metres of depth (Fisher, Bauchot and Schneider 1987, Notarbartolo and Bianchi 1998) though the species has been recorded to 2 200 m (Sion, D'Onghia and Carlucci 2004). The maximum length of this species is about 60 cm (Compagno 1984) even if in the Mediterranean it rarely reaches 50 cm total length (TL) with a medium size between 20 and 30 cm TL (Bini 1967, Tortonese 1956, Notarbartolo and Bianchi 1998).

The velvet belly is a viviparous aplacental shark that gives birth to 6-14 pups born at 9–11 cm TL. The TL of first maturity is 28 cm for males and 34 cm for females (Vacchi and Relini-Orsi 1979). *E. spinax* are caught as bycatch by the Italian bottom-trawl fishery and all specimens caught are discarded at sea. The species is an important component of the shrimp fishery discard of the Tuscany fleet (Abella and Serena 2002) and of the Italian artisanal and bottom trawl fisheries (Fisher *et al.* 1987, Bini 1967).

2. MATERIAL AND METHODS

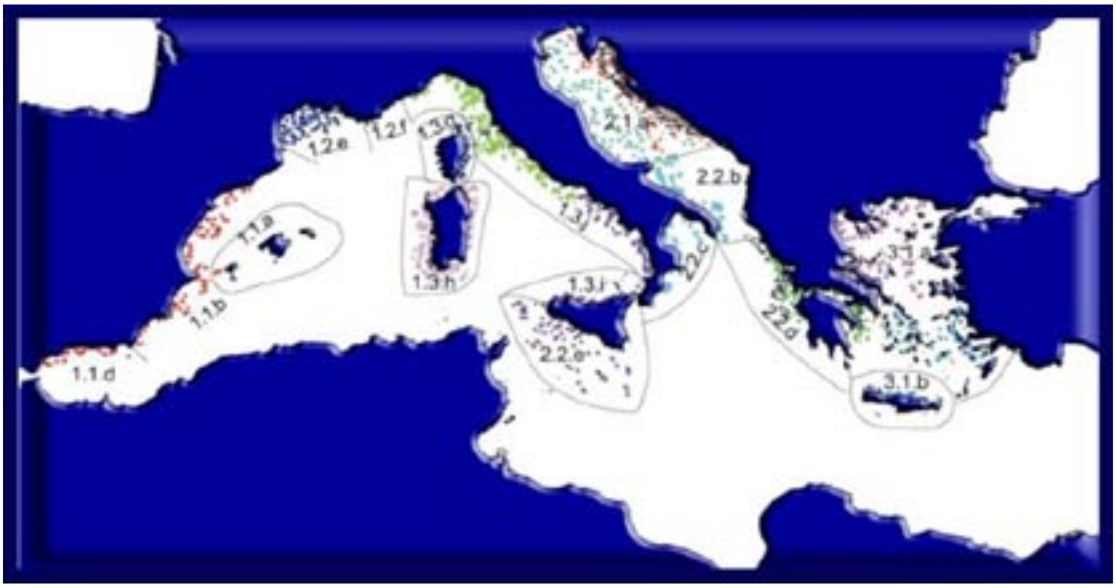
The data analyzed were obtained from 35 scientific bottom trawl surveys aimed at assessing demersal resources and were conducted between 1985 and 2002 by the Italian national GRUND[1] project (GRUppo Nazionale risorse Demersali), and from 1994 to 2002 in the Mediterranean MEDITS[2] project (MEDIterranean Trawl Survey) (GRUND and MEDITS – Relini 1998, Bertrand *et al.* 1997). The area studied in the Tuscany Archipelago of the Tyrrhenian Sea was, from Magra River to Elba Island and between 10 and 800 m of depth (Figure 1).

For the MEDITS project the standard sampling gear is a bottom trawl designed for scientific experimental fishing with a vertical opening of 2.5 m, horizontal opening of 15-18 m and codend stretched-mesh size of 20 mm. For the GRUND trawl surveys, a commercial gear was utilized, always in the autumn period with a codend stretched-mesh size of 20 mm.

[1] The GRUND programme is conducted thanks to the financial support of the MIPAF (Ministero per le Politiche Agricole e Forestali).

[2] The MEDITS programme is conducted thanks to the financial support of the European Commission (Directorate for Fisheries) jointly with the contribution of the partner countries.

FIGURE 1
Map of the tows location in the European Mediterranean MEDITS trawl surveys



All specimens collected were counted and weighted. The biomass index (BI, kg/ km^2), the density index (ID, N/km^2) and the coefficient of variation were estimated for both the GRUND and MEDITS trawl surveys. A sample of the collected fishes was measured to record total length (cm), weight, sex and maturity stage. The total length data were also correlated with depth considering depth strata of 50 m. The χ^2 test was used to verify the presence of a possible significant difference in the length frequency distribution by depth. The length–weight relation was fitted for both sexes using the function

$$W = a * L$$

The stage of maturity was defined using the method of Bass, D'Aubrey and Kistnasamy (1973) and Stevens and Lyle (1989).

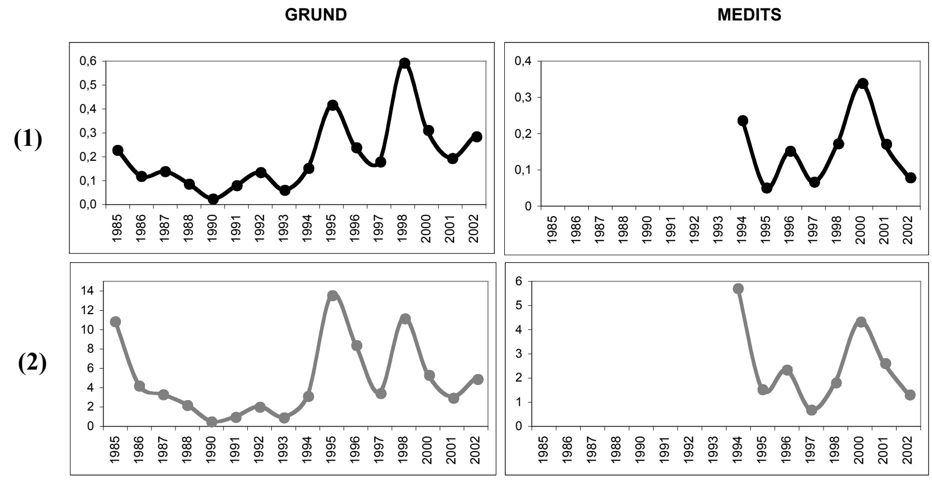
The estimation of growth parameters for each sex was done using the FISAT programme (Gayanilo, Sparre and Pauly 1995). The sex ratio (females number/total number) and the feeding preferences also were investigated. The analysis of the stomach contents was only qualitative and only the number of prey for each stomach was registered. The data of the autumnal period were related to the total length of the specimens and compared to the results given by MacPherson (1980) and Wurtz and Vacchi (1981).

3. RESULTS AND CONCLUSIONS

A total of 3 542 individuals were caught in the study area between 322 and 633 m of depth. The analysis of the biomass index (kg/km^2) and the density index (N/ km^2) of *E. spinax* caught show a positive trend during the years even if the trend is characterized by clear oscillations probably caused by stochastic effects (Figure 2). In the 1980s densities decreased followed by a strong increase. The indexes show oscillations between 0.05 and 0.35 kg/km^2 (MEDITS survey) and 0.05–0.6 kg/km^2 (GRUND survey). This suggests a steady state of the velvet belly stock abundance in the study area. This resource, in fact, does not suffer intense exploitation by the local fisheries due to the distance from the homeports and depth of the grounds it prefers.

The analysis of georeferenced data using ArcView (ESRI 1996) of the velvet belly catches shows a bigger concentration of the species in the northern part of the studied

FIGURE 2
Trends of Biomass Index (BI kg/km²) (1) and Density Index (DI n/km²) (2) of *E. spinax* from 1985 to 2002 related to the GRUND and MEDITS projects

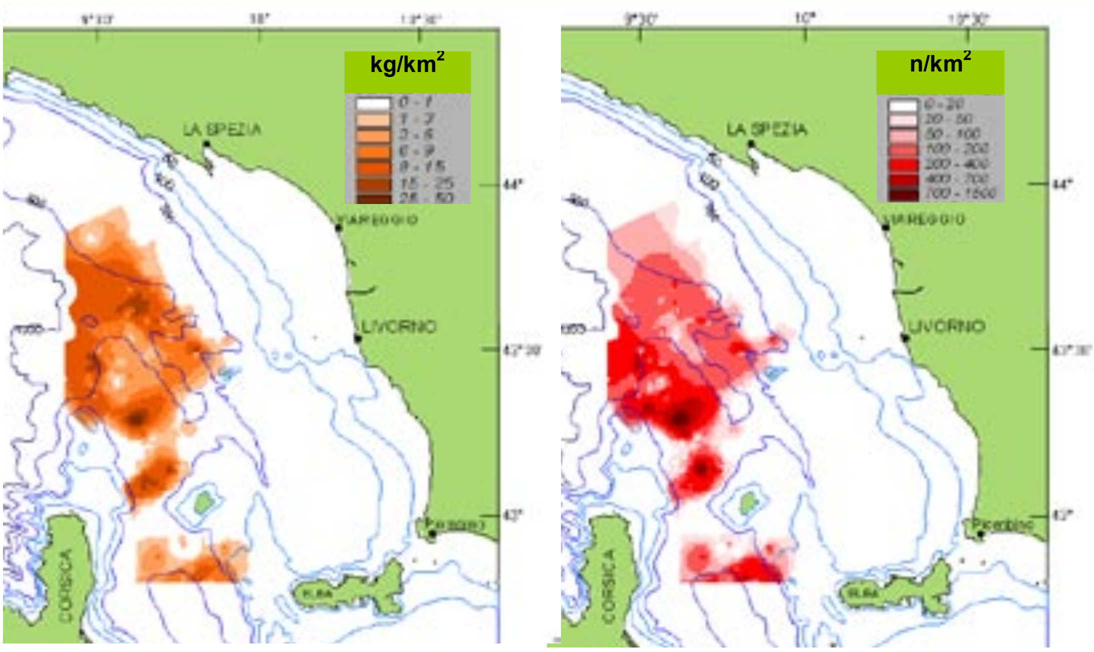


area, north west of the Capraia and Gorgona islands (Tuscany, Italy) (Figure 3). This pattern remains fairly constant in all seasons of the year.

The morphometric data of total length, weight and sex were registered for 2 304 specimens. Males (n = 1 127) showed a range in TL between 10 and 37 cm while for females (n = 1 177) the minimum TL was 9 cm and the maximum 40.5 cm.

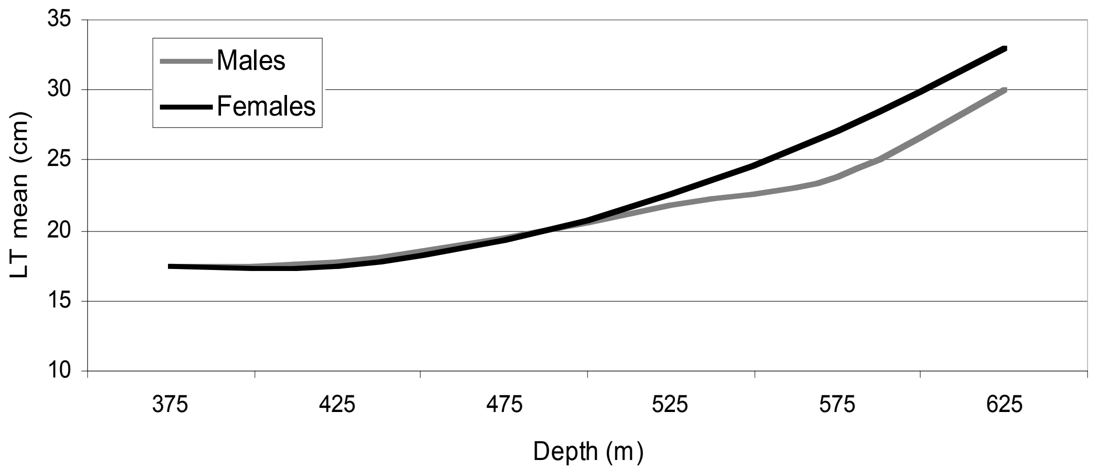
A χ^2 test confirmed that there was a significant difference ($p < 0.01$) between length distribution of the specimens at different depths (for more than 450 m of depth). No significant difference exists in the distribution of the two sexes between 350 and 450 m

Figure 3
Geographical distribution of Biomass Index (BI kg/km²) and Density Index (DI n/km²) of *E. spinax* in the study area



of depth. In this layer the mean total length of both sexes is 17.5 cm. The mean total length increased with depth: 19.4 cm at 500 m, 22.2 cm at 550 m, 25.0 cm at 600 m and 31.5 cm at 650 m (Figure 4). This observation agrees with the results of Vacchi and Relini Orsi (1979) who gathered specimens with bottom nets in the Genoa Gulf.

FIGURE 4
Mean size of *E. spinax* related to depth



These authors caught adult individuals (20–36 cm) between 600–700 m of depth. The sex ratio (0.51) is well balanced up to length 30 cm, then females become more common. This can be explained by the bigger size females reach relative to males (Vacchi and Relini Orsi 1979).

The relation between length (cm) and weight (g) for the specimens analyzed (828) is:

for males (n = 386)

$W = 0.0050 L2.971$

$r^2 = 0.966$

for females (n = 442)

$W = 0,0056 L2.938$

$r^2 = 0.978$.

The coefficient b for males (LF 95% 3.06 and 2.94) and females (LF 95% 3.00 and 2.90) is not significantly different from 3, so the growth for this species can be considered to be isometric.

Analysis of the length frequency distribution by sex shows a peak for males at about 21 cm TL and for females at 22 cm TL (Figure 5). The Bhattacharya method and the Normsep algorithm allowed us to estimate the growth parameters. The length-at-age derived from growth curves are similar and comparable to those calculated by Sion *et al.* (2002) who read dorsal spine growth rings. Only the 0+ class shows a slight difference in the correspondence with the estimated length (Table 1). In the present work the smaller specimens collected were 9-11 cm long and were represented as term embryos with a little scar on their abdomens, a signal of the recent detachment of the yolk sac. This agrees with the observation of Vacchi and Relini Orsi (1979) who found 4° stage for the embryo of about 10 cm TL.

FIGURE 5
Length frequency distribution of *E. spinax* by sex

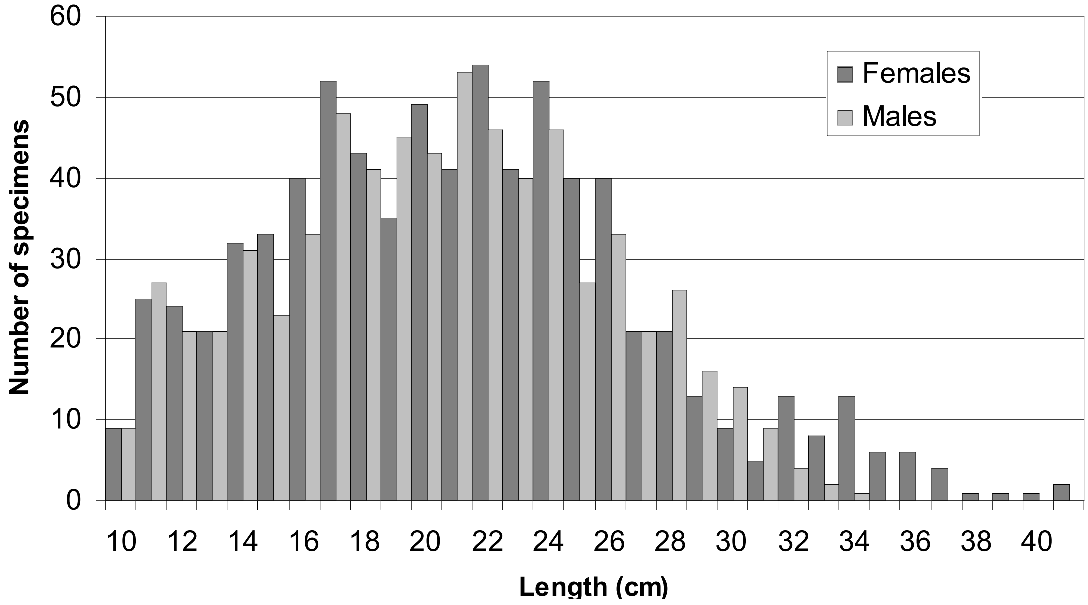


TABLE 1
Growth parameters and estimation of length by age for *Etmopterus spinax*

K =		0.35	0.23	0.27	0.24
L_∞ =		40.10	46.56	45.82	42.00
t_o =		-0.72	-1.19	-1.09	-1.31
S (L_t) =		1.7	1.6	2.1	1.8
Age	*Sion et al. 2002*	Female Bhattacharya	Female Normsep	Male Bhattacharya	Male Normsep
0	13.4	8.9	11.1	11.7	11.3
1	17.2	18.1	18.4	19.8	17.9
2	21.6	24.6	24.2	25.9	23.0
3	25.5	29.2	28.8	30.6	27.1
4	29.3	32.4	32.4	34.2	30.3
5	33.4	34.7	35.3	37.0	32.8
6	37.3	36.3	37.7	39.1	34.7

We observed mature females with maximum total length of 46 cm TL. One female (TL = 40 cm) was captured in October at 532 m of depth. She had six embryos of about 6.5 cm TL in the uterus still retaining a yolk sac; another female caught in the same month was 46 cm long and had 18 embryos between 9.9 and 11.2 cm TL. These embryos, like the one we observed, had a little ventral vitelline mark and the yolk sac was already reabsorbed.

The 445 samples of stomach contents were analyzed and related to the specimens' TL. The stomach contents of some individuals captured in autumn were analysed in preliminary way: the diet of the bigger specimens was more simple and showed fewer species. The stomach contents of the specimens with a TL between 29.5 and 40 cm showed only a few taxonomic groups. Diet components belonged to four taxonomic groups: 74.8 percent crustaceans, 16.9 percent fishes, 6.9 percent cephalopods and 0.9 percent polychaetes (Table 2). Other species represented 0.5 percent of the diet. It is important to underline the presence of polychaetes as a component of the stomachs analyzed in our studied area even if with a low percentage. This result differs from those of Macpherson's study (1980) in the Alicante, Spain area in the same autumn period and on individuals of the same size range (10–40 cm). The same author observed a larger presence of cephalopods and fishes instead of crustaceans. Also Vacchi and Wurtz (1981) and Relini, Orsi and Wurtz (1976) stated that *E. spinax* feeds essentially on cephalopods, teleost fishes and crustaceans but they do not mention the presence of nematodes, polychaetes and chondrichthyan fishes. Bello (1998) reports cephalopods, teleost fishes and crustaceans also to be present in the stomach of the specimens caught in the Adriatic Sea.

TABLE 2
Relative presence (%) of the different taxonomic groups in the stomach of the sampled individuals of *E. spinax* analysed by size intervals

LT (cm)	Nematodes	Polychates	Tunicates	Cephalopods	Crustaceans	Chondrichthyans	Osteichthyes
9.5 – 19	0.0	0.3	1.3	6.3	77.9	1.5	12.7
19.5 – 29	1.0	0.6	0.0	7.5	72.9	0.0	18.0
29.5 – 40	0.0	10.2	0.0	4.1	61.2	0.0	24.5

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Catch composition and abundance of deep-sea elasmobranchs based on the MEDITS[1] trawl surveys

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1. INTRODUCTION

Elasmobranchs (sharks, skates and rays) are generally characterized by a *K* life history strategy, i.e. slow growth, late attainment of sexual maturity, low fecundity and long life spans (Hoenig and Gruber 1990). They play an important ecological role since they are positioned on the top of trophic web and, being sensitive to any change in the ecosystem, are often used as biological indicators (Pratt, Gruber and Taniuchi 1990, Dayton *et al.* 1995, Stevens *et al.* 2000). Both these biological and ecological characteristics, together with frequent pessimistic results of stock assessments, which have become common in the last decades (Walker 1996), have led to doubts on the feasibility of sustainable harvesting of many elasmobranch stocks (Bonfil 1994, Punt and Walker 1998).

Although many Mediterranean stocks show clear signs of depletion (and some such as *Squatina* spp. and *Rhinobatos* spp, have practically disappeared), at least in some areas (Aldebert 1997, Fiorentini, Caddy and de Leiva 1997, Jukic-Peladic *et al.* 2000), suitable information for stock assessment purposes is generally still poor and fragmentary (Muños-Chápuli 1985).

The Mediterranean Sea extends for about 3 000 000 km^2 with a variety of biogeographic features. Most of it is characterized by a narrow continental shelf (only 23 percent of the whole surface) and therefore the ground fish stocks are mainly exploited along the coasts. Elasmobranchs are generally represented in the Mediterranean fisheries only as bycatch (Serena and Abella 1999, Vacchi and Notarbartolo 2000), and yield yearly around 2 500 t in Italian waters (Fiorentini *et al.* 1997) and 10 000 t/yr for the whole Mediterranean (FAO 1995), mainly from bottom trawl fisheries (Relini, Bertrand and Zamboni 1999).

In many Mediterranean areas trawl surveys are the main source of data for acquiring biological knowledge on demersal species and evaluating the status of these resources. Many research programmes focused on the assessment of demersal resources by direct methods have been carried out over a period of 20 years (e.g. by GRUND in Italy;

[1] The Mediterranean Trawl Survey Programme (MEDITS) is financed by the European Commission (Directorate for Fisheries) together with contributions from the partner countries.

Relini *et al*. 2000) at national levels. The MEDITS programme was the first coordinated project along the whole European coastal area (500 000 km²) to a depth of 800 m.

The MEDITS project aimed at the standardisation of the survey methodology among the different countries and started in 1993. Within the frame of the MEDITS project nine trawl surveys have been carried out from 1994 to 2003. Therefore, a time series of nine years is available for the French, Spanish, Italian and Greek coasts of Mediterranean. Since 1996 data from the east coast of the Adriatic Sea (Slovenia, Croatia and Albania) have also become available.

The research efforts within the MEDITS programme represent an important basis for a more advanced development of both the knowledge on the dynamics of the demersal resources at Mediterranean level and of collaboration among the European scientists. Until now the data from the MEDITS trawl surveys have been mainly used to estimate abundance indices and length frequency distributions of the species of fishery interest as indicators of the status of resources. Indeed, the current database has the potential also to be employed for estimating the demographic patterns of the main demersal resources and for prediction purposes for the management of the fishery resources.

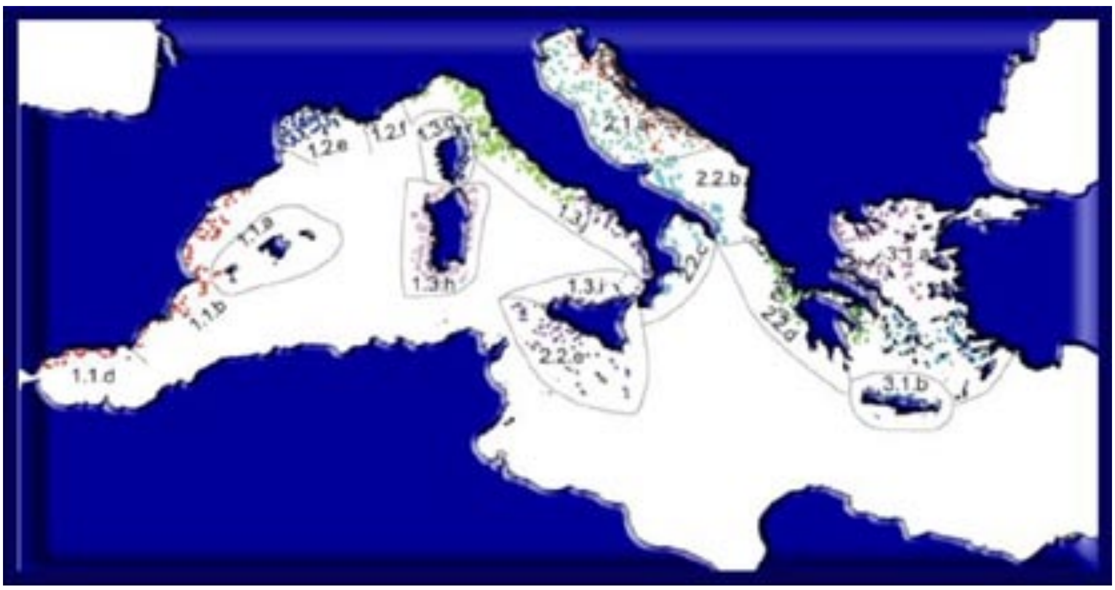
2. MATERIAL AND METHODS

In this work data from six bottom trawl surveys are considered. They were carried out from the Alboran to Aegean Seas, between April and June 1994–99 within the MEDITS International programme (Bertrand *et al.* 1997). In total, 6 336 tows were done during daylight hours.

A random stratified design was adopted with stratum depth limits of 50, 100, 200, 500 and 800 m (Figure 1); the sampling density was one three miles tow for each 60 square nautical miles (about 1 000 tows) repeated each year. The standard sampling gear was a bottom trawl designed for scientific experimental fishing with a vertical opening of 2.5 m, horizontal opening of 15–18 m and codend stretched-mesh size of 20 mm. This gear was used during the same period (about one month in summer) by ten vessels throughout the whole survey area.

FIGURE 1

Map of the tows location in the European Mediterranean MEDITS trawl surveys



A common survey protocol was adopted for all the cruises (Anon. 1998, Fischer *et al.* 1987). After each tow the species in the catch were identified, weighed and counted to estimate biomass and abundance indices (kg/km² and number of individuals/km²) and to construct length-frequency distributions. Further biological analyses were performed on 30 species on a common reference list because of their high commercial relevance: of these only three species were chondrichthyans, *Galeus melastomus, Scyliorhinus canicula* and *Raja clavata.*

Biomass indices and standing stock estimates (by means of the swept-area method and assuming full vulnerability to capture) were estimated from the database produced by IFREMER. The biomass indices were referred to four arbitrary geographical areas identified using a land-oriented criterion: *Western* (WA; Morocco, Spain and France coasts), *Western Central* (WCA; Tyrrhenian, Corsica, Sardinia and Sicily coasts), *Eastern Central* (ECA; Adriatic, Ionian and Albanian), and *Eastern* (EA; Aegean Sea).

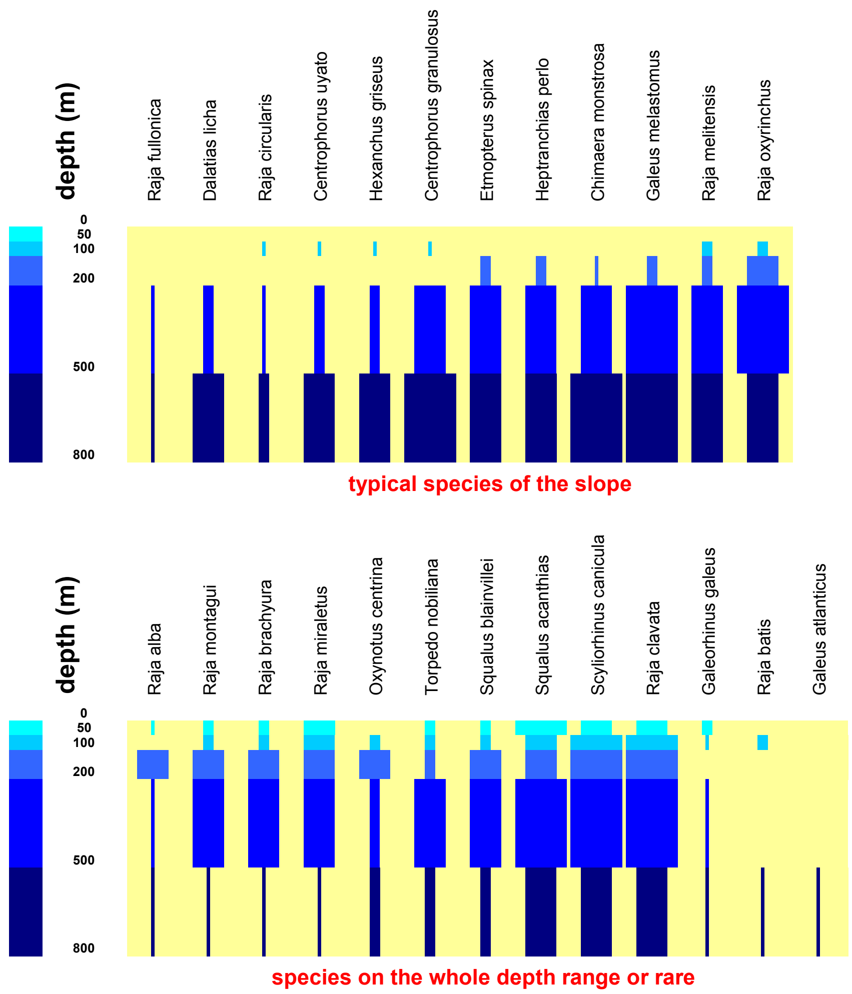
3. RESULTS

Only 25 of the 45 species of elasmobranches in the area can be considered as deep-sea species (Figure 2). They include 13 sharks, three skates, seven rays, one electric ray and one rabbitfish. Single or sporadic captures were also recorded e.g. of *Hexanchus griseus, Galeus atlanticus* and *Raja batis.*

FIGURE 2

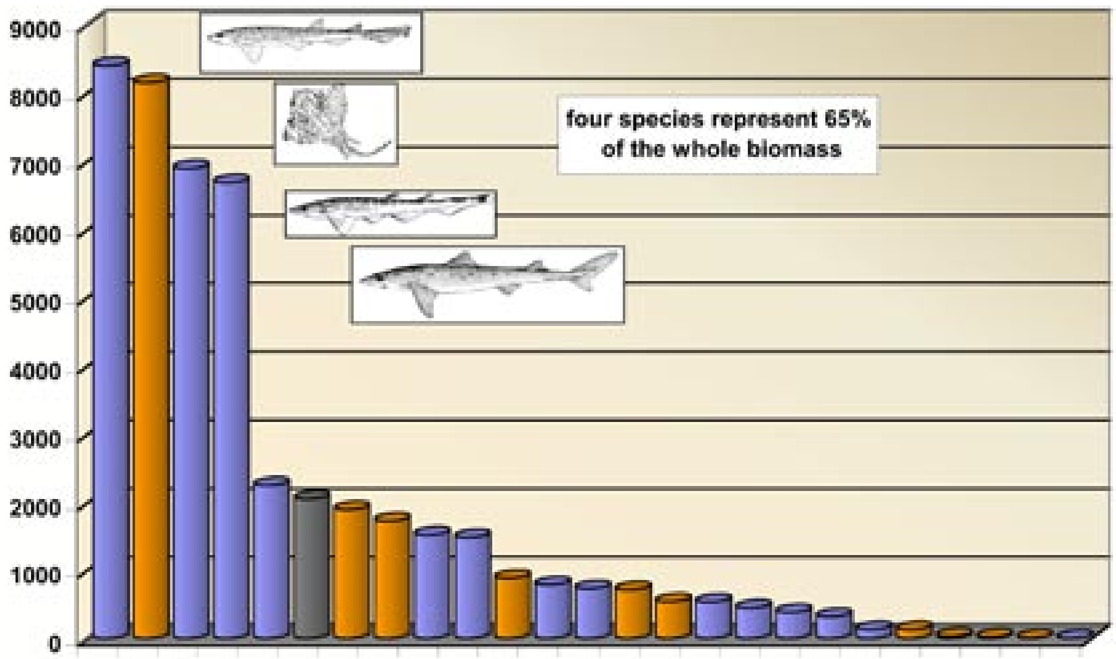
Depth distribution of the 25 species of deep sea elasmobranchs from the trawl surveys

Bar width represents the density index with the ranges: <0.1, 0.1-1, 1-10, >10 kg/km².



Three sharks and one ray (*Scyliorhinus canicula, Raja clavata, Galeus melastomus* and *Squalus acanthias*) showed both high occurrence (>5 percent of the hauls) and high abundance (> 10 kg/km² or >10 percent of relative biomass) and altogether represented 65 percent of the whole biomass of deep-sea sharks (Figure 3).

FIGURE 3
Index of abundance of deep sea elasmobranchs in the European Mediterranean



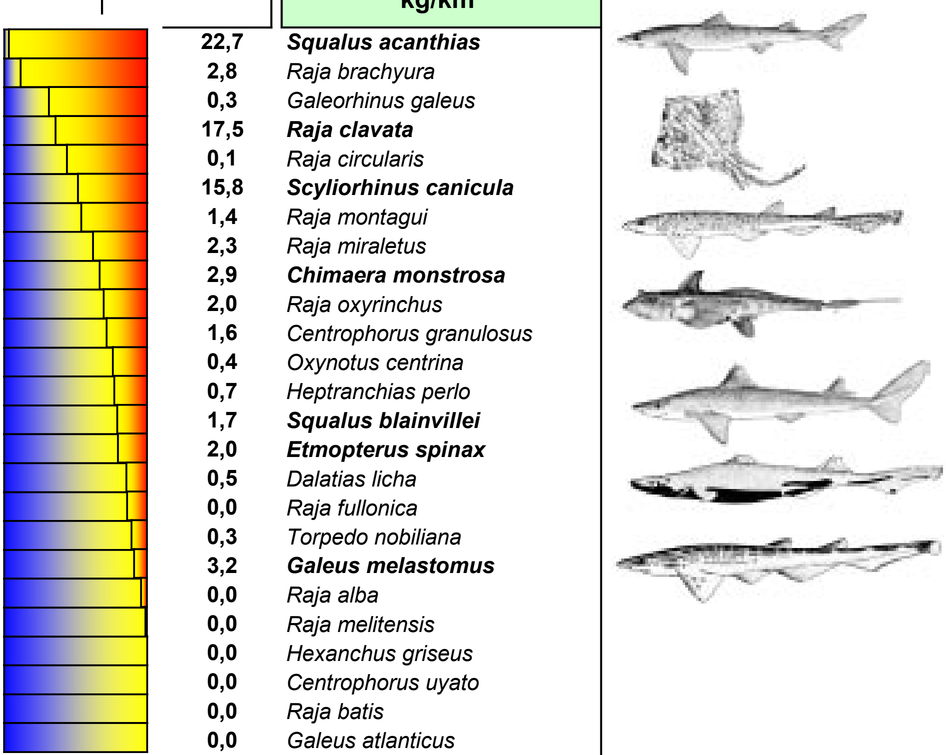
Two faunistic groups can be identified with regard to depth distribution: (a) species well represented at all depths such as *R. clavata* and *S. canicula* and (b), with a preference for the slope such as *Centrophorus granulosus* and *Etmopterus spina*x. Only a handful of species showed levels of abundance of commercial interest and just a few are actually marketed. The large shark species (e.g. *Squalus* spp.) show signs of depletion although they occurred in zones of relatively high density (e.g. on rough ground usually not exploited by fishermen).

From a geographical perspective (Figure 4), some species are abundant in all areas (*S. canicula, R. clavata, Chimaera monstrosa),* while others are most common in the west (*G. melastomum, Etmopterus spinax* and *Squalus blainvillei*) or the east *(S. acantias* and *Raja brachiura*); some species are localised in restricted areas (*Raja miraletus* in the Tyrrhenian, *Raja brachiura* and *Raja undulata* in the Aegean Sea, *Galeus atlanticus* in the Alboran Sea). Globally, the eastern basins (Adriatic and Aegean Seas) showed higher standing stocks, mainly due to the wider continental shelf.

The blackmouth catshark (*G. melastomus*) was caught in all areas (Figure 5a) with the exception of the North Adriatic and this species was mainly distributed in the deeper strata of the slope. Densities consistently higher than 100 kg/km² occurred in the Gulf of Lions and in the Sardinian waters, with a maximum of 1040 kg/km² in the Alboran Sea. In regard to total stock biomass estimates, 40 percent of the Mediterranean blackmouth catshark stock was found in the Alboran Sea (2 600 t); elsewhere the only significant stocks (300–400 t) were in the central Tyrrhenian and in the Sicilian Channel.

FIGURE 4
Biomass indexes in the European Mediterranean related to their east-west distribution

Western Mediterranean	Eastern Mediterranean	Biomass Index kg/km^2
0,8	22,7	***Squalus acanthias***
0,4	2,8	*Raja brachyura*
0,1	0,3	*Galeorhinus galeus*
9,8	17,5	***Raja clavata***
0,1	0,1	*Raja circularis*
16,8	15,8	***Scyliorhinus canicula***
1,6	1,4	*Raja montagui*
3,8	2,3	*Raja miraletus*
5,9	2,9	***Chimaera monstrosa***
4,5	2,0	*Raja oxyrinchus*
4,1	1,6	*Centrophorus granulosus*
1,2	0,4	*Oxynotus centrina*
2,3	0,7	*Heptranchias perlo*
6,6	1,7	***Squalus blainvillei***
7,8	2,0	***Etmopterus spinax***
3,0	0,5	*Dalatias licha*
0,0	0,0	*Raja fullonica*
2,1	0,3	*Torpedo nobiliana*
32,6	3,2	***Galeus melastomus***
0,8	0,0	*Raja alba*
4,9	0,0	*Raja melitensis*
1,5	0,0	*Hexanchus griseus*
1,4	0,0	*Centrophorus uyato*
0,1	0,0	*Raja batis*
0,0	0,0	*Galeus atlanticus*



in bold most abundant species

The small spotted catshark (*S. canicula*) was caught in all sectors and depth strata with the exception of the Adriatic Sea, Eastern Sicily and Northern Ionian Sea. Taking into account the biomass indexes (Figure 5b), values higher than a threshold of 100 kg/km^2 were found on the shelves off Corsica and Sardinia. Significant abundances (30–50 kg/km^2) were also found in the Gulf of Lions, Catalan and Aegean Seas. The maximum biomass index (340 kg/km^2) was detected in North East Corsica in the 50-100 m depth stratum. A different picture is given when considering the total biomass estimates; due to the difference in the shelf areas, the higher standing stocks (3 400 t) occurred in the easternmost sectors.

The thornback ray (*R. clavata*) (Figure 5c) occurred preferentially at the edge of the shelf and on the upper slope (200–500 m). However, it showed an irregular distribution with scanty or no catches recorded in the westernmost and East-Central Mediterranean. The highest biomass indexes (above 200 kg/km^2) were observed in the waters surrounding Sardinia and Corsica where the maximum biomass indexes (418 kg/km^2) were detected between 50 and 100 m depth. The highest total biomass estimates of the standing stocks occurred in the easternmost sectors (> 3 000 t), but other significantly abundant stocks (biomass between 300 and 500 t) were found in the Aegean, South Western Sardinia and in the Sicilian Channel.

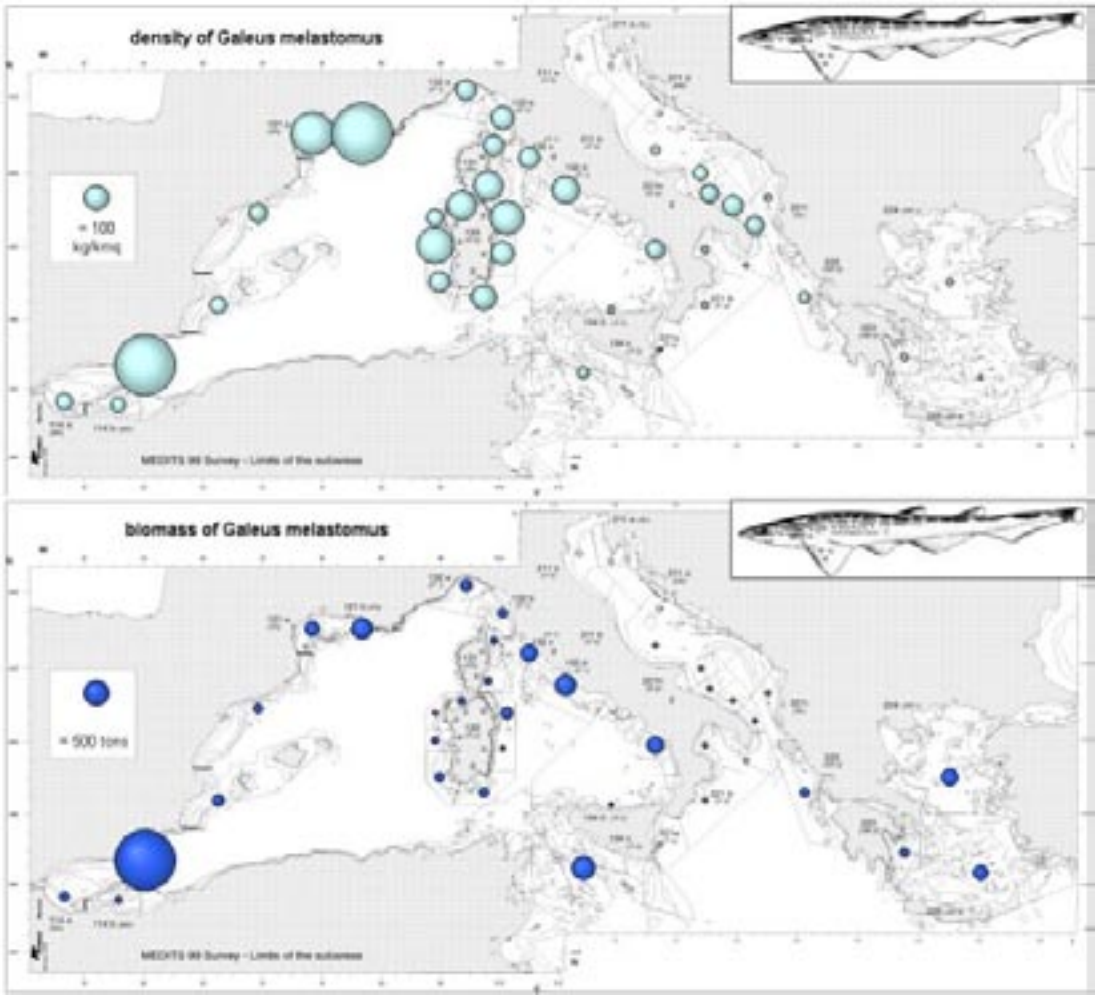
The good yields of *R. clavata*, (the most abundant ray in the Mediterranean) seem to reflect a higher ecological performance than a true resilience to exploitation; in fact, biomass densities (up to 100 kg/km^2), likely closer to the "virgin" conditions, are found only locally in the Gulf of Lion, Corsica, Sardinia and Greece waters. Up to 64 percent of the total biomass is located in the Aegean Sea, where trawling deeper than 400 m is practically absent.

The length frequency distributions of only few species of selachians (*G. melastomus, S. canicula* and *R. clavata*) were prepared. The length frequency distributions of these sharks are similar (Figure 6a and Figure 6b) with a modal peak around 20 cm of total length and on asymptote between 30 and 40 cm TL. The size range is fairly wide ranging from 8 to 68 cm for *G. melastomus* and from 10 to 50 cm for *S. canicula*. In both cases the immature individuals represented about 80 percent of the sampled population.

The size distribution of *R. clavata* shows a lognormal shape (6c): from 10 cm TL the frequencies increased gradually up to 35 cm TL, thereafter they decreased progressively up to the maximum-recorded size of 90 cm TL. Most individuals are therefore smaller than the size at first maturity (55–60 cm TL) and the spawning stock fraction by number represented only 15 percent of the population.

The location of nursery areas can be identified by observing the high concentrations of juveniles. The most likely nursery area for *G. melastomus* is the depth range between 200–500 m. Only in the South-Eastern Tyrrhenian Sea were the highest concentration of juveniles found in deeper waters (500–800 m). The most important nursery areas (values above a threshold of one million juveniles) were observed in the Alboran

FIGURE 5A
Density and biomass estimates of *Galeus melastomus*



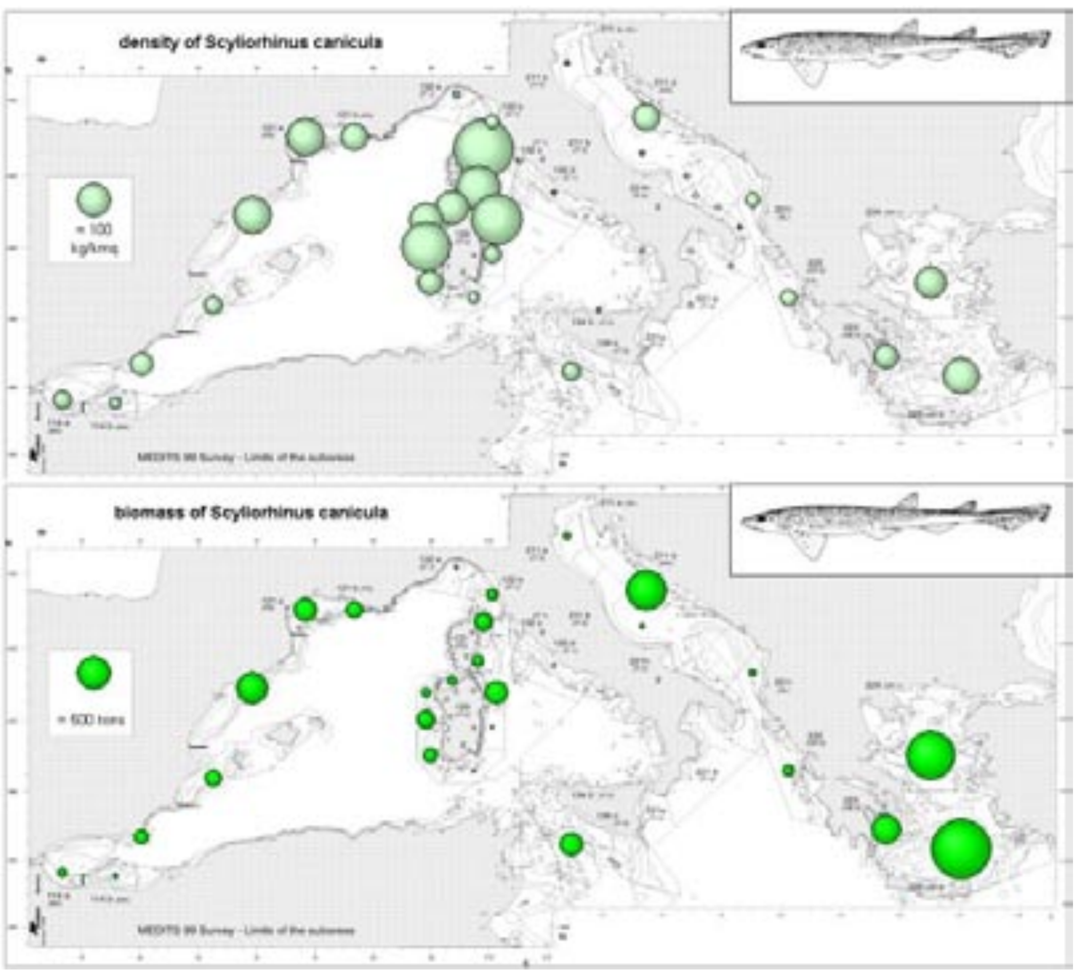
Sea, Sardinian waters and South-Eastern Tyrrhenian Sea. The main concentrations of *S. canicula* juveniles were located on the upper slope (200-500 m), especially in the North East Corsica and North East Sardinia areas (1.3 and 1.2 million juveniles respectively). However, the highest number of juveniles (2.4 millions) was found on the edge of the shelf of Western Morocco.

Given that catches of *R. clavata* usually included both juveniles and large-sized animals in the same haul, the mean size per tow did not allow a clear identification of the nursery areas: in fact only one area was evident in the Eastern Ionian Sea between 50 and 100 m.

Even if the MEDITS data do not yet represent an extensive time series, some 20 years data are available for the GRUND programme in Italy (Relini *et al.* 2000). Figure 7a shows the abundance indices of three sharks and *C. monstrosa*, reported since 1985 for the Northern Tyrrhenian Sea. No clear trend can be found in this period, even though the biomass estimates suggest that the stocks increased and decreased more than twice in this period of 10–12 years. Decidedly greater fluctuations were observed for some rays (Figure 7b), in particular *Raja montagui* and *Raja miraletus*, which showed a biomass increase of up to 8–10 times over the last decade.

Catches statistics of commercial fisheries in the last 30 years are reported by GFCM (FAO 1995 available through www.fao.org) for each statistical subdivision (Figure 8) though no species breakdown can be considered reliable. With the exception of the

FIGURE 5B
Density and biomass estimates of ***Scyliorhinus canicula***



Black and Ionian Seas, the landings of the Mediterranean commercial fishing fleets is usually around 5 000 t/yr (Figure 9). In the Black and the Ionian Seas, the fisheries targeted at *Mustelus* spp. rapidly developed with catches up to 10 000 t/year in the late 1980s and then declined in little more than a decade.

4. DISCUSSION AND CONCLUSION

These preliminary results are only a first step towards a future assessment aimed at the production of management advice regarding elasmobranchs stocks. Notwithstanding this, the analysis of MEDITS data indicated signs of depletion for most sharks and rays and for deep species such as *G. melastomus.*

The survey programme gave useful basic information that enlarged the knowledge of demersal resources in the Mediterranean. They have drawn attention to the wide variety of situations encountered and the care needed for elaboration of general diagnoses of the present status concerning demersal resources in the Mediterranean Sea. This attention should be expanded to include analyses of critical development stages, such as recruitment, and focus on groups of species vulnerable to fishing and potentially in danger, such as elasmobranchs (Bertrand *et al.* 2000).

The utility of such a programme to support fishery management is strongly related to its ability to produce indices suitable for the characterization of the different species situations in the whole area, their variation and trends over time. So far, the main

FIGURE 5C
Density and biomass estimates of *Raja clavata*

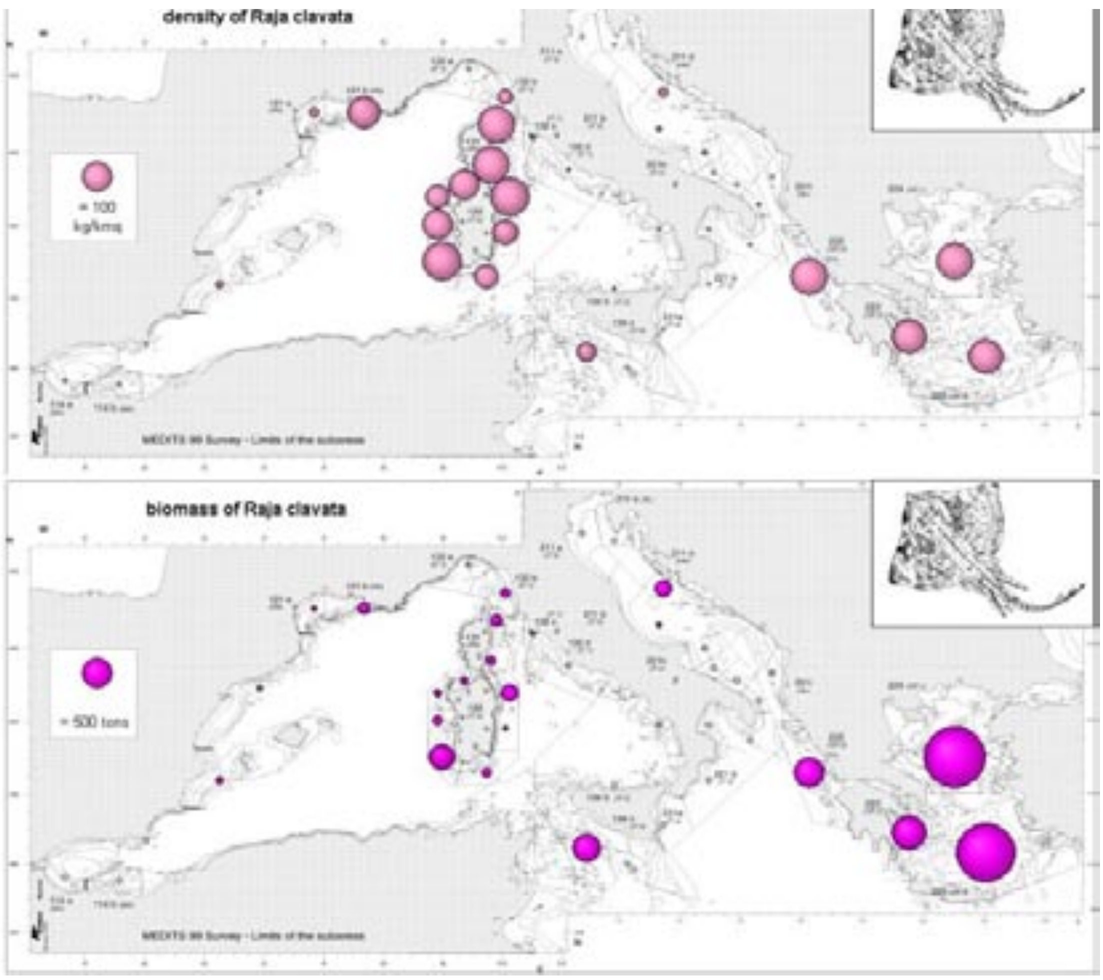


FIGURE 6A
Length frequency distribution of ***Galeus melastomus***

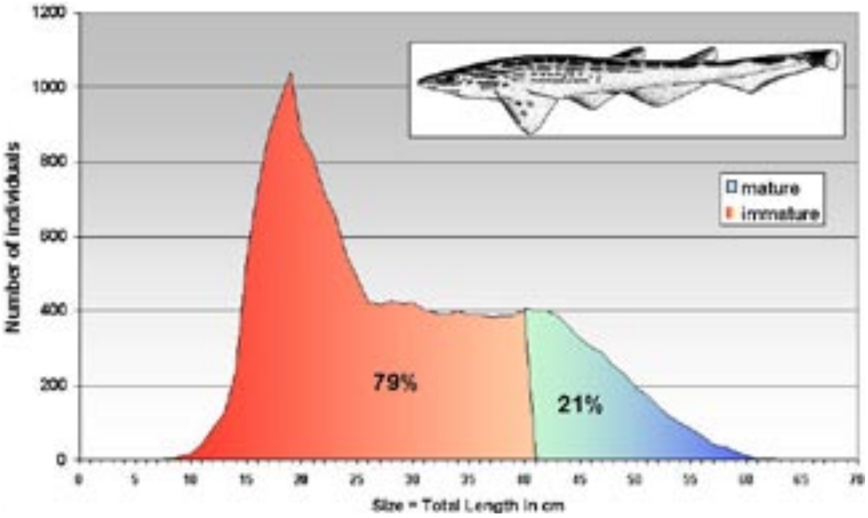


FIGURE 6B
Length frequency distribution of ***Scyliorhinus canicula***

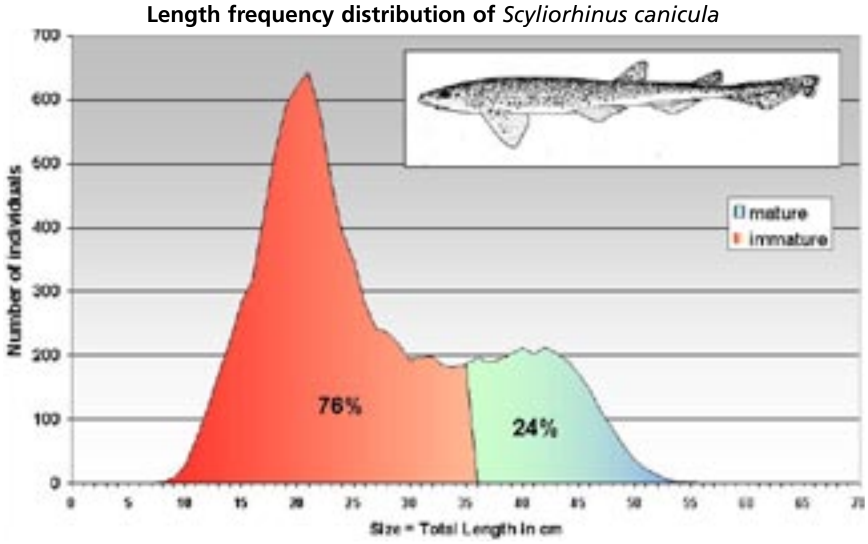
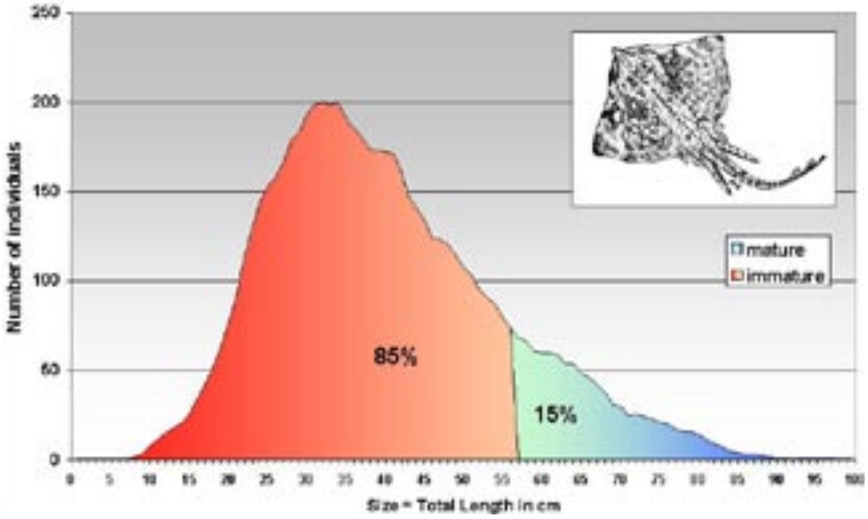


FIGURE 6C
Length frequency distribution of ***Raja clavata***



goal has been the production of relative abundance indices and the reconstruction of demographic structure of the main exploited species. Further activities may include the analyses of interannual variation, regional studies of biology and ecology of the species, including multispecies modelling.

From the data examined, no particular trend occurs in density indices over the years for any of the three species. The same phenomenon was observed by Bertrand *et al*. (2000) although in some parts of the Mediterranean basin (e.g. Tyrrhenian Sea) *G. melastomus* shows a slight increasing trend and some seasonal fluctuations in biomass in the last years, with a maximum biomass in winter and a minimum in summer (Baino and Serena 2000).

It is clear from analyzing the length frequency distributions, that in some areas the smallest size-classes of these species are underestimated. This can be due to the lack of samples in nursery areas (e.g. due to operational depth limits, untrawlable grounds or randomised tow positions), since the small mesh size of the MEDITS net reduces selectivity effects (Ragonese, Di Stefano and Bianchini 2000). Nevertheless, in almost all the cases the populations are mainly composed of juveniles well below the size at first maturity, for example, the overall immature specimens are around 80 percent of the catch for *G. melastomus* and for *S. canicula* and 85 percent for *R. clavata*.

Rey and Gil de Sola (1998) observed that the *G. melastomus* population in Spain is also composed mostly of immature specimens, smaller than 40 cm of total length (75 percent) including recruits below 21 cm (18 percent). The analysis of the densities of individuals smaller than 21 cm showed recruitment to occur in spring in the Alboran Sea, with catch rates of 62 an hour fishing (Tursi *et al*. 1993). But, for this species the MEDITS sampling programme did not cover the whole range of *G. melastomus*, cited as down to 2 000 m in the Catalan Sea by Stefanescu, Llorys and Rucabado (1992).

From the length frequency distribution of *S. canicula*, and in accordance with D'Onghia *et al*. (1995) and Relini *et al*. (1999), the nurseries of this species are located on the bottoms around 200 m depth. As sharks increase in size, they move towards coastal waters and only the mature adults return to the shelf edge to reproduce. In some areas of the Mediterranean basin (e.g. Northern Tyrrhenian Sea) the stocks of small-spotted catshark currently show a sharp geographical division between young and adult individuals (Baino and Serena 2000).

It is important to know the characteristics and distribution of the effort exerted by the commercial fishery fleets to understand the present spatial distribution for this species, as well as for the others. Data on distribution and abundance represent only a first step in implementing assessments aimed at the management of the elasmobranch stocks. In particular stock units could be better identified by a spatial analysis that included information about maturity conditions and other life history features in order to verify the presence of sub-stocks whose fishing pattern may be considered homogeneous. Although local productivity can play an important role, the shape of length frequency distributions, presented in this paper, suggests the existence of sub-areas that are exposed to different levels of fishing effort (e.g. *S. canicula* seems being more heavily exploited in the Tyrrhenian Sea than in the Aegean Sea).

The assessment of the standing stock biomass of chondrichthyans obtained through trawl surveys is substantial, but may underestimate the real size of the stocks as some species live well below the investigated depth range. Further, the catch rates of other fishing gears than trawl can be sizeable. Moreover, in the commercial trawl fishery, the importance of discards (both by species and by size) should not be neglected. These amounts should be added to the landings data reported by the national institutions to accurately provide catch estimates.

It seems unavoidable that to formulate reasonable management advice requires the integration of the information produced by the scientific cruises (such as the MEDITS programme) with specific research to improve the collection of the landings and discards data.

FIGURE 7A

Trends of biomass index in the northern Tyrrhenian sea: sharks

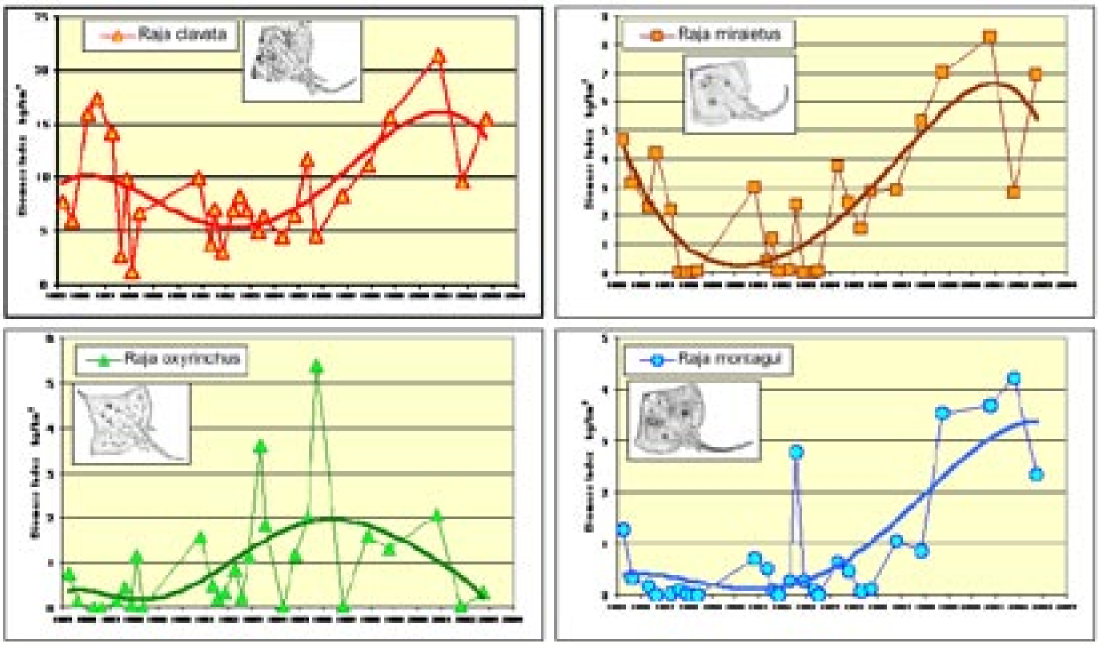


FIGURE 7B

Trends of biomass index in the northern Tyrrhenian sea: rays

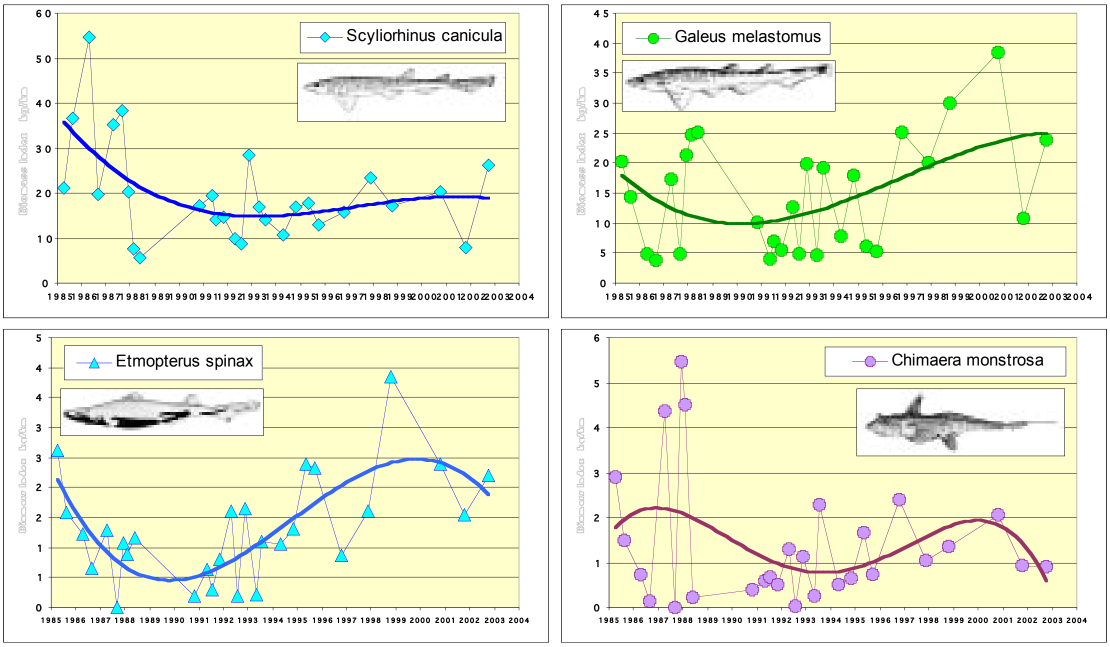


FIGURE 8
Statistical subdivision of the Mediterranean Sea following FAO-GFCM

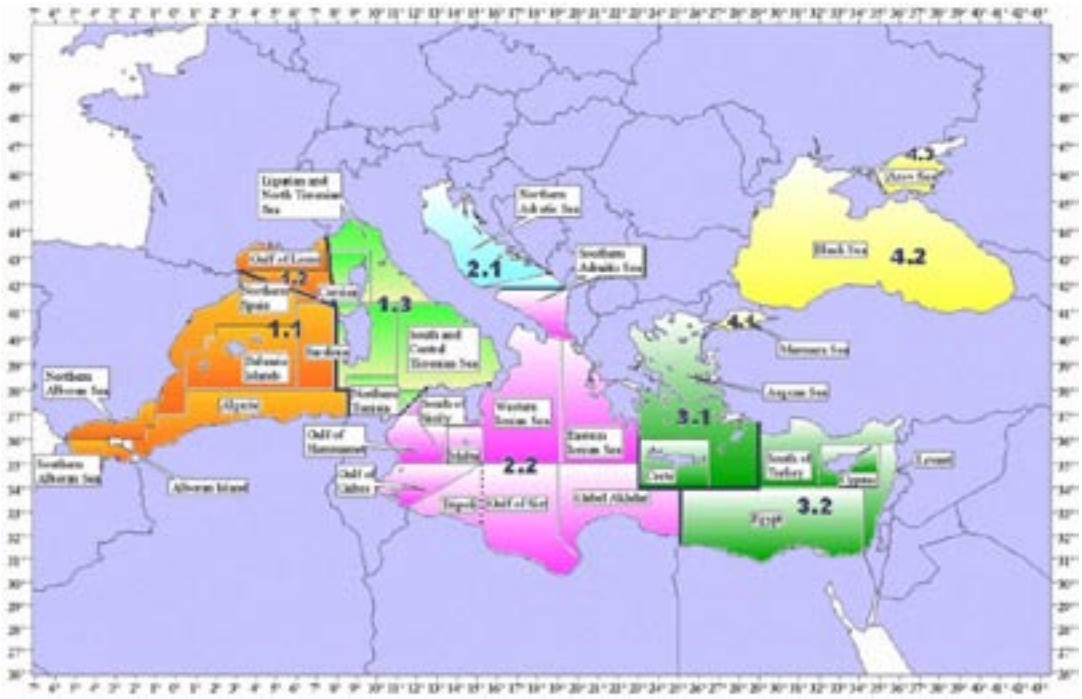
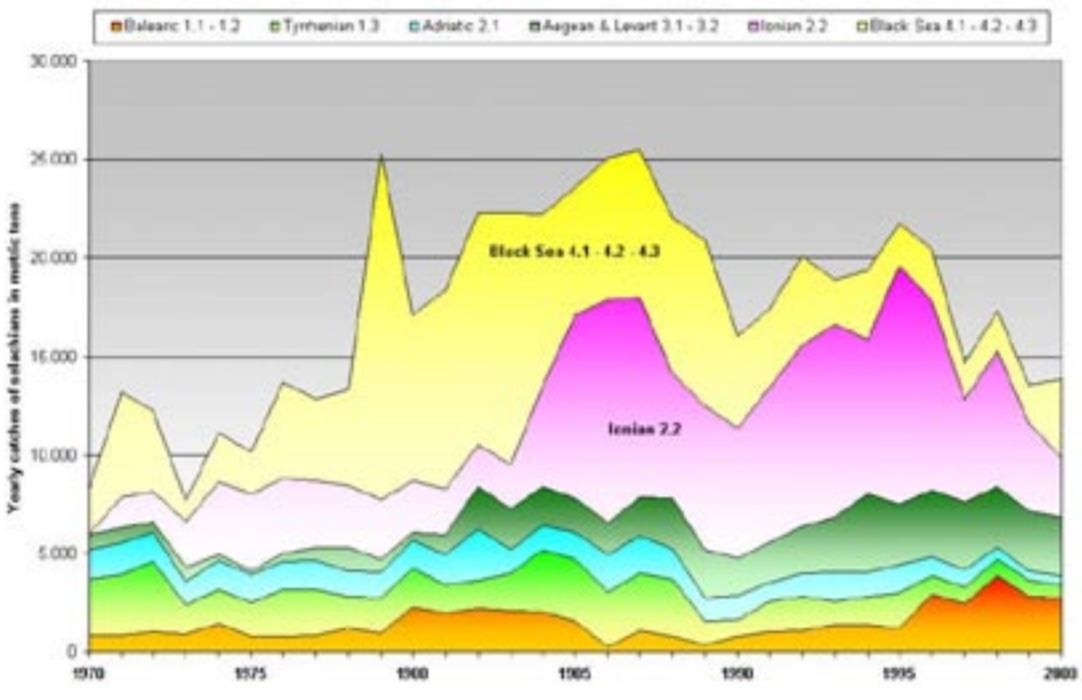


FIGURE 9
Commercial landings of elasmobranchs in the Mediterranean Sea



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Aspects of the biology of two deepwater sharks *Centrophorus squamosus* and *Centroscymnus coelolepis* from Hatton Bank and the Mid-Atlantic Ridge

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1. INTRODUCTION

Samples for this project were secured from two trawl surveys in 1993 and 1998 and five longline surveys in the period 1991 to 2000 (Figure 1 and Tables 1 and 2). The purpose of these surveys was to obtain samples of deepwater fish for biological and food-technology analyses. In addition, the surveys provided important information on catch rates and distribution of deepwater fish (Hareide and Garnes 2001). All surveys were carried out using chartered commercial vessels. Information from 168 trawl stations and 609 longline stations is presented. The expeditions carried out during the years 1991–1996 were organized by Møre Research Ålesund, and the later expeditions were organized by The Directorate of Fisheries Norway.

FIGURE 1
Positions for stations for exploratory fishery surveys, 1991–2000, and fishing areas used by the International Council for the Exploration of the Sea (ICES)

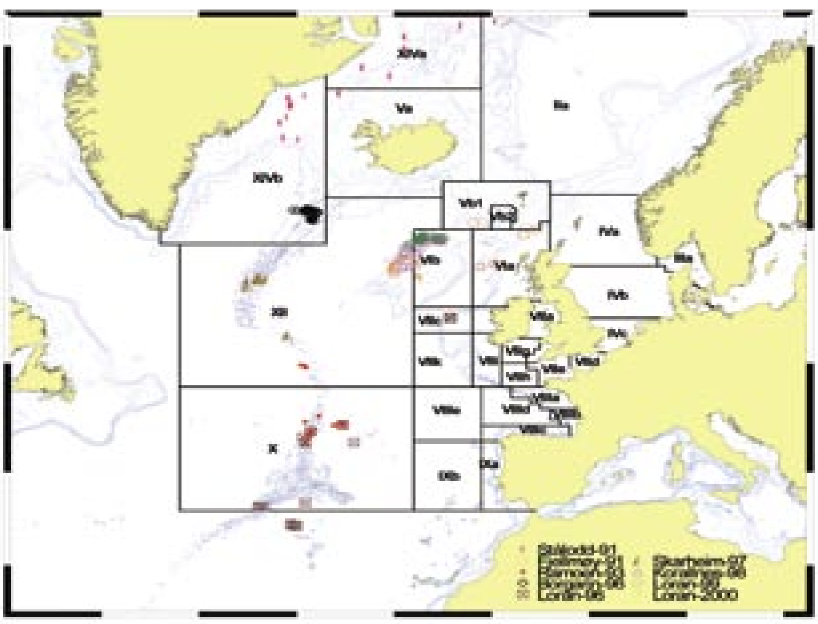


TABLE 1
Trawl stations by year and ICES area

	Vib	X	XII	Total
1993		116	7	123
1998	34		11	45
Total	**34**	**116**	**18**	**168**

TABLE 2
Longline stations by year and ICES area

	S of ICES	Vb1	Via	VIb	VIIc	X	XII	XIVb	Total
1991		7	19	7			12	2	47
1996	23				4	54		80	161
1997							251	1	252
1999				59			8		67
2000				44			38		82
Total	23	7	19	110	4	54	309	83	609

2. MATERIAL AND METHODS

Length frequency information was collected for 2 536 specimens of *Centrophorus squamosus* and 1 727 of *Centroscymnus coelolepis* (Tables 3 and 4). Catch per unit of effort (CPUE) was calculated for each station. For trawl surveys CPUE was calculated as kilogram a haul. During longline surveys the number of magazines of hooks shot at each station was recorded. For longline surveys CPUE for each station was calculated as kilogram per 1 000 hooks.

TABLE 3
Number of records of length, sex and maturity by year and ICES area for *Centrophorus squamosus*

	VIb			VIIc		X			XII			Total length	Total sex	Total mat
	Length	Sex	Mat	Length	Sex	Length	Sex	Mat	Length	Sex	Mat			
1991	9								4			13		
1996				201	79	271	141	3				493	220	3
1998	1	1							1			2	1	
1999	1250	1250	340						68	67	27	1318	1317	367
2000	408	405	107						302	297	140	710	702	247
Total	**1668**	**1656**	**447**	**201**	**79**	**271**	**141**	**3**	**375**	**364**	**167**	**2536**	**2240**	**617**

TABLE 4
Number of records of length, sex and maturity by year and ICES area for *Centroscymnus coelolepis*

	VIb			X		XII			XIVb		Total length	Total sex	Total mat
	Length	Sex	Mat	Length	Sex	Length	Sex	Mat	Length	Sex			
1991	15					1					16		
1996				32	5				2	2	34	7	
1997						59	48	25			59	48	25
1998	36	3				10					46	3	
1999	587	581	229			59	58	56			646	639	285
2000	346	345	127			580	551	173			926	896	300
Total	**984**	**929**	**356**	**32**	**5**	**709**	**657**	**254**	**2**	**2**	**1727**	**1593**	**610**

Length frequency (5 cm interval) distributions were calculated for 100 m depth strata for each species (Figures 14–19 and 37–42). The sex ratio was calculated for 100 m depth strata (Figures 21 and 44).

Maturity was assessed by means of the maturity scale devised for use in the European Community FAIR deepwater research programme (Stehmann 1998). This scale was used on surveys after 1996. The scale made use of several criteria for assessing the state of maturity. These criteria are described in Clarke (2000). We have participated in Irish longline surveys in 1997 and 1999 and have developed our interpretation in cooperation with The Marine Institute of Ireland.

During the surveys before 1997 maturity was not assessed for the two species. During sampling after 1996 617 specimens of *Centrophorus squamosus* and 610 of *Centroscymnus Coelolepis* were classified (Tables 3 and 4).

3. RESULTS

3.1 *Centrophorus squamosus*

Distribution

The CPUE from trawl and longlines is presented in Figures 4–13. Highest catches were recorded in some areas of the Hatton Bank slopes. The absolute depth range for this species was 470–1 950 m. Peak catch rates of *Centrophorus squamosus* for longlines came from 1 000 to 1 100 m. Few specimens were caught by trawl compared to longlines (Figures 2 and 3).

FIGURE 2

Catch composition for trawl 1998, Hattonbank (ICES areas VIb and XII combined)

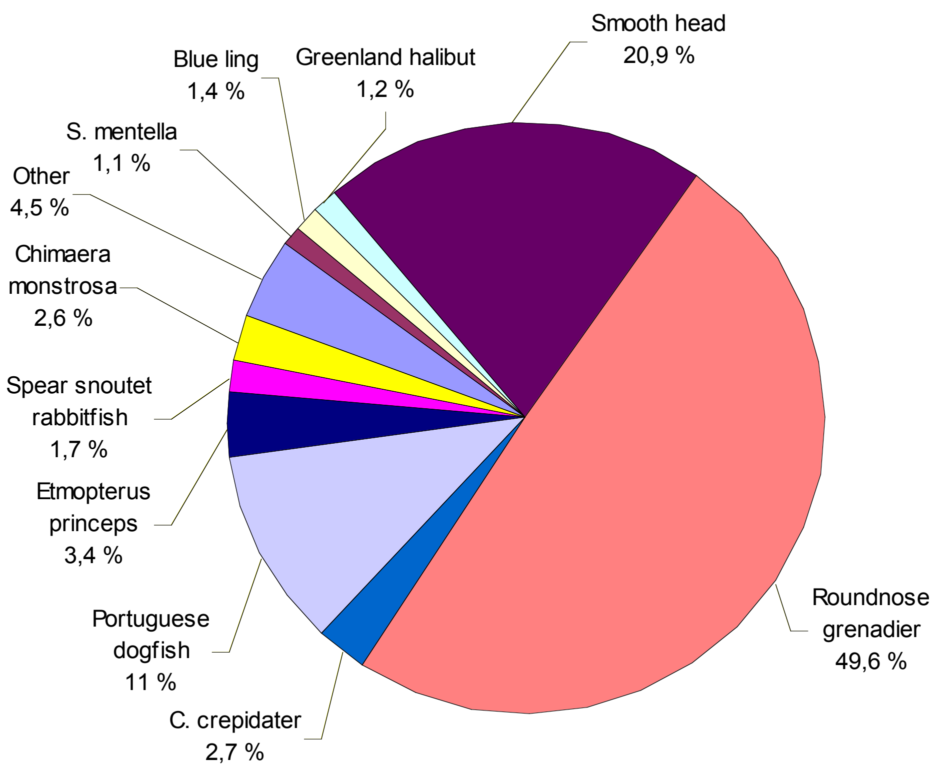
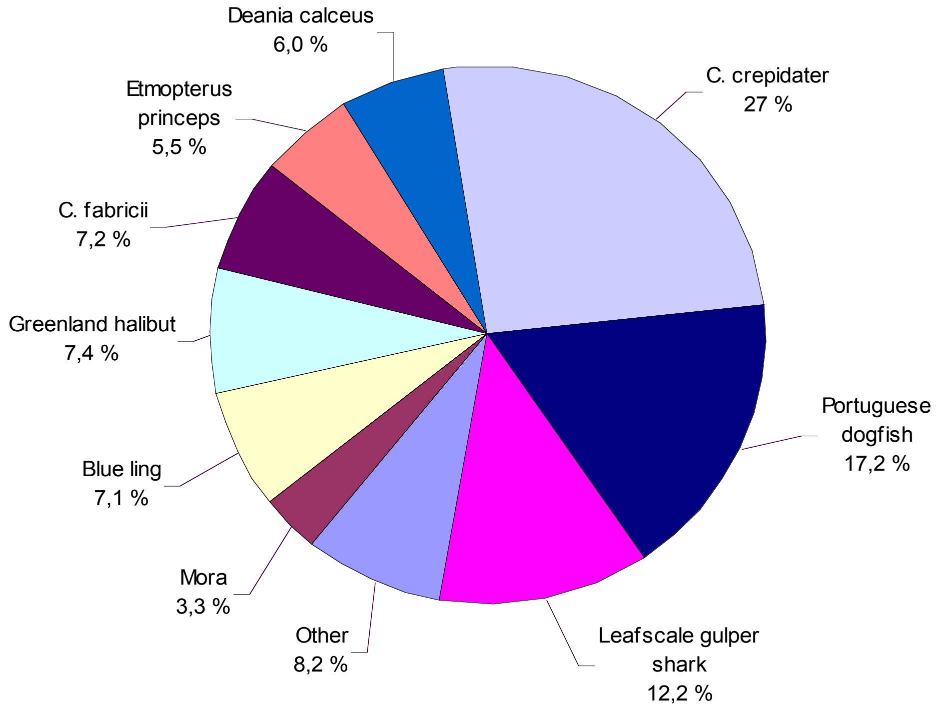


FIGURE 3
Catch composition for longline 1999, Hattonbank (ICES areas VIb and XII combined)



Length frequencies

The smallest length recorded was 53 cm for females and 56 cm for males. The greatest lengths were 136 cm for males and 135 cm for females. Figure 20 shows mean length by sex for each 100 m depth interval. There is a trend of decreasing size with depth in both sexes.

Reproduction

The relative frequencies for each maturity stage from Hatton Bank for the years 1999 and 2000 are shown in Figures 22 and 23. During this study two pregnant females were recorded. They were caught on the northern slope of Hatton Bank at depths between 1 155 and 1 300 m at a temperature of 4.7 °C.

Feeding

Stomach contents were found in only 20 specimens. Of these specimens, 18 were collected on Hatton Bank. The main prey species was *Coryphaenoides rupestris* (Table 5). Different types of fish amounted to 80 percent, whale meat to 10 percent, and squid and octopus to 10 percent.

TABLE 5
Stomach contents of *Centrophorus squamosus*

Food items	Number	%
Argentines	1	5
Different fish	4	20
Mora moro	1	5
Coryphanoides rupestris	7	35
Sebastes Mentella	1	5
Smoothhead	2	10
Squid	2	10
Whale	2	10
Total	**20**	**100**

3.2 *Centroscymnus coelolepis*

Distribution

The CPUE from trawl and longlines is presented in Figures 24–35. Highest catches were recorded in some areas of the Hatton Bank slopes. The absolute depth range for this species was 497–1950 m. Peak catch rates of *Centroscymnus Coelolepis* for longlines came from 1 000 to 1 400 m.

Length frequencies

Length distributions are shown in Figures 37–42. The smallest length recorded was 59 cm for females and 59 cm for males. The greatest lengths were 137 cm for males and 130 cm for females. Figure 43 shows mean length by sex for each 100 m depth interval. There is a trend of decreasing size with depth for females, but not for males.

Reproduction

The relative frequencies for each maturity stage from Hatton Bank for the years 1999 and 2000 are shown in Figures 45 and 46.

Feeding

Stomach contents were found in 68 specimens. All of these were collected on Hatton Bank in 1999 and 2000. The prey consisted of different types of fish (43 percent), whale meat (33 percent), and squid and octopus (24 percent) (Table 6).

TABLE 6
Stomach contents of *Centroscymnus coelolepis*

Food items	Number	%
Molva dypterygia	4	5.9
Chalinura sp.	1	1.5
Coryphanoides rupestris	6	8.8
Different fish	8	11.8
Grenland halibut	2	2.9
Myctophidae	1	1.5
Mora moro	4	5.9
Octopus	5	7.4
Smoothhead	3	4.4
Squid	11	16.2
Whale	23	33.8
Total	**68**	**100**

4. ACKNOWLEDGEMENT

This paper is a result of The EC funded projects (EC FAIR 95/655 and DG fish study Contract 99/55). The expeditions were funded by The Norwegian Directorate of Fisheries, The Faroese Government and several private companies. The authors thank these organizations very much and also all crew and staff involved in the investigations.

FIGURE 4
Catch-per-unit-of-effort for *Centrophorus squamosus* in kg per 1 000 hooks during a longline survey in September 1996

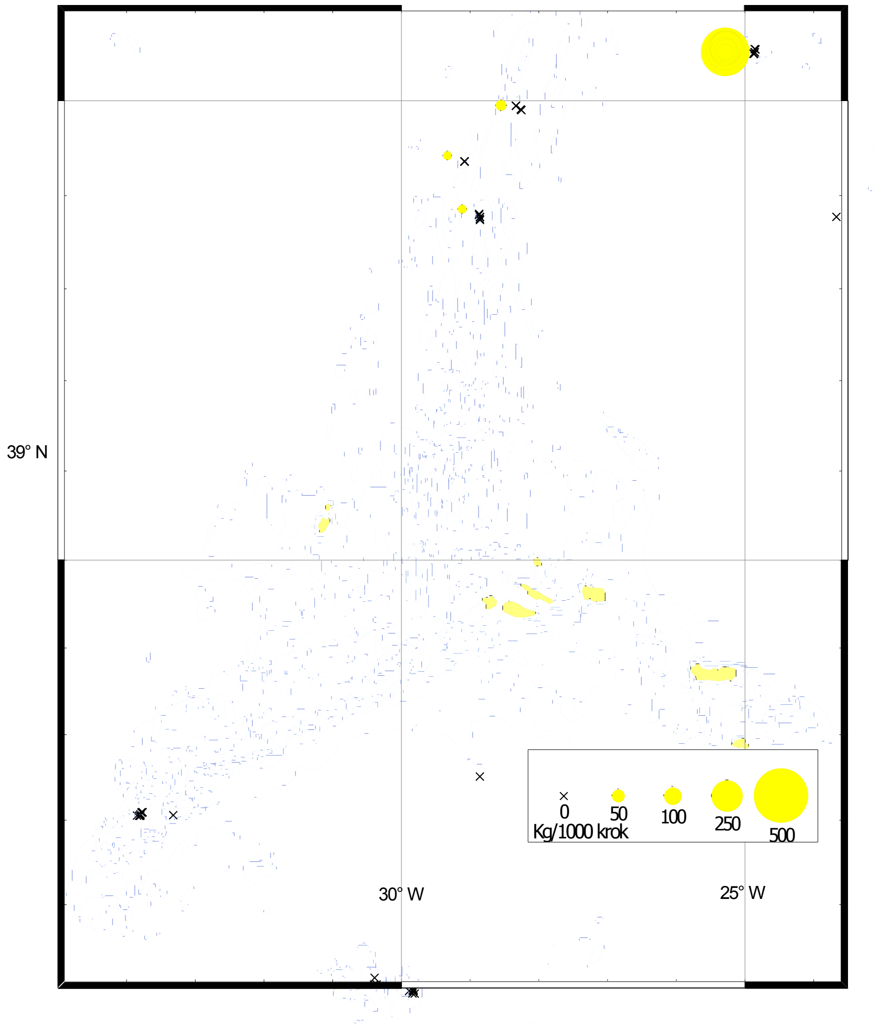


FIGURE 5
Catch-per-unit-of-effort for *Centrophorus squamosus* in kg per haul during a trawl survey in September 1993

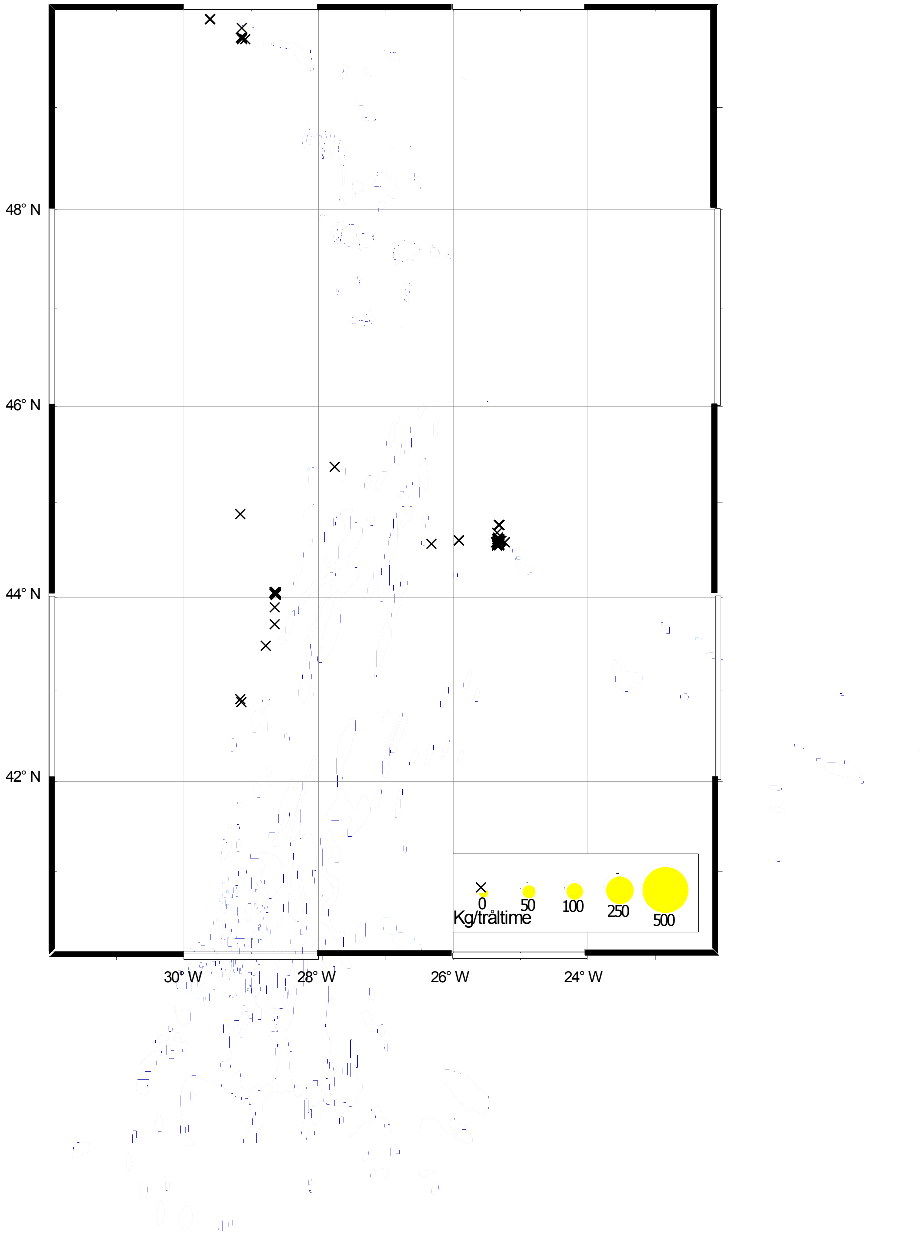


FIGURE 6

Catch-per-unit-of-effort for *Centrophorus squamosus* in kg per 1 000 hooks during longline surveys in September 1999 and June 2000

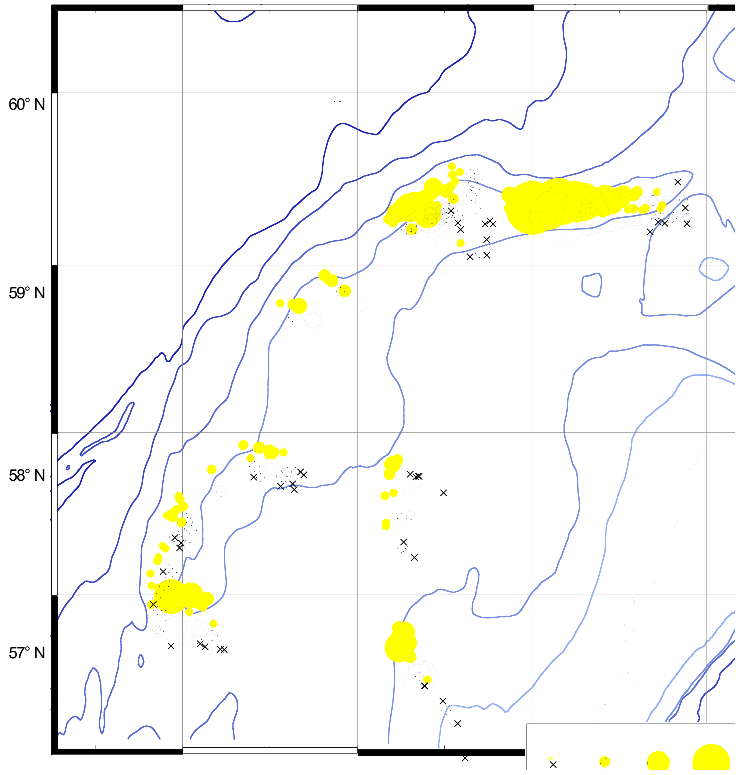


FIGURE 7

Catch-per-unit-of-effort for *Centrophorus squamosus* in kg per haul during a trawl survey in September 1998

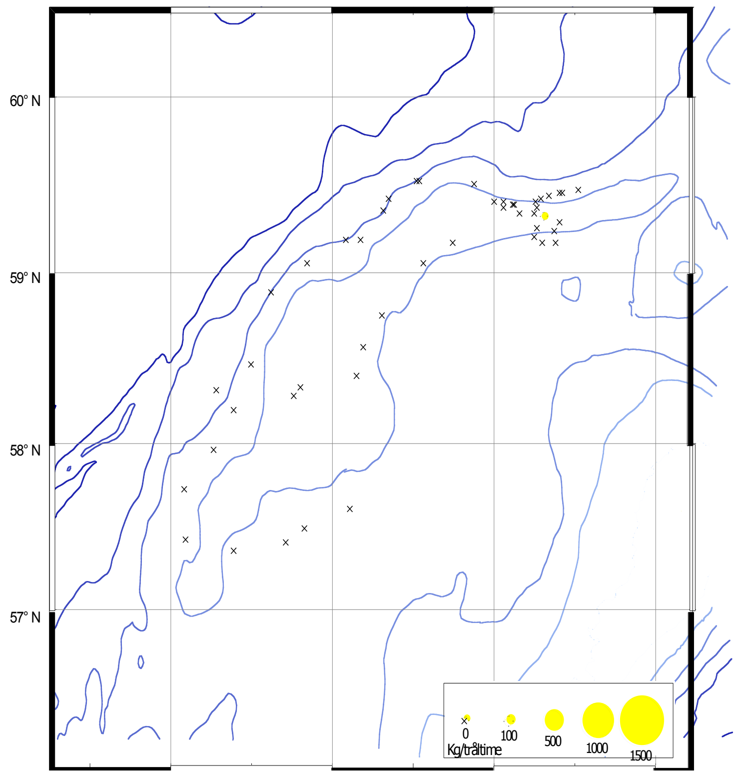


FIGURE 8

Catch-per-unit-of-effort for *Centrophorus squamosus* in kg per 1 000 hooks during a longline survey in July–August 1997

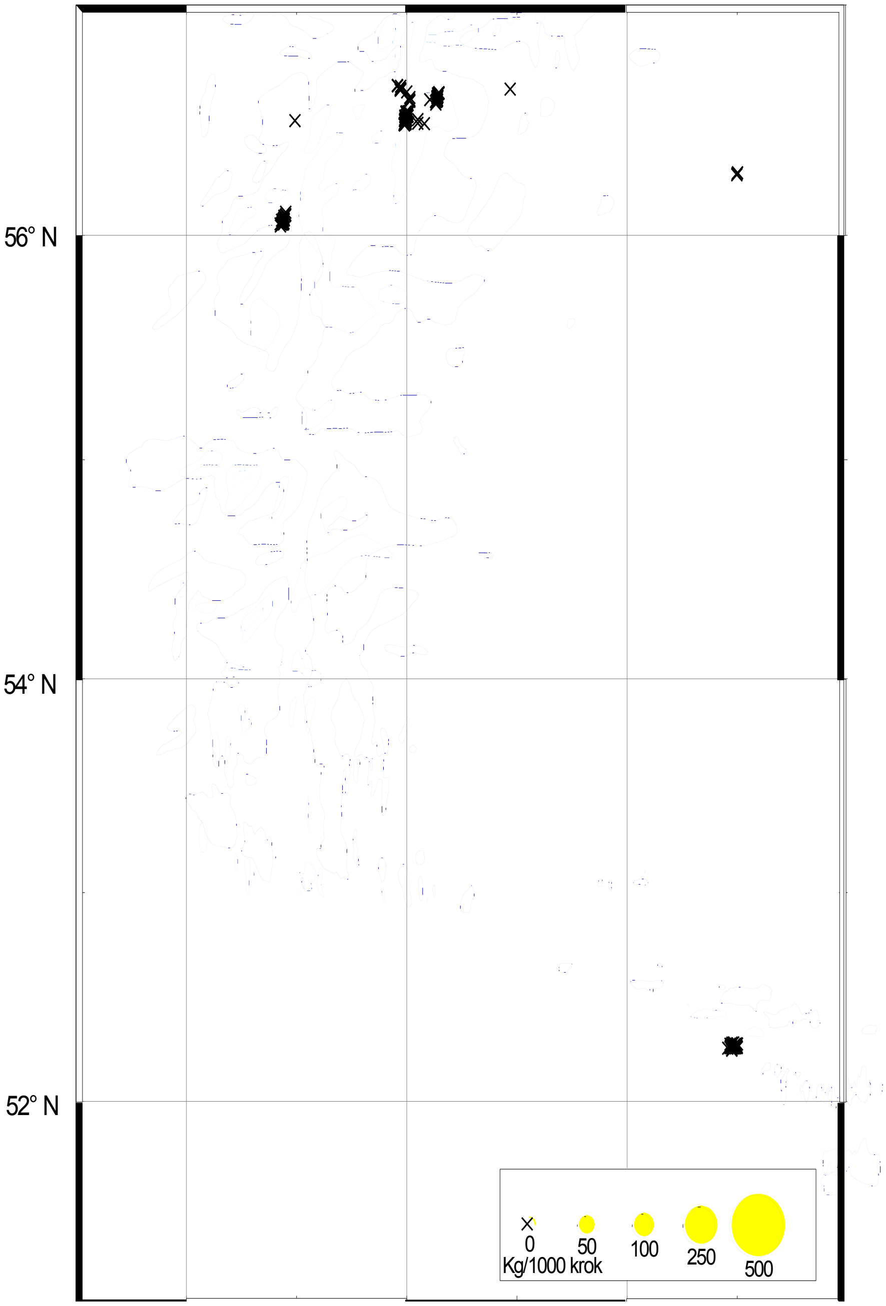


FIGURE 9
Variation in CPUE (kg per 1 000 hooks) for *Centrophorus squamosus*, based on all longline surveys in the period 1991–2000

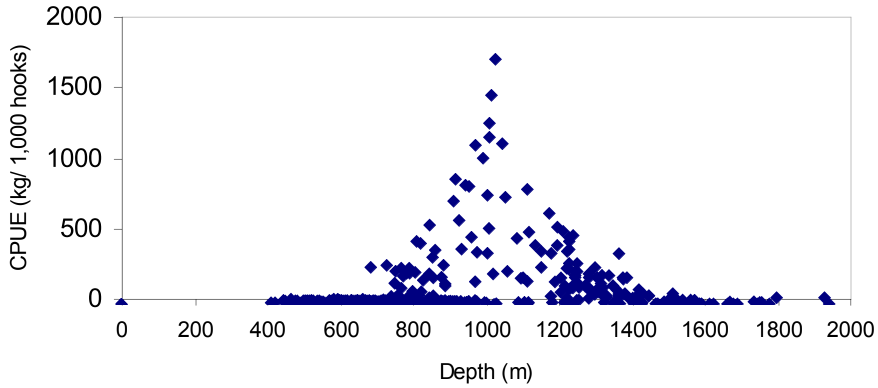


FIGURE 10
Variation in CPUE (kg per 1 000 hooks) for *Centrophorus squamosus*, based on longline surveys in 1999 and 2000 in ICES area VIb, Hatton Bank

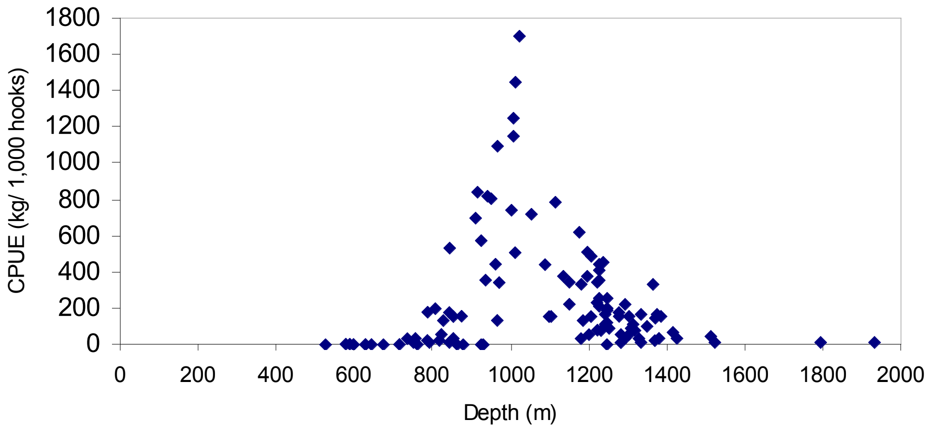


FIGURE 11
Variation in CPUE (kg per 1 000 hooks) for *Centrophorus squamosus*, based on longline surveys in 1999 and 2000 in ICES area XII, Hatton Bank

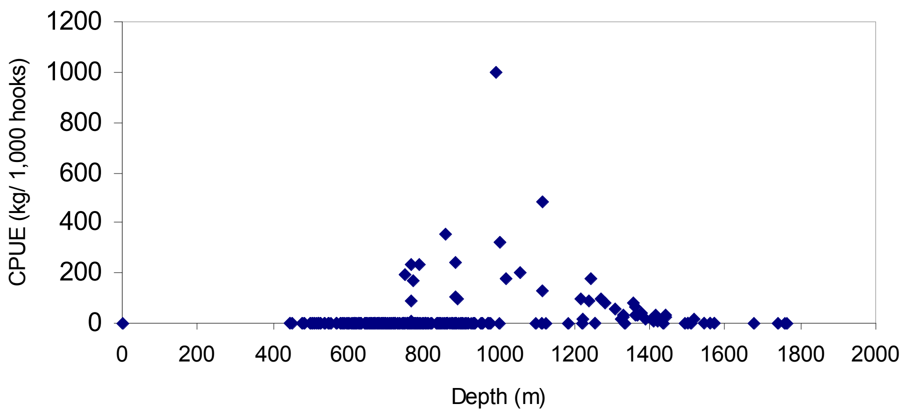


FIGURE 12

Variation in CPUE (kg per 1 000 hooks) for *Centrophorus squamosus*, based on a longline survey in 1997 in ICES area X, Mid-Atlantic Ridge

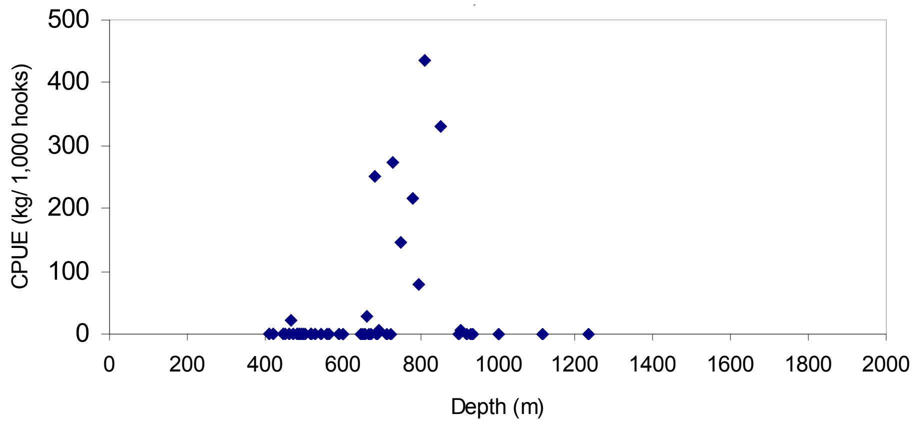


FIGURE 13

Variation in CPUE by depth and by temperature for *Centrophorus squamosus*, based on all longline surveys where this species was caught

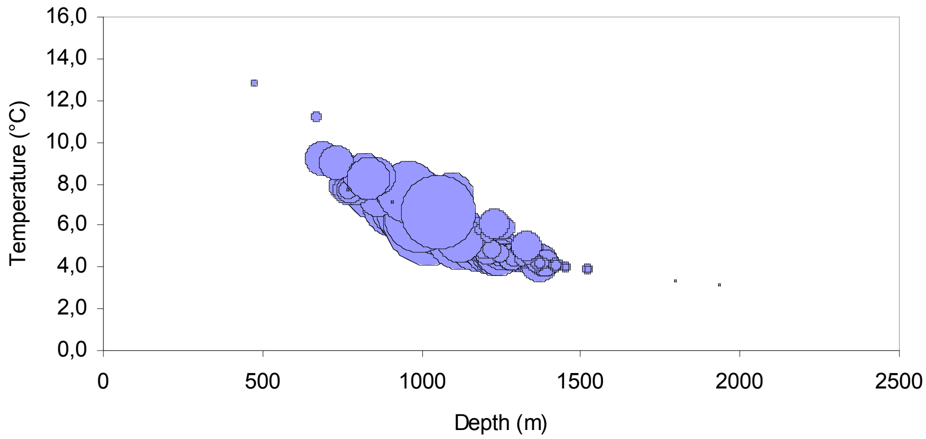


FIGURE 14

Length frequency for *Centrophorus squamosus* caught during a longline survey in ICES area Vib in 1999

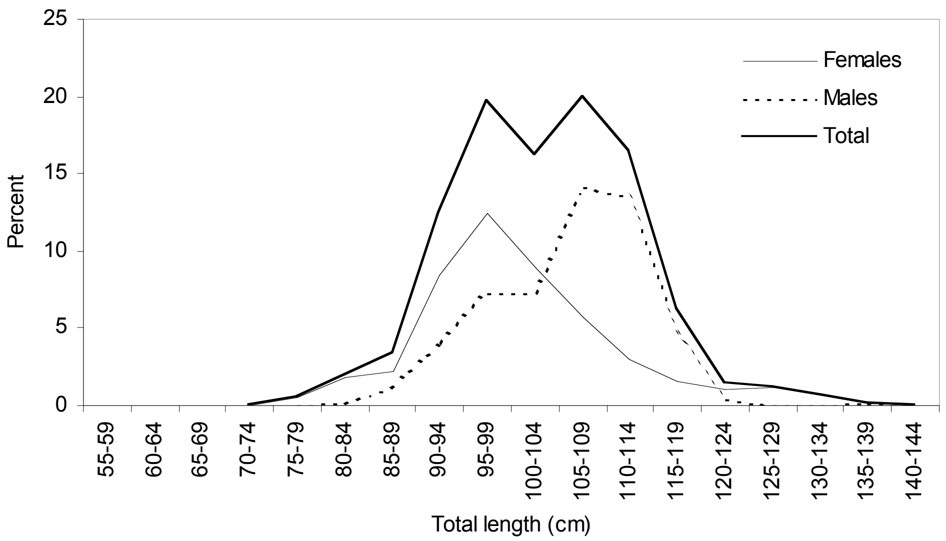


FIGURE 15

Length frequency for *Centrophorus squamosus* caught during a longline survey in ICES area VIb in 2000

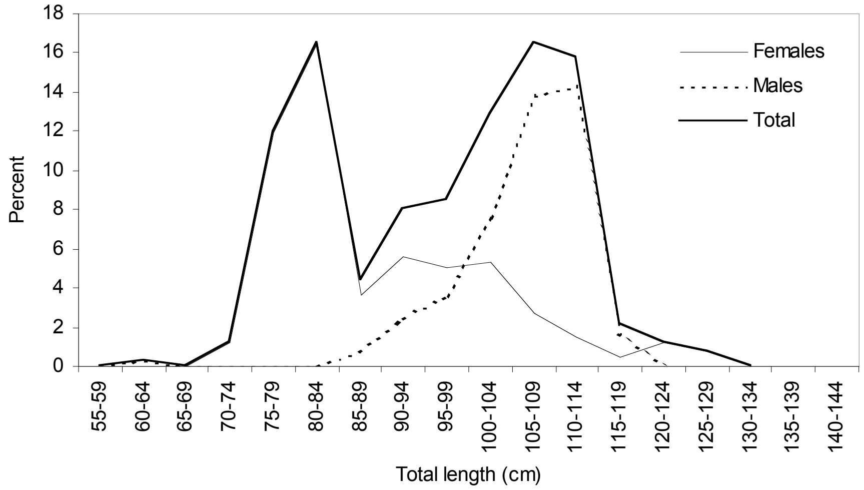


FIGURE 16

Length frequency for *Centrophorus squamosus* caught during a longline survey in ICES area X in 1996

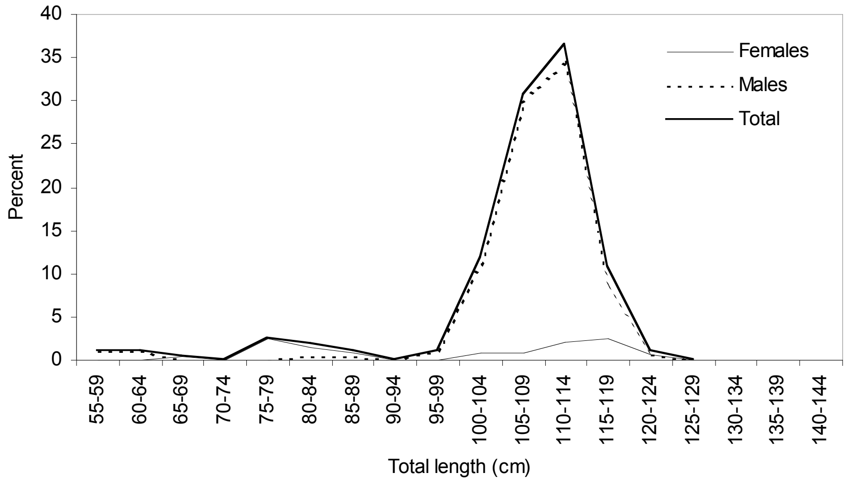


FIGURE 17

Length frequency for *Centrophorus squamosus* caught during a longline survey in ICES area XII (Hatton Bank) in 1999

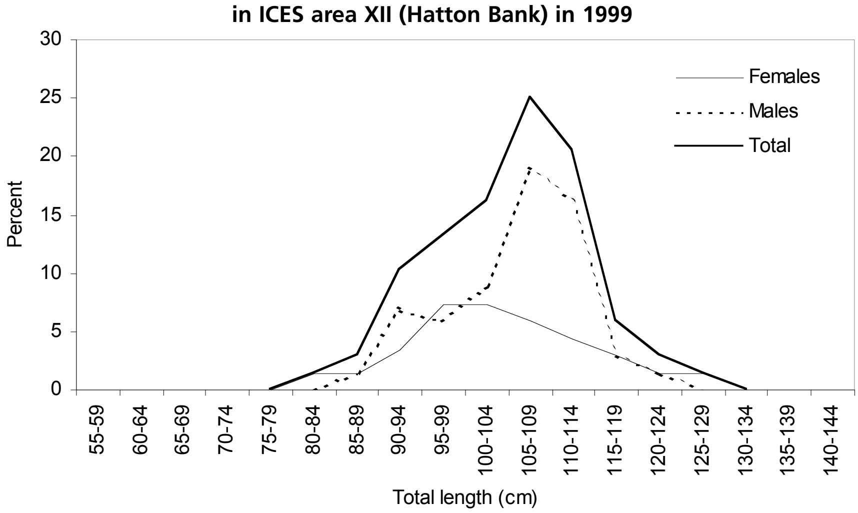


FIGURE 18

Length frequency for *Centrophorus squamosus* caught during a longline survey in ICES area XII (Hatton Bank) in 2000

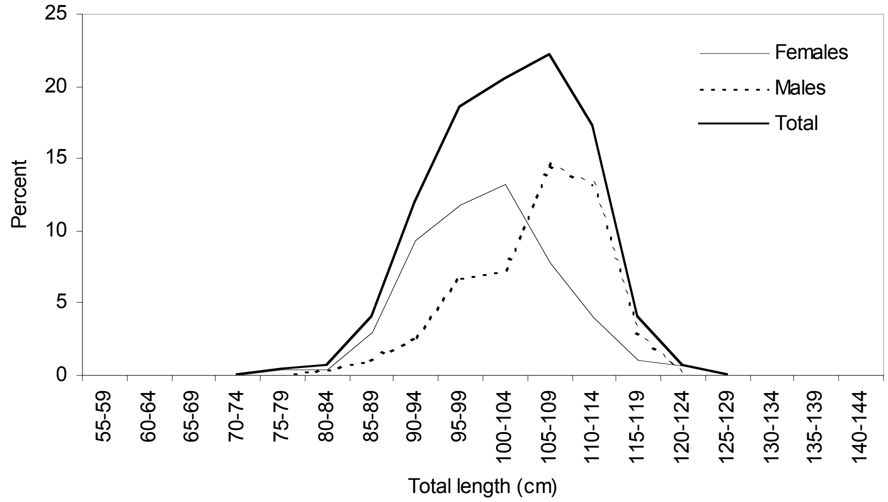


FIGURE 19

Length frequency for *Centrophorus squamosus* caught during a longline survey in ICES area VIIc in 1996

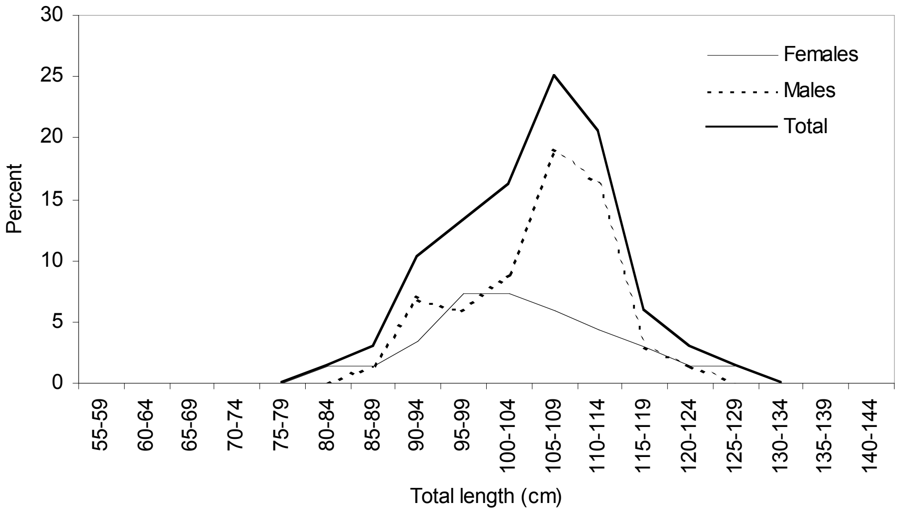


FIGURE 20

Variation in mean length by depth for *Centrophorus squamosus* comprizing all samples collected during all surveys

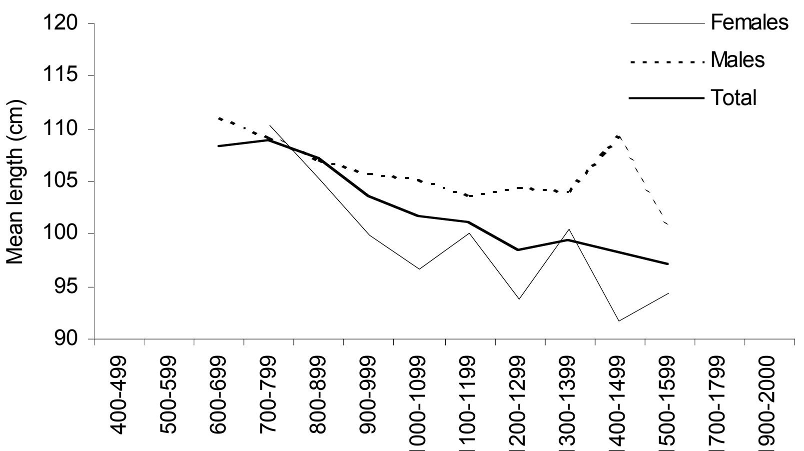


FIGURE 21
Variation in sex ratio (%) with depth in 100 m intervals for *Centrophorus squamosus* comprizing all samples collected during all surveys

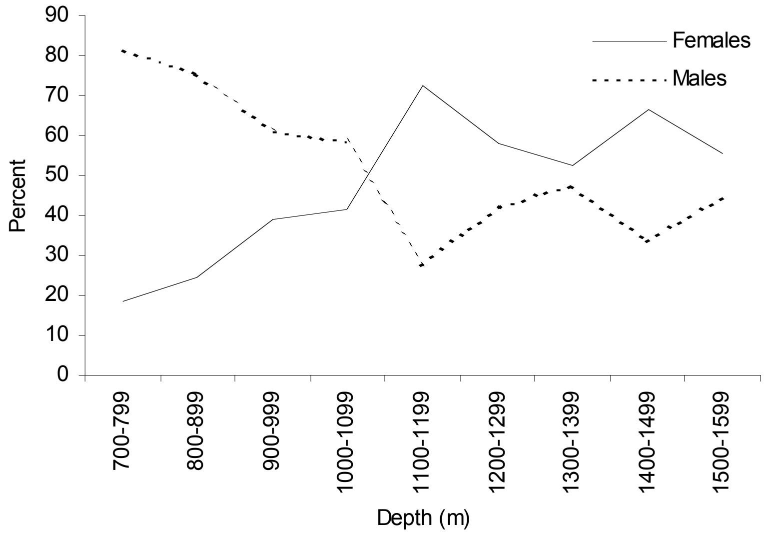


FIGURE 22
Frequency of occurrence of each maturity stage for *Centrophorus squamosus* females from ICES areas VIb and XII (Hatton Bank) in September 1999

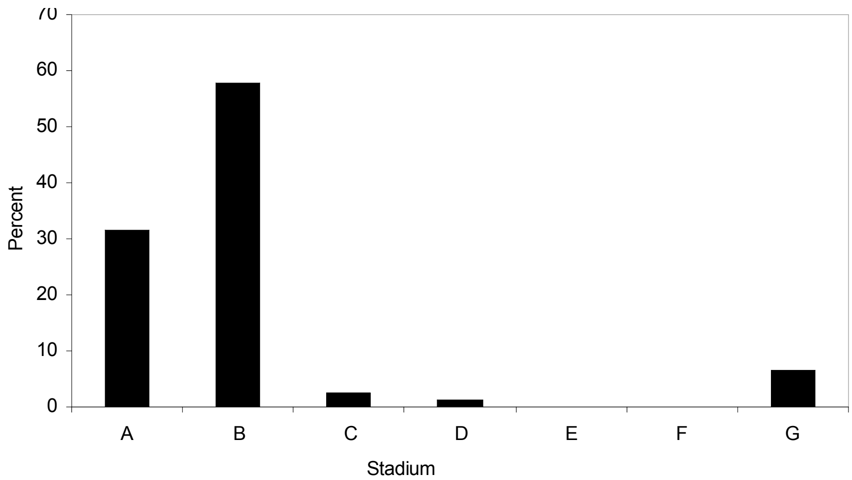


FIGURE 23
Frequency of occurrence of each maturity stage for *Centrophorus squamosus* females from ICES areas VIb and XII (Hatton Bank) in June 2000

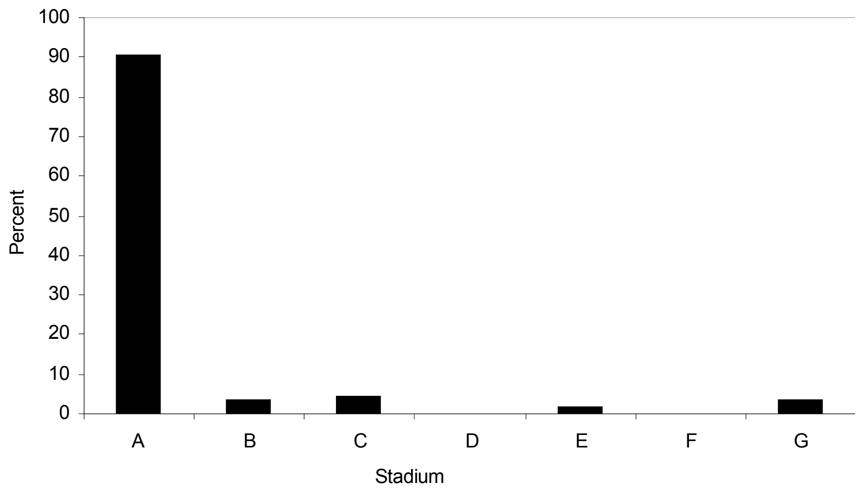


FIGURE 24
Catch-per-unit-of-effort for *Centroscymnus coelolepis* in kg per 1 000 hooks during a longline survey in September 1996

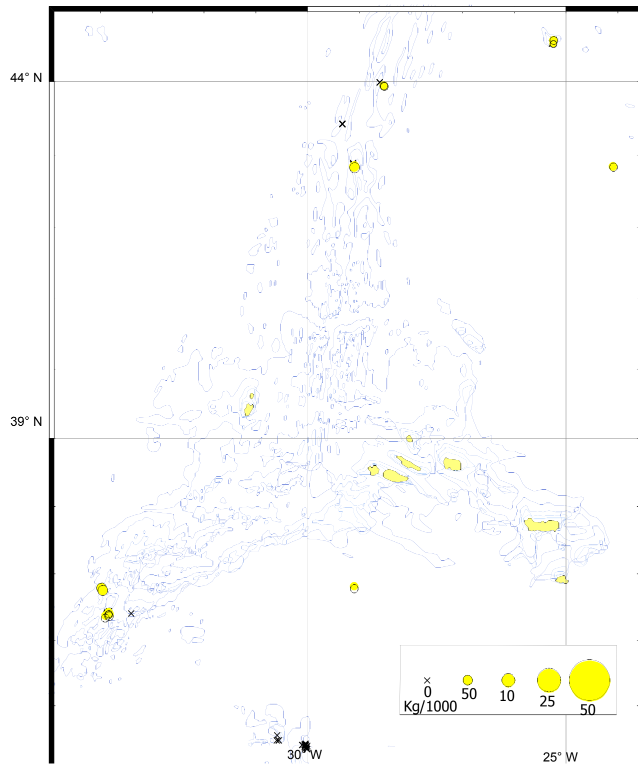


FIGURE 25
Catch-per-unit-of-effort for *Centroscymnus coelolepis* in kg per haul during a trawl survey in September 1993

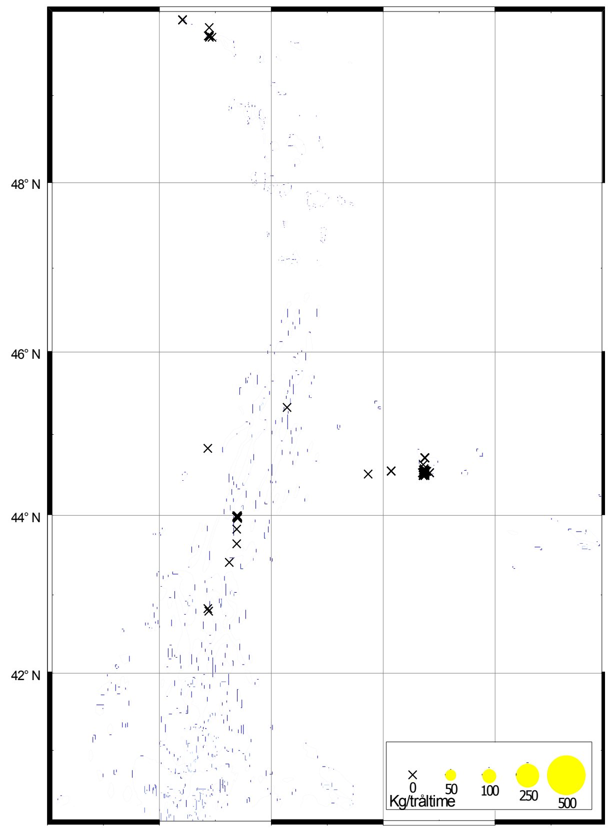


FIGURE 26

Catch-per-unit-of-effort for *Centroscymnus coelolepis* in kg per 1 000 hooks during longline surveys in September 1999 and June 2000

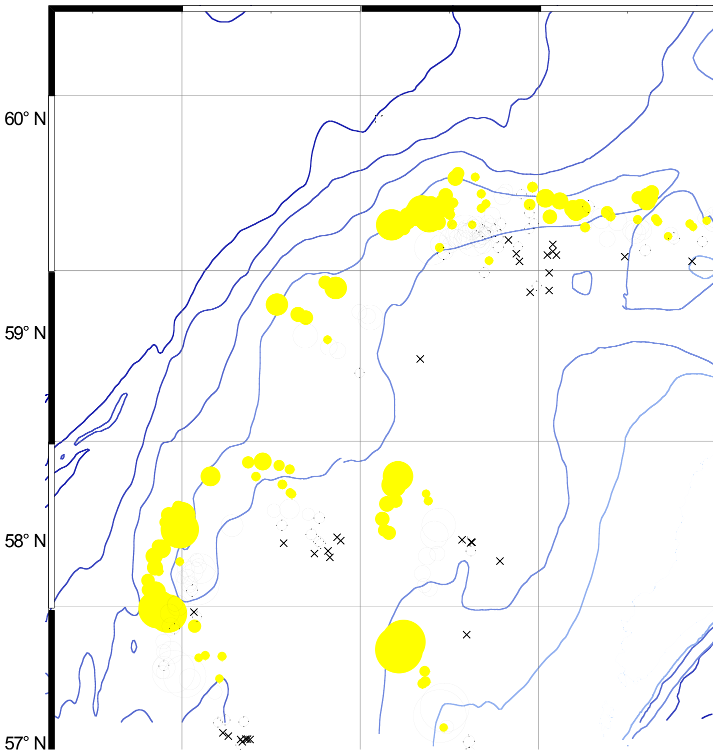


FIGURE 27

Catch-per-unit-of-effort for *Centroscymnus coelolepis* in kg per haul during a trawl survey in September 1998

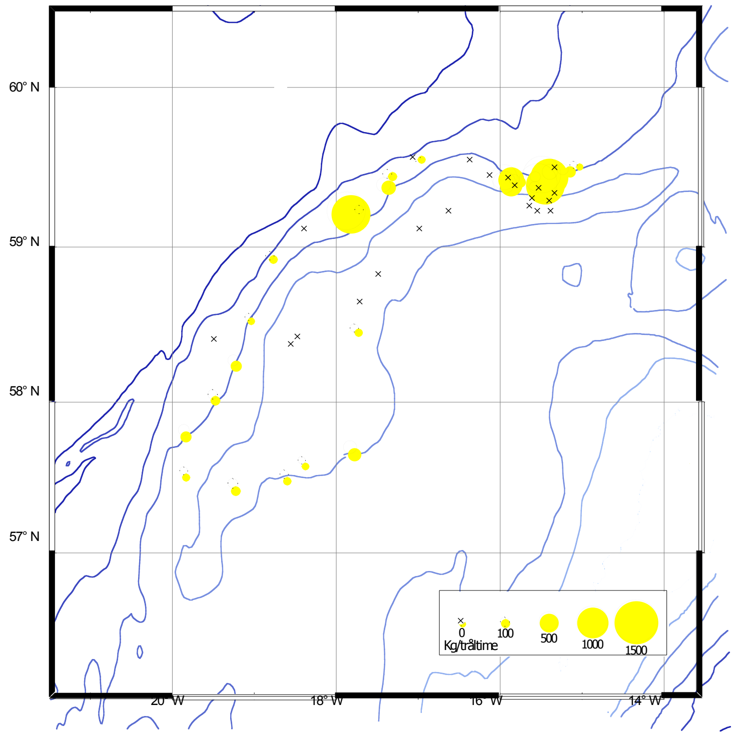


FIGURE 28
Catch-per-unit-of-effort for *Centroscymnus coelolepis* in kg per 1 000 hooks during a longline survey in July–August 1997

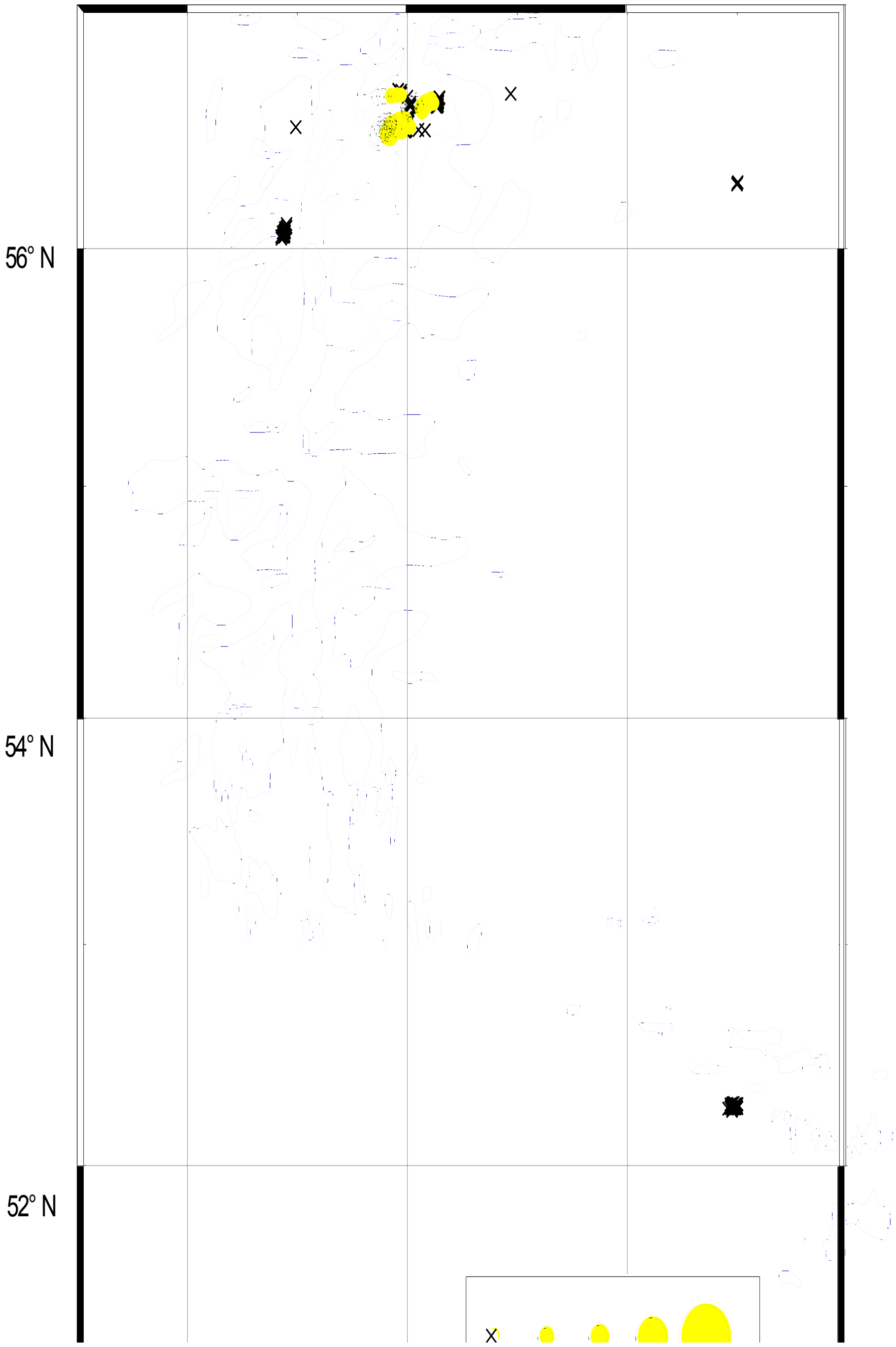


FIGURE 29
Variation in CPUE (kg per 1 000 hooks) for *Centroscymnus coelolepis*, based on all longline surveys in the period 1991–2000

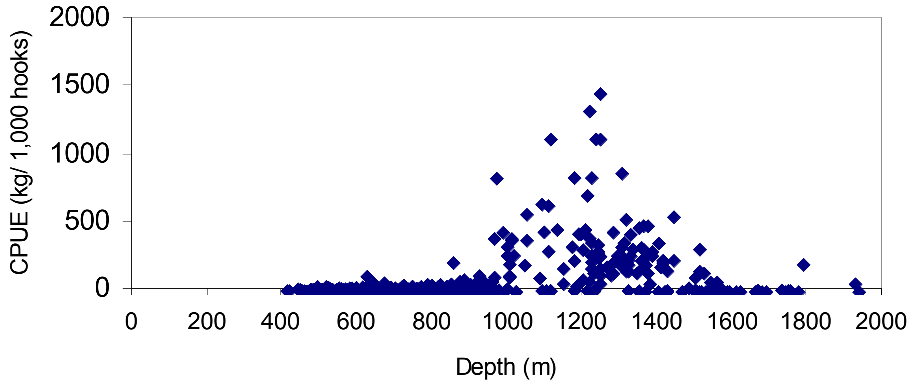


FIGURE 30
Variation in CPUE (kg per 1 000 hooks) for *Centroscymnus coelolepis*, based on longline surveys in 1999 and 2000 in ICES area VIb, Hatton Bank

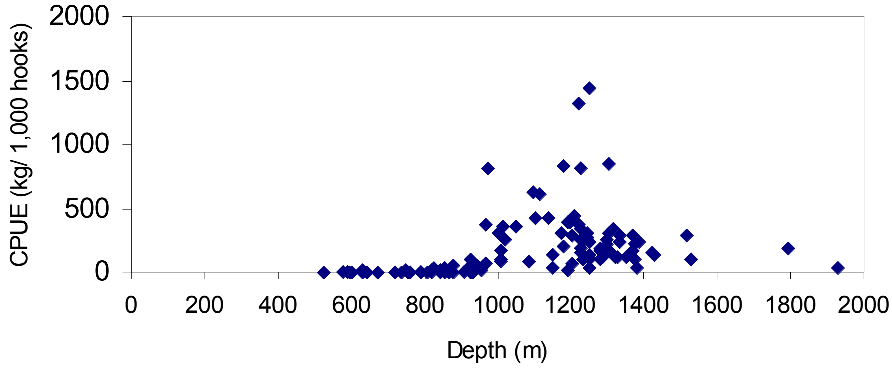


FIGURE 31
Variation in CPUE (kg per 1 000 hooks) for *Centroscymnus coelolepis*, based on a longline survey in 1997 in ICES area X, Mid-Atlantic Ridge

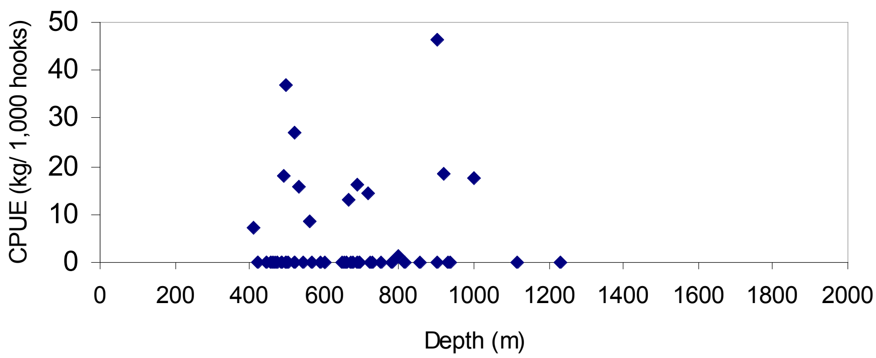


FIGURE 32
Variation in CPUE (kg per 1 000 hooks) for *Centroscymnus coelolepis*, based on longline surveys in 1999 and 2000 in ICES area XII, Hatton Bank

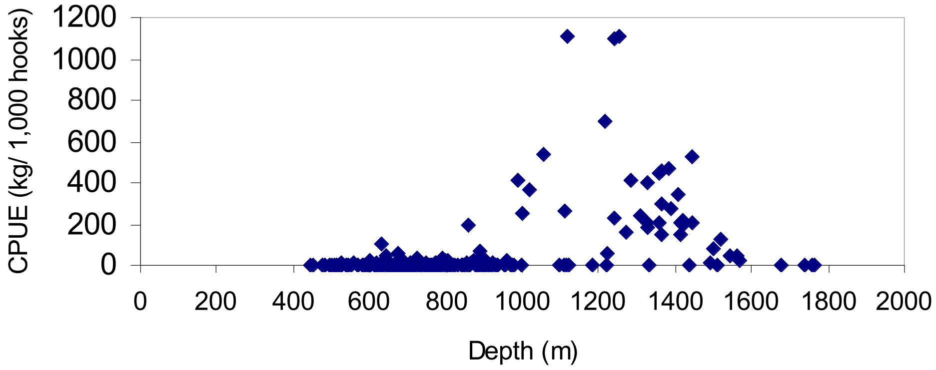


FIGURE 33
Variation in CPUE (kg per haul) for *Centroscymnus coelolepis*, based on trawl surveys in 1993 and 1998

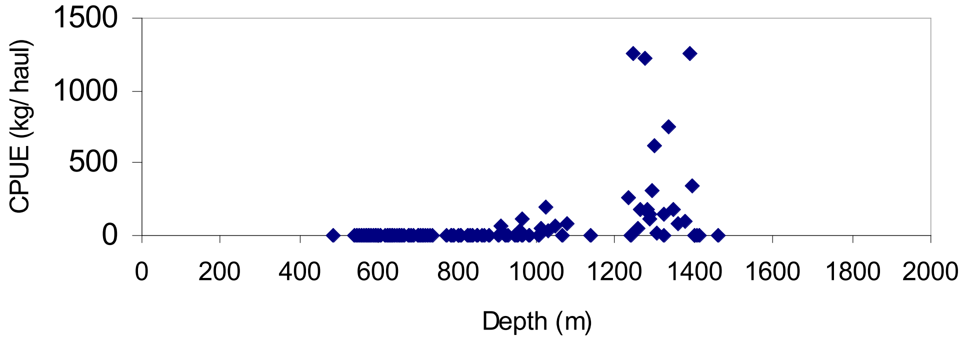


FIGURE 34
Variation in CPUE (kg per haul) for *Centroscymnus coelolepis*, based on a trawl survey in 1998 in ICES area VIb

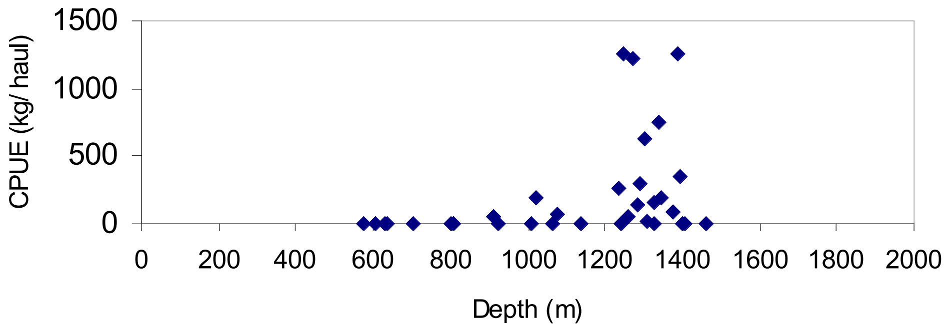


FIGURE 35

Variation in CPUE (kg per haul) for *Centroscymnus coelolepis*, based on a trawl survey in 1998 in ICES area XII (Hatton Bank)

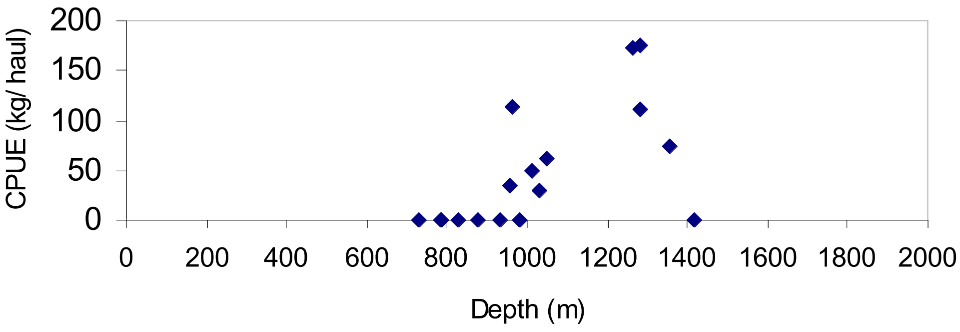


FIGURE 36

Variation in CPUE by depth and temperature for *Centroscymnus coelolepis*, based on all longline surveys, where this species was caught in the period 1991–2000

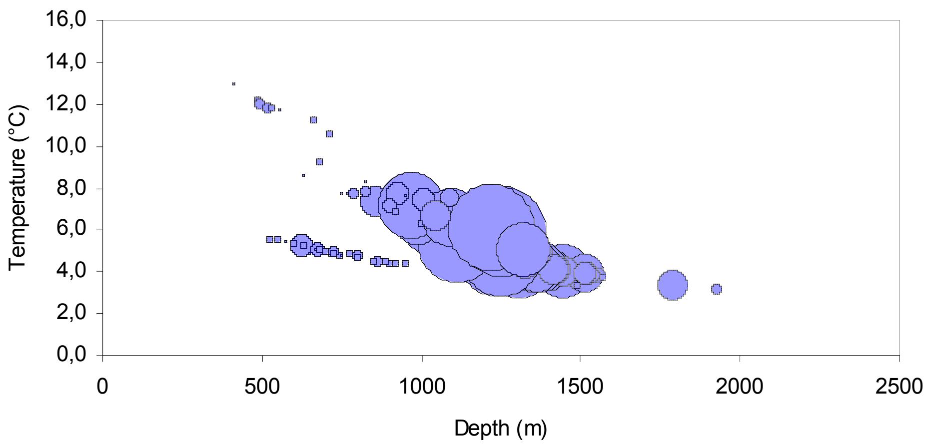


FIGURE 37

Length frequency for *Centroscymnus coelolepis* caught during a longline survey in ICES area VIb in 1999

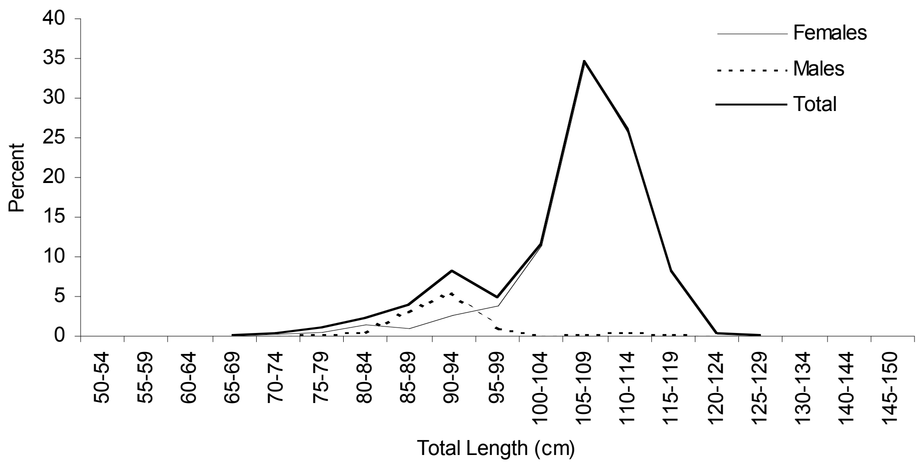


FIGURE 38

Length frequency for *Centroscymnus coelolepis* caught during a longline survey in ICES area VIb in 2000

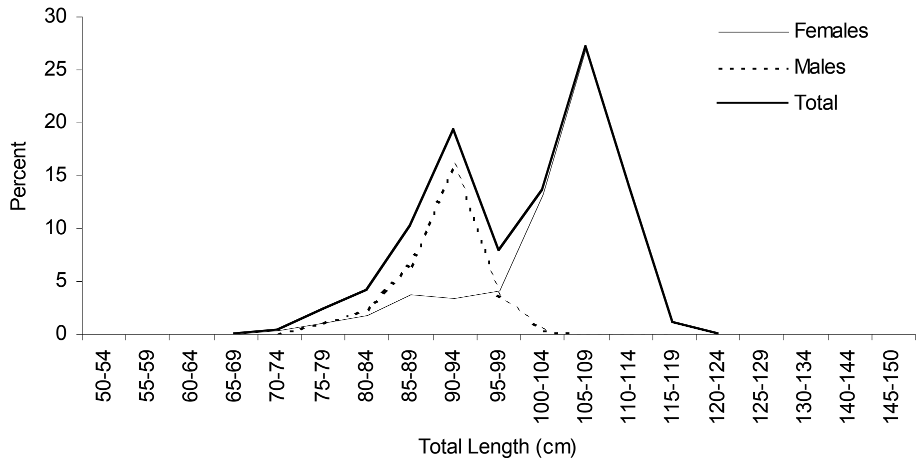


FIGURE 39

Length frequency for *Centroscymnus coelolepis* caught during a longline survey in ICES area XII (Mid-Atlantic Ridge) in 1997

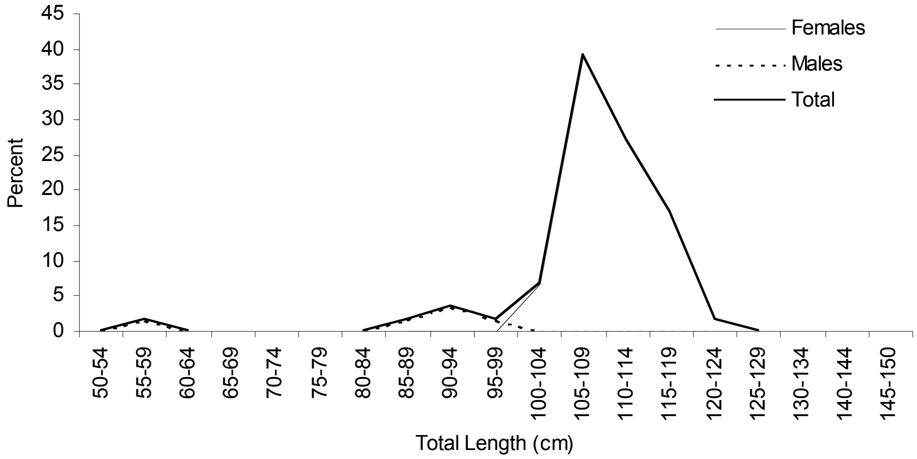


FIGURE 40

Length frequency for *Centroscymnus coelolepis* caught during a longline survey in ICES area XII (Hatton Bank) in 1999

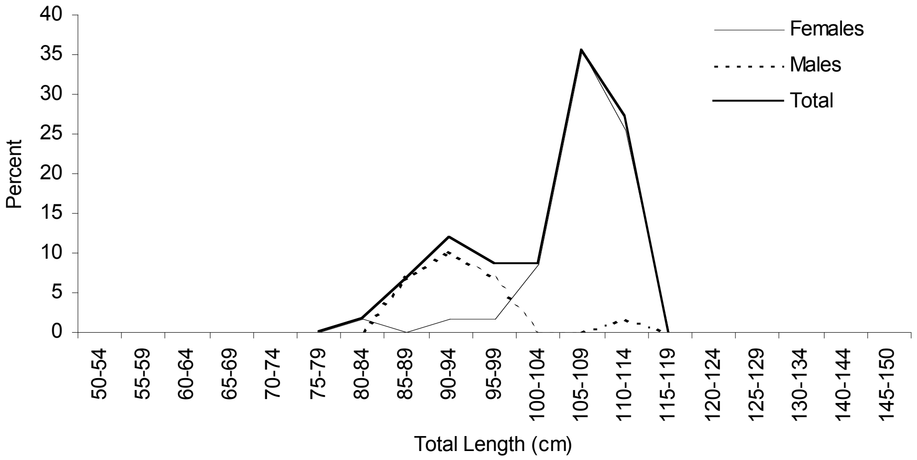


FIGURE 41
Length frequency for *Centroscymnus coelolepis* caught during a longline survey in ICES area XII (Hatton Bank) in 2000

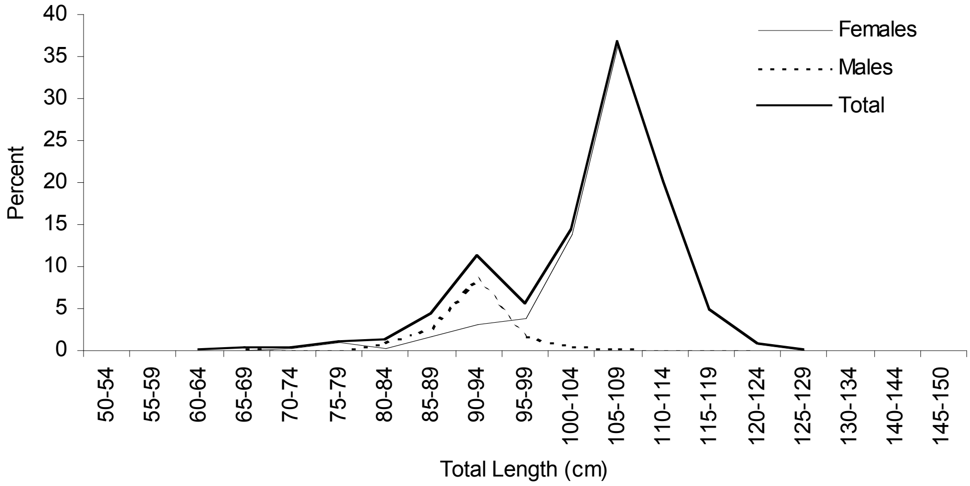


FIGURE 42
Length frequency for *Centroscymnus coelolepis* caught during a trawl survey in ICES area XII (Hatton Bank) in 1998

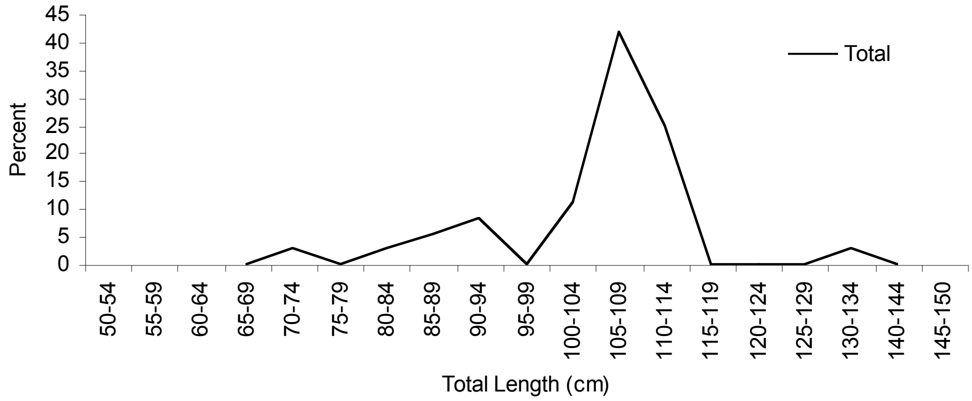


FIGURE 43
Variation in mean length by depth for *Centroscymnus coelolepis* comprizing all samples collected during all surveys

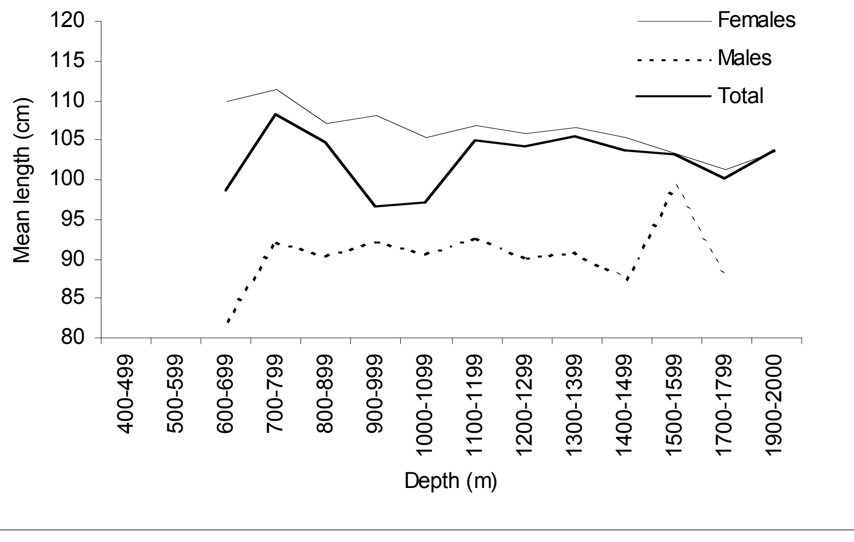


FIGURE 44

Variation in sex ratio (%) with depth in 100 m intervals for *Centroscymnus coelolepis* comprizing all samples collected during all surveys

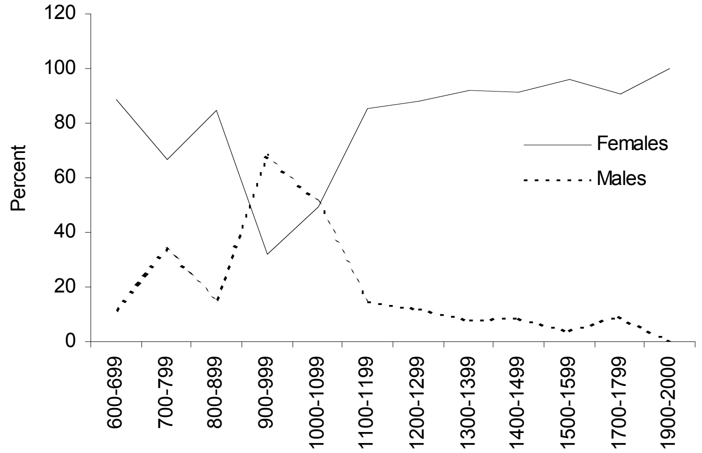


FIGURE 45

Frequency of occurrence of each maturity stage for *Centroscymnus coelolepis* females from ICES areas VIb and XII (Hatton Bank) in June 1999

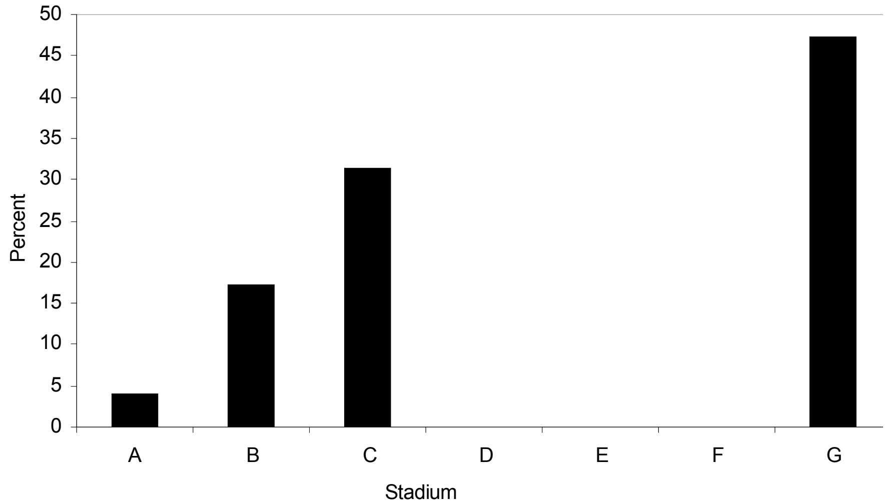
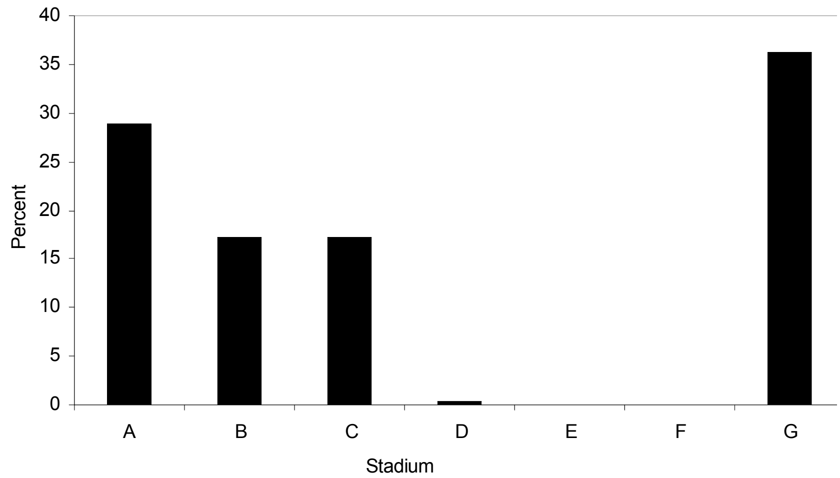


FIGURE 46

Frequency of occurrence of each maturity stage for *Centroscymnus coelolepis* females from ICES areas VIb and XII (Hatton Bank) in June 2000



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Workshop on Marine Bioprospecting

Synopsis

The objective of this Workshop was to identify and discuss the nature of current activities, including sustainability, limits to growth, timelines, regulatory requirements and potential environmental consequences. The programme and participants are listed in FAO (2005) together with a more comprehensive meeting summary.

The Workshop addressed a number of important pre-identified questions.

Biological Research & Technology:

i. Why conduct bioprospecting in the high seas?
ii. What is happening now and what are the prospects for the future?
iii. What are the bioresource and biotechnological spin-offs from bioprospecting?
iv. What new or adaptive technology exists?
v.To what extent are technology and cost-limiting factors to the growth of high seas bioprospecting?

Industry:

i. How do the downstream processes following sample collection work (including technology, time, cost, intellectual property, etc)?
ii. Who is bioprospecting, where, in collaboration with whom and how are these partnerships achieved and managed?

Law & Policy:

i. What are the jurisdictional issues (state, multinational companies, nationals, vessel flag state, etc.)?
ii. What is the legal status of the activity of "sample collection" (a) in the water column? (b) in the top layer of seabed sediment? and (c), from a sediment core.
iii. Is high seas bioprospecting in need of further regulation, i.e. is the existing regime adequate?
iv. How do intellectual property laws interact with other laws relating to bioprospecting on the high seas? Is the balance appropriate?
v. What states have policies on high seas bioprospecting?

In this context the workshop examined existing policies and their use as exemplars for others.

There were divergent interpretations of the terms “bioprospecting” and “high seas” and it found important to define how the terms were used. It was noted that there is already considerable bio-discovery in high seas areas with the potential to expand and yield valuable products. However, marine research is expensive and technological challenges limit the industry. Except in general terms, high-seas bio-discovery and bioprospecting are unregulated with no clear legal regime for management, benefit sharing (who "owns" the resources?) and access.

There appeared to be no evidence that bio-discovery and bioprospecting have greater impact on the marine environment than any other marine scientific research and fishing and mining appear to have a greater effect. The need for regionally and globally consistent approaches to access and benefits, sustainable sample collection and environmental impact assessment were identified. It was concluded that the high seas are a global commons and its biodiversity could be considered a "common heritage of mankind".

Bioprospecting in the high seas – Summary

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A group of experts met at the University of Otago, Dunedin, New Zealand, 27–29 November 2003 to discuss bioprospecting in the high seas. The objective of the meeting was to identify and discuss the nature of current activities, including sustainability, limits to growth, timelines, regulatory requirements and potential environmental consequences.

1. OVERVIEW OF PRESENTATIONS

1.1 Science

Research scientists working on sponges, microorganisms and fish gave an overview of their experiences with regard to sample collection, laboratory investigation, findings and knowledge of the bioprospecting industry.

The group heard that the oceans are the largest ecosystems on earth with immense biodiversity already known and thousands of new species being discovered as marine scientific research intensifies. Novel marine biodiversity is concentrated most specifically in four areas or *hot spots*: coral and temperate reefs, seamounts, hydrothermal vents and abyssal slopes and plains. These concentrations of biodiversity are largely untouched, despite being highly sought after by scientists, governments and companies that have speculated about the immeasurable pharmaceutical potential of novel structures. However, each of the *hot spots* also has idiosyncrasies that make them particularly vulnerable to other ocean uses such as trawl fishing.

Case studies of work in progress highlighted the nature of some current activities. A compound, IPL576,092, based on the sponge steroid *contignasterol* completed US Phase I trials as an asthma drug in 2000. Cytotoxins from deep-water sponges found on the Chatham Rise 400 km off the New Zealand coast are also under investigation. Other work in progress involves the *Conus* venoms (the source of the first of the modern marine-based drugs and cytotoxic organic extracts); cold adapted enzymes from deep-sea microbial extremophiles in the Southern Ocean and deep-sea extreme environments such as hydrothermal vents; and genes for "anti-freeze" proteins from fish (Southern Ocean). The difficulties with assay and the long time frame of investigation of potential leads were explained. In the case of fish proteins, for example, it was noted that the proteins could be replicated from genetically modified organisms and did not require the direct harvesting of fish. In a similar fashion, most bacteria can be cultured. Sponges have historically been harvested, but it is also possible to culture them under certain conditions in a natural environment.

Potential applications from marine-sourced material include:

- Pharmaceuticals
- Enzymes
- Cryoprotectants
- Cosmaceuticals
- Fine chemicals
- Agrichemicals
- Bioremediators
- Nutraceuticals.

1.2 Industry

A study of small-molecule new chemicals introduced globally as drugs between 1981–2002 showed that 61 per cent can be traced to, or were inspired by, natural products (Newman, Cragg and Snader 2003). This figure rose to 80 per cent in the year 2002–2003. Compounds from natural products are considered to be more agreeable to consumers and two-thirds of the anti-cancer drugs, for example, are derived from both terrestrial and marine natural products. Marine-sourced material (e.g. from sea water and marine sediments) has a higher chance of a successful commercial ‘hit’ because of its mega-diversity (using the assumption: samples x biodiversity x assays = probability of a hit).

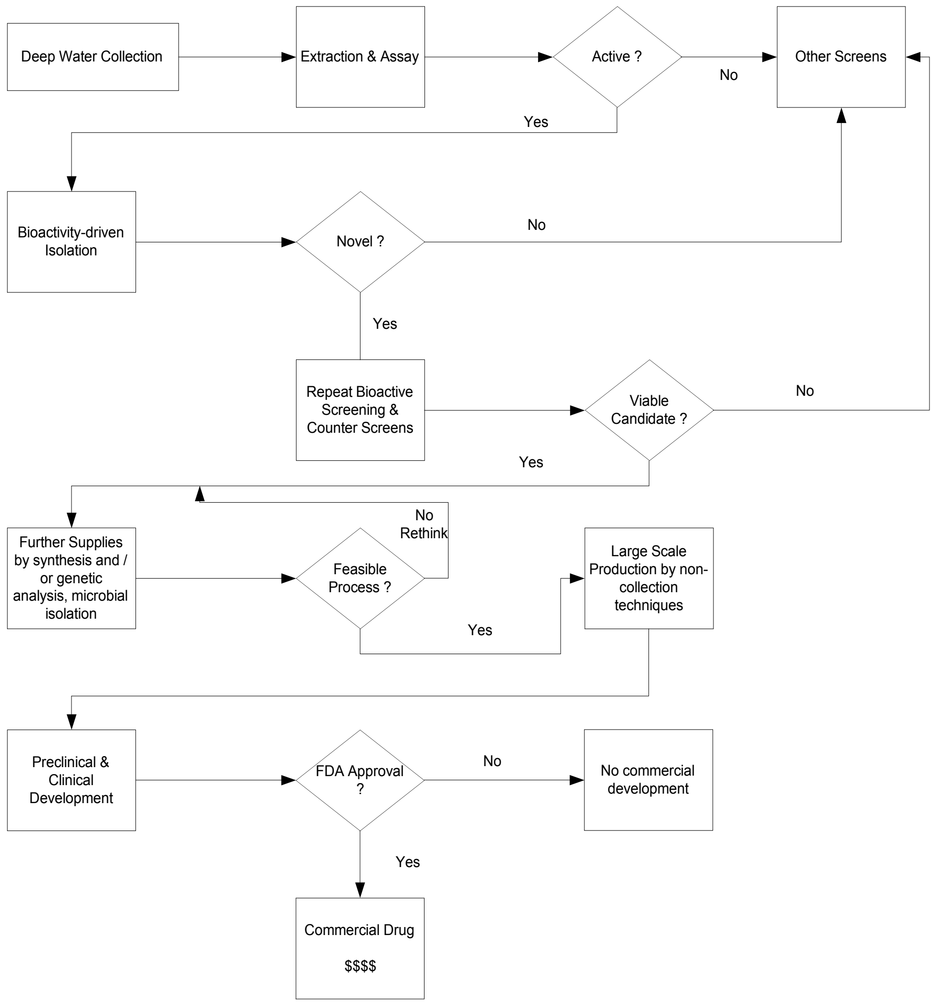
The USA National Cancer Institute (NCI) was one of the first organisations to begin systematic large scale collection of marine invertebrates and in the mid–1980s formal collection programmes were initiated to protect access to the original material (Newman, Cragg and Snader 2003). The cost of sample collection, laboratory investigation and further downstream processing is high, and there is only an estimated 1:50 chance of successfully producing a marketable product beyond a pre-clinical lead. For example, one kilogram of shallow water marine invertebrate collected, prepared for sampling, identified and transported costs approximately US$1 000 a sample. From the one-kilogram sample, only approximately 20–50 g of liquid and 4–15 g of organic material will be extracted, costing approximately US$200 a sample. Subsequent testing (in the 60 cell line screen, for example) may cost as much as US$300 a sample. If all associated costs (laboratory staff and equipment) are included, the total rises to tens of thousands of dollars a sample. However, only about 10 per cent of samples are eventually determined to be 'active'. These figures refer to shallow water collections (Newman, Cragg and Snader 2003).

Sampling from shallow water is economically more viable than from the deep-sea, from which specimens may be difficult to retrieve. Early NCI collection programmes used submersibles and remote operated vehicles (ROV), but the cost was too high and their deep-sea programme was suspended. Others have had more success. Harbour Branch Oceanographic Institution uses manned submersibles and has successfully synthesized a molecule, *discodermolide*, from a previously undescribed deep-sea sponge. Another compound, *halichondrin B*, has also been isolated from a sponge species by a New Zealand joint venture. In the latter case, one tonne of sponge was harvested that yielded 300 mg of pure *halichondrin B*. This process cost approximately US$500 000 (Newman, Cragg and Snader 2003). The scheme shown in Figure 1 represents the NCI approach to the processes of biological prospecting.

It is important to note that current US legislation prohibits government institutions from "encumbering a future invention" (Newman, Cragg and Snader 2003) therefore in terms of sharing benefits, they are prohibited from entering into royalty agreements in the phases of sample collection and testing. This may bring the government institutions into contravention of the Convention on Biological Diversity (CBD) if the US Government ratifies it. NCI approaches benefit sharing in a novel way, it began prior to the CBD, but in many ways in conformity with the principles contained therein. It involves a 'letter of collection' agreement, which requires absolutely that any licencee of an NCI patent must involve the country of origin in the further development of the compound (Newman, Cragg and Snader 2003). Despite the argument that the acts of collection and routine testing of extracts are not inventions in themselves, institutions such as NCI cannot infringe US law by collecting in some countries where the CBD

FIGURE 1

NCI schema of bioprospecting process (from Newman and Crag 2005)



(and its royalty provisions) would apply. Another significant point is the fact that no sample collected by an NCI collector may be analysed by other researchers.

Ongoing access to material (i.e. because it cannot be replicated in a laboratory or because further samples are sought) is of primary importance. Aquaculture and mariculture have both been used successfully in some cases (e.g. shallow-water sponges).

Industry presentations at the Workshop placed great emphasis on the odds of success, with a figure of approximately only one to two percent of preclinical candidates actually becoming commercially produced.

1.3 Law and policy

Presentations were made giving an overview of international law and international obligations, protecting the biodiversity of hydrothermal vents and the unique situation in the Southern Ocean. Relevant laws include intellectual property laws, environmental protection and biodiversity conservation laws, the United Nations Convention on the Law of the Sea (LOSC) and Antarctic-specific laws.

It was noted regarding patentable inventions (i.e. products and processes that provide a technical solution to a technical problem) that patenting involves elements of novelty, an inventive step and industrial applicability (or utility, i.e. it can be commercialized). The patenting of living organisms and products of nature is a poorly defined area in the law. While products of nature are currently excluded, even minor modification that introduces the elements noted above may allow patenting to proceed. Patentable biotechnological inventions may include genetically modified plants, animals, and microorganisms, and isolated, synthetically produced, cells, proteins and genes of known function. Important points for discussion were the potential for conflict between sovereign rights over resources and patent rights over inventions; bioprospecting and biopiracy, traditional knowledge and novelty (e.g. does traditional knowledge compromise the element of novelty?); and equitable access and benefit sharing (consistent with the Convention on Biological Diversity but see earlier comments regarding US legislation).

The applicable legal regime, if any, to monitor activities and provide protection and regulation of hydrothermal vents will depend on their location. If the vents are located within territorial waters and exclusive economic zones (EEZs), coastal state jurisdiction prevails over access to, and use of, genetic resources. If they are located on the continental shelf beyond the EEZ, the coastal state can only regulate access to sedentary species. If hydrothermal vents are located outside national jurisdiction, access is largely open and unregulated except where states regulate the activities of their nationals, consistent with the Convention on Biological Diversity and other international law (Leary 2005). Discussion ranged across broad areas of potential international regulation, including expanding the mandate of the International Seabed Authority to include the superjacent waters above the area.

It was acknowledged that the Southern Ocean is a special case because of the overlap of international law and Antarctic-specific law as well as the unproven nature of sovereignty over the continent and, thus, the marine areas. This complex case highlights how the traditional freedoms of the sea have been modified in the Antarctic. A regional fishery body – the Commission for the Conservation of Antarctic Marine Living Resources – regulates the conservation and rational use of all Antarctic marine living resources (but excluding whales and seals). Furthermore, an environmental protocol – the Madrid Protocol to the Antarctic Treaty – requires environmental evaluation of all activities in the Antarctic Treaty Area (i.e. south of 60° South) prior to the operation being undertaken. Activities in this case include marine scientific research. The initial phase of bioprospecting (sample collection) would be unlikely to breach either of these arrangements, but large-scale collection through harvesting would require closer scrutiny.

Consideration was also given to the Southern Ocean as a global commons and its resources, the "common heritage of mankind", not unlike the situation with the deep-sea bed of the high seas.

1.4 Case studies

The first case study described the extent of some of the leads discovered by one institution – the Australian Institute of Marine Science (AIMS). The collection housed by AIMS includes 10 000 species of marine bacteria, fungi and microalgae and 12 000 species of invertebrate macroorganisms. The presentation also introduced new terminology and a new concept: a dichotomy between *biodiscovery* (primary collection to find leads) and *bioprospecting* (looking for more of the lead material – re-collection).

Biodiscovery was considered to have the following practical applications in addition to the ones listed above: seafood toxin testing, antifoulants, bioremediation, environmental monitoring and as research tools. The latter is a lucrative application with some marine natural products valued extremely highly, e.g. Neosaxitoxin derived *inter alia* from dinoflagellates, blue-green algae and toxic shellfish is valued at US$21 400 per milligram. In terms of supply, however, AIMS (citing Garson 1994) noted the following quantities of original material required to yield relative quantities of lead material.

Original material	Quantity yielded
450 kg acorn worms	1 mg cephalostatin
1 600 kg sea hares	10 mg dolastatin
2 400 kg sponge	<1 mg spongistatin
847 kg moray eel livers	.35 mg ciguatoxin

This table highlights the importance of sustainable methods of wild harvest, chemical synthesis, aquaculture, cell and tissue culture and genetic splicing.

The AIMS presentation also considered Australian policy. Prior to 1994 the AIMS collections were undertaken in conformity with a scientific research permit and no benefit sharing was applied. Subsequent collections were subject to new permit conditions, which meant that new permits became more difficult to obtain in some jurisdictions and doubt was cast over the legal certainty of some existing collections. In addition, permit conditions restricted use. Benefit sharing also became difficult with questions arising about a lack of process and legislative basis, who should be beneficiaries and what exactly are the benefits? As a result, AIMS put in place best practice guidelines on these issues. In addition, the Queensland government (the Australian state in which AIMS is located) is introducing a Biodiscovery Bill into Parliament, which will provide greater clarity as to the legal obligations in this area.

The presentation on environmental aspects of bioprospecting acknowledged that many agencies expect environmental impact to occur with bioprospecting activities because historically, extracting resources from the oceans (especially fishing) has had environmental consequences. Conversely, the proponents would be inclined to see bioprospecting as posing no, or only slight, risk to the environment. It is likely that the proponents see their activities this way, e.g. because they are comparing their level of activity with hyper-extractive fishing. It was considered, however, that this generation of bioprospectors represent only the artisanal stage of the activity. All human activities related to ocean usage have impact. Those relating to bioprospecting will be relative to the location; the modes of transport, support and sample retrieval; the discard of unwanted material; and the nature of the target (i.e. compare microorganisms with fish). It was noted that the presumption that extraction of target taxa will have a negligible impact is only a presumption.

There are considerable legal obligations arising from, *inter alia*, the LOSC and CBD for the protection and preservation of the marine environment, including the conducting of environmental evaluation of proposed activities. The final message from the Workshop was that the juridical situation is complex and is still evolving.

2. CRITICAL POINTS AND CONCLUSIONS EMERGING FROM GENERAL DISCUSSION

2.1 Definitions

It became apparent from the outset that there were divergent interpretations of the critical words "bioprospecting" and "high seas" and, therefore, it was important to define the way in which the terms were used throughout the meeting.

- "High seas" was used in terms of LOSC definition, i.e. maritime areas "outside national jurisdiction". The group also included "the Area" (i.e. the deep-sea bed) and the sub-sea biosphere in its discussion. There was considerable discussion about the status of the Southern Ocean. Although there are similarities between the Southern Ocean and other high-seas areas, the complex legal situation arising from unproven sovereignty means that the Southern Ocean is a special case subject also to the legal regimes established within the Antarctic Treaty System.
- There was no universally agreed definition of "bioprospecting", rather it was viewed as a broad concept embracing a number of phases of research that investigate a region's biodiversity and collect samples of biological organisms. It was suggested that the definition be split into two discrete terms: "biodiscovery", i.e. the first phase of scientific research into a region's biodiversity, and "bioprospecting", i.e. the second and subsequent phases of the re-collection of biological resources for the purposes of further investigation. It was noted that the distinction may, at times, be for expedience only and that the two classes of activity may have, e.g. different objectives, different outcomes, and different requirements for permit conditions and the environmental reporting attached to them.

2.2 Level of activity and future potential

There is already a considerable amount of marine scientific research conducted in high-seas areas, including biodiscovery, and this has the potential to expand into more substantial bioprospecting activities in the future. Biodiscovery activity can be both targeted (e.g. at locations such as hydrothermal vents and seamounts, or at events such as the death and decay of marine mammals) and the serendipitous (e.g. curiosity-driven marine scientific research, bycatch, etc.).

The rich biological diversity of the high seas has the potential to yield biological products of broad ranging applicability. In particular there are unique mega-diverse areas where the biodiversity is relatively untouched. Significantly, the ratio of potentially pharmaceutically useful compounds to compounds screened is higher in marine-sourced materials. There is, therefore, a higher probability of commercial success. However, marine research is expensive and the high cost together with difficult technological challenges of retrieving material from the deep ocean impose significant limitations on the industry.

2.3 Spin-offs

Spin-offs include the dedicated technology that is required to assist in biodiscovery. It is important to note that technology developed from high-seas experiences has much wider application. Bioresource spin offs include:

- contributions to the store of scientific knowledge about previously unexplored regions and taxa and
- identification of biodiversity 'hot spots' with new information contributing to the implementation of better management strategies.

2.4 Legal status

Except in the general terms prescribed in the LOSC and the CBD, biodiscovery and bioprospecting in the high seas are largely unregulated. Specifically there is no clear legal regime for:

- environmental management
- benefit sharing (who "owns" the resources?) and
- access.

Patenting is the main avenue for securing economic benefit as a return for investment. But there is a dividing line between biodiscovery, bioprospecting and the requirement to share benefits from commercialisation.

2.5 Environmental vulnerability

There is at present no evidence that biodiscovery and bioprospecting are having any greater impact on the marine environment than any other form of marine scientific research. Currently there are greater threats to high-seas biodiversity from other activities such as various technical aspects of fishing and mining. However, a precautionary approach was agreed as necessary.

3. CONCLUDING REMARKS

In conclusion, three ways forward were advanced.

i. The approach to conditions for access and benefit sharing must be regionally and globally consistent.

ii. Sample collection and associated activities must be sustainable and subject to environmental impact assessment.

iii. In lieu of economic benefit sharing, access to data, scientific knowledge and information that reveals intrinsic values may be considered appropriate alternatives.

The high seas is a global commons and it was considered that its biodiversity could, therefore, be considered “common heritage of mankind” in similar fashion to the mineral resources of the deep-sea bed.

4. ACKNOWLEDGEMENTS

This work was supported by the Australian Government's Cooperative Research Centres Programme through the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) and the University of Tasmania's Institute of Antarctic and Southern Ocean Studies, Centre for Law and Genetics and Tasmanian Institute of Agricultural Research.

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Programme abstracts

BIODIVERSITY, BIOPROSPECTING AND THE HIGH SEAS

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Loosely defined biodiversity is “the variety of species and ecosystems in any given area” and is a measure of the abundance of life at that site. When biodiversity is coupled with research that is looking for a useful application or product from nature the term bioprospecting is often used. Typically, bioprospecting is a search for useful organic compounds from microorganisms, fungi and terrestrial and marine macroorganisms. Bioprospecting is nothing new. In fact, people have been bioprospecting since the dawn of civilization. Much of the bioprospecting that is taking place in the marine environment is focused on discovery of pharmaceuticals. But, is this the best way to discover new pharmacueuticals? Three methods are used: the traditional approach based on natural products (bioprospecting), the empirical approach based on rational design and more recently the molecular approach based on the better understanding now possible of the molecular target. Each approach has its strengths and weaknesses and each has found favour from time to time.

The role and the strengths of the biodiversity approach to drug discovery will be addressed and illustrated with relevant examples including current work on drug discovery from Antarctic organisms.

MICROBIAL BIOPROSPECTING IN THE HIGH SEAS THE PROSPECTS FROM HOT TO COLD

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Microbial bioprospecting may be considered as the search for valuable chemical compounds and genetic material from microorganisms. In the High Seas, those areas falling outside zones of exclusive economic interest, microbial communities exist in both the free oceanic environment, the deep ocean and sediment. This presentation will address the case of bioprospecting from both bacterial and archaeal communities (prokaryotes) from deep-sea ecosystems. In global oceanic waters below 200m, prokaryotic abundance is estimated at 6.5×10^{28} cells. The large population size of prokaryotes may imply that events considered as relatively rare (e.g. genetic mutations) could occur relatively frequently. Hence marine prokaryotes have a large potential to accumulate unique genetic and metabolic diversity. Two specific examples where this appears to be the case are: 1. abyssal sediments which harbour bacterial populations highly adapted to low temperature and high pressure 2. hydrothermal vents which harbour prokaryotic populations adapted to high temperature and unique energy metabolism. Examples of bioprospecting from these habitats will be discussed and potential biotechnological outcomes highlighted.

SOUTHERN OCEAN BIOPROSPECTING

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The extreme Antarctic environment has led to the evolution of a range of novel physiological adaptations in the local biological species, drawing bioprospectors to the region. Indigenous microorganisms, bacteria, krill and fish are all seen as potentially rich sources of raw material for the pharmaceutical industry, for example. However, the Antarctic is not a “normal” place. Nobody “owns” the continent, although seven countries, including Australia and New Zealand, claim parts of it. Nevertheless, the whole of the Southern Ocean is considered high seas. The “government” consists of a group of 45 countries that have ratified the Antarctic Treaty. There is no indigenous population and therefore no indigenous knowledge or folk-lore to protect. This situation raises questions of a very different kind; notwithstanding, Antarctica and the Southern Ocean are possibly more interesting than they are contentious, at this stage in the development of bioprospecting industries in the region. However, it is likely that the Treaty Parties will want to address the possibility that in the future the bioprospecting industries will pay more serious attention to the living resources of the region than they do now. Because the Parties already regulate all marine living resources activity, they may also decide to regulate bioprospecting.

PLUMBING THE DEPTHS OF MARINE BIODISCOVERY

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Can we have it all: drugs and other products from the deep sea, royalties, ownership, international investment, sustainability, and conservation outcomes? The answer is an emphatic Yes! if we heed some of the legislative and policy progress made in recent times associated with biodiscovery. Advances in areas such as access and benefit sharing policy linked to state and federal legislation and the CBD; clarity of jurisdictional responsibility; streamlining environmental compliance while permitting biodiscovery; non-exclusivity; and stakeholder identification, can provide a blueprint for the future. The glue that binds this, is robust science.

Drawing on recent, albeit continental shelf, examples of biodiscovery research activities from around Australia and New Zealand we will describe how national and international industrial investment and success can be harnessed in harmony with sound biodiscovery ethic and beneficial return to the country, state and/or region of origin of any biochemical discovery. We will describe why rigorous scientific strategies, at the earliest stages of discovery, are essential to successful commercialisation and conservation of resources.

ENVIRONMENTAL IMPACTS AND HIGH SEAS BIOPROSPECTING

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Compared with historic and contemporary levels and types of harvesting on the high seas, bioprospecting may be seen as posing no, or far less, environmental risk. This may or may not be true – the present state of development of the activity makes it too early to know. But human attitudes to, and the environmental consequences of, exploitation of the high seas have usually been problematical. History in this area hardly offers reassurance. It is therefore appropriate to consider the potential to create adverse environmental impact through bioprospecting activity and this paper offers a preliminary examination of some of the issues.

These include a background of standards and expectations of environmental protection in the marine environment almost everywhere lower, and environmental management regimes less developed, than in terrestrial environments. That standard tool of scrutiny, the Environmental Impact Assessment, is not evident in the marine environment. The least developed regulatory system in the marine environment is that applying to the high seas. We still have only limited scientific knowledge about ecosystem functioning and particular taxa in this area. The basis for modern governance of the high seas, UNCLOS and associated instruments, essentially predate the emergence of bioprospecting as a viable activity, and reflect the norms of the 1970s.

The possible economic benefits of bioprospecting, and the likely relative high costs of acquiring those benefits, will occur in a poorly developed but complex international legal and policy context. This may pose challenges to wise management of any environmental impacts arising through bioprospecting.

BIOPROSPECTING FROM POLAR FISH

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Will polar fishes be the source of interesting and unusual proteins for applications? It is well known that most Antarctic fishes have so-called "antifreeze" proteins in their blood to stop them from freezing in the sub-zero temperatures. Only very small numbers of these fish are currently being sacrificed for scientific study of the proteins and their method of action. Many possible uses have been suggested for the novel, ice-active properties of these proteins, including preservation of human organs, transgenic salmon, making smoother ice cream, de-icing of airplane wings, making crops frost-tolerant, freezing beef with less drip-loss and many more. Most of these suggestions have been tried to some extent and little success is evident to date.

Biosynthesis of some of the classes of these molecules has been successful and may be scaled up. However, some classes remain elusive and aquaculture or other harvesting of fish to extract proteins from the blood is not impossible.

Higher forms of life living under extreme conditions, such as polar fish, may have other molecules of interest, such as myoglobin and heat shock proteins optimized to work in other than temperate conditions.

THE ROLE OF LAW IN BIOPROSPECTING

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One of the key debates in relation to bioprospecting is the relationship between sovereign rights over biological resources and intellectual property rights in inventions developed from those resources. The Agreement on Trade-related Aspects of Intellectual Property requires that members of the World Trade Organisation must allow patents to be granted for inventions in all areas of technology, aside from a few specific exclusions. At the same time, the Convention on Biological Diversity and Bonn Guidelines establish the principal international legal regime for regulating access to biological resources in areas of national jurisdiction. The situation is more complex in regions of the world where sovereign rights are disputed or absent. One such region is the deep sea bed and another is the Antarctic. In this talk I examine the roles played by the various international legal regimes in these areas, particularly focusing on the interplay between freedom of scientific research and commercially sponsored bioprospecting.

Of themselves, patents may not impinge too greatly on freedom of scientific research, provided that they only claim rights over pharmaceutical and other downstream applications. However, the situation becomes more problematic where patent rights are claimed at the boundary between discoveries and inventions, for such things as genes and proteins. Freedom of scientific research and free exchange of observations and results may be further constrained by confidentiality and non-publication obligations required by commercial partners. For these and other reasons, it is timely to examine the need for regulation of bioprospecting in areas outside national jurisdiction.

Political, legal, scientific and financial aspects of marine biodiscovery programmes

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1. THE NATIONAL CANCER INSTITUTE (NCI) COLLECTION PROGRAMMES

The NCI has had a programme for over 35 years that is designed to investigate the potential of Mother Nature's pharmacopoeia as a source of antitumor and, for a significant time, anti-HIV agents. The original collections, which could be best described as being "opportunity-based", were made by various groups of botanists, marine biologists and microbiologists as they saw fit. Thus the plant collections that led to the discovery of paclitaxel (Taxol®) and camptothecin were made by USDA botanists as part of a programme of economic botany and resulted totally as a matter of happenstance. In a similar fashion, the marine invertebrates were collected as bycatch in some cases and by small collection programmes in others and the microbial samples were either from pharmaceutical houses who wanted their fermentations checked for anti-tumor activity or were simply "cupboard cleaning" of assembled extracts and organisms when programmes altered course in pharmaceutical houses.

The NCI offered screening in animals and the ability to follow activities in cell lines derived from the animals (originally mouse leukemia lines), which then developed into screening against mouse lines and follow-up in immunologically compromised mice with implanted human cell lines. From these relatively simple screens the vast majority of the well known agents (the *Vinca* alkaoids, the anthracyclines, bleomycin, etc.) were discovered and developed further.

However, by the late 1970s to the early 1980s it was realized in 20/20 hind sight that the agents now in use were active against fast growing tumors, but not as potent against the solid tumors, which was not surprising when one realized that the test systems were themselves fast-growing cell lines, the leukemias. Thus, there was an element of "shoot the messengers" and stop the natural product collection and assay programmes. So for around five years, no direct NCI collections were made. It should be pointed out that these collections were all made under the then current world political, social and governmental systems that did not consider any "rights" of the producing countries.

In the years between 1981 and 1986, one man, Michael Boyd, a physician and pharmacologist at the NCI, had the idea that if the assay systems could be modified to look for selectivity against a tumor type in a non-animal model as the primary screen, and followed up with suitable animal models utilizing the same cell lines as xenografts in *nu nu* or SCID mice, then one should be able to screen only compounds that demonstrated a "biochemical selectivity" from the beginning.

It took over four years to finalize the process and to develop the original NCI 60 cell line screen as a (then) high throughput assay that would permit both the screening of synthetic compounds, and most importantly, natural product extracts from all sources. Luckily, Michael Boyd was (and still is) a proponent of natural product sources as a source of test agents for antitumor use. It did not hurt that at the time that this screening system was coming on line, that paclitaxel was demonstrating its unique mechanism of action and potential utility in ovarian cancer and that derivatives of camptothecin were also demonstrating activity in pre- and early clinical trials.

At the same time (middle 1980s), the Developmental Therapeutics Programme of the NCI (which Boyd led), began the process of setting up formal collection programmes in marine and plant areas, together with small programmes looking at cyanobacteria and other sources such as fungi, micro, and macroalgae that could be cultivated. The fundamental reason for the formal collection process (and it applied to all collections that occurred thereafter) was that we had learned from our earlier programme, in particular the collection that led to paclitaxel, that we had to be able to generate enough of the initial extract to be able to follow through to chemical identity from the original sample. This was particularly evident in the earlier studies with the bryostatins, interesting agents isolated from certain "strains" of *Bugula neritina* in vanishingly small amounts, and was replicated in the studies with the dolastatins, isolated originally from the nudibranch, *Dolabella auricularia*.

Thus, NCI set up a series of competitive collection contracts that required the collection, taxonomic identification, site identity and suitable photographs of all samples of marine invertebrates (initially between the tropics), with concomitant processes for terrestrial plants. These samples would then be shipped to NCI, processed and screened, using the 60 cell line assay. If of interest, the compound(s) then would be isolated using bioactivity-driven isolation processes and then further investigated.

2. THE NCI'S LETTER OF COLLECTION

At the same time that the collection programmes were announced as being open for competition, NCI started to consider what could be done to persuade countries to permit what would now be large-scale collecting programmes operating on their lands and, or, from their seas. From these discussions within NCI, and also involving some source country personnel, the first NCI Letter of Collection (LOC) was formulated and signed by Madagascar in 1989. This was a full three years before the Convention on Biodiversity (CBD) and the LOC had as part of its non-negotiable requirement, that a "best effort" should be made to make certain that any company or organization that licensed any product from an NCI collection would have to involve the source country in the further development of that agent.

Over the years, with significant input from countries with extensive biodiversity (in particular, the State of Sarawak in Malaysia), the document has been refined and now, fifteen years after the first agreement was signed, the document has an absolute requirement that any licensee of an NCI patent must involve the country of origin it the further development of the compound.

There is one major difference between the LOC and the CBD. The CBD implies that royalty statements should be made when permission is granted for collections and this particular statement has led to major differences in perception between the collectors and the countries. We often use the term "green gold" to denote the misunderstanding that every collection has a new and very powerful drug within it. Nothing could be further from the truth. In a later section, we will give some odds on a discovery versus the size of the collection.

We, being a US government institution, have yet another problem related to royalties and incorrect perceptions. By US law, we are forbidden from "encumbering a future invention". Or to use the vernacular, "if it ain't been invented yet, we cannot list royalties". Since the simple act of collection is not an invention, and neither is the routine testing of extracts, then to establish a royalty stream in advance would infringe US law. This has caused immense difficulties with some countries, and we have in fact, ceased collections in a number following the CBD and the slight differences between the LOC and the CBD.

Another oft-held perception that is totally incorrect can be expressed as "if it is patented then it will be a drug whose sales will be measured in hundreds of millions of US dollars". Nothing could be further from the truth. What a patent is, is a licence to sue somebody who infringes it, thus protecting your intellectual property, but only if you patent in the country where the infringement is taking place. If you simply go back 10 or so years, and look at the number of patents issued to companies such as Merck, Glaxo SmithKline, Pfizer etc., and then look forward 8 to 10 years at the drugs that have been approved for sale for any disease, you can see the vast disparity between the International Patient (IP) protected drugs and the drugs subsequently developed from these agents and approved for sale. The discrepancy between number of patents approved and drugs approved from those patents is measured in orders of magnitude. However, the perceptions as a result of totally incorrect information often disseminated by the media and some NGOs, still causes major disruption in totally beneficial collection programmes that take into account all of the tenets of the CBD.

3. SHALLOW WATER MARINE COLLECTIONS

The US government, through a variety of funding mechanisms has effectively paid (directly or indirectly) for a substantial number of all marine natural products that are currently in clinical trials, or in the earlier pipeline, for a substantial number of diseases, not just cancer. However, the figures that we will discuss are those from our anticancer and the coincident anti-HIV programme.

If we use current US dollar figures, then the collection of 1 kg wet weight of a marine invertebrate from anywhere on the globe (the programme was expanded to all seas a couple of years ago) consisting of collection, voucher sample preparation, identification, and shipping to NCI-Fredrick is approximately $1000 a sample. From this 1 kg (and we require that better than 75 percent of samples be of this weight), we will obtain around 20–50 g of an aqueous extract and 4–15 g of an organic extract, depending upon the phylum. The cost of extraction and storage at -20^{o} C is ~ $200 a sample initially. Then, depending upon the type of storage container, costs vary.

Subsequent testing of a sample in the 60 cell-line screen in a two-step process is between $30 for those that "fail" and $300 for those that "pass". We usually see around a 10–15 percent pass rate, though in earlier years, the costs were significantly higher due to differences in the prescreen (60 cell lines versus the current three).

The rate-limiting-step in reduction to a compound (and hence a possible inventive step if utility and novelty criteria are met) is the number of chemists and associated biologists that can be assigned to the task. Suffice to say that we are now approaching figures in the many tens of thousand dollars per new compound, particularly when the costs of the associated equipment are included.

We realized many years ago that these collections were an invaluable resource for mankind and in 1991, we began to permit groups outside of the US government to access these materials under strictly controlled conditions. This was originally known as the "Open Repository" programme and used only those extracts that we had decided did not show utility in our screens. However, they could and did, show activity in other screens with different *modus operandi.* All recipients had to agree, *a priori*, and in writing that if anything commercially valuable came from their work, the country of origin must be involved in its development, and most importantly, that the raw material should come from their waters (lands). We also notified countries that their materials were tested but in a way that did not infringe on IP rights. There was also one other important requirement. If the recipient needed more material, then they had to negotiate with the source country for permission to recollect. At this stage, not being the US government, the recipient could write royalty statements.

This programme was successful and from the middle of 1996, the programme was expanded to include the approximately 10 percent of samples that were in the "Active" category. Subsequently, the requirements were significantly relaxed as to who could receive materials and now they can be used for investigating any disease of interest to the NIH and foreign investigators are also permitted to access materials. These are all provided simply for the payment of the cost of shipping though there are restrictions on the number of samples that can be held at any one time depending upon their initial activity in the NCI screen.

There were two important tenets that we invoked from the beginning. The first was that if the source country wished, they could have access to the extracts from materials collected in their waters and lands. There have been materials sent back to some countries where they have the technical capabilities to screen and isolate materials. Secondly, we also have a clause that permits suitably trained scientists from the source countries to come to the US at NCI's expense for up to one year to learn the processes involved, and if they prefer, to work not only at NCI but at other laboratories in the US where they may learn different techniques.

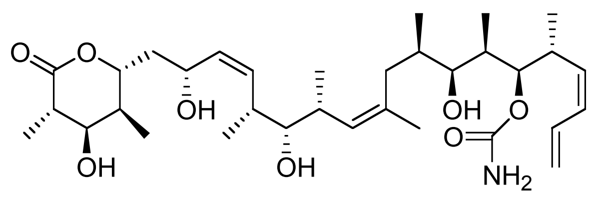
4. DEEPER WATER COLLECTIONS

In the early collection programme, we had a "deepwater collection" system whereby manned submersibles and also some remote-operated vehicles (ROV-based) collections were made. However, these turned out to be extremely expensive and were mutually discontinued after about 15 months. Subsequently, we have permitted some dredging sub-programmes usually as a part of a bycatch opportunity when we know that we can go back if necessary. These are almost always performed in a particular country's EEZ. We have also had some experimental collections to 100-120 m using mixed gas rebreathers in Palau and a successful demonstration of the use of the "Deep Rover" one-man submersible, again in Palau, where due to the safety considerations of only having access to one submersible, a 400 m limit tether was used. The cost of these particular experiments was absorbed in the overall collection programme .

To give an idea of the costs involved in manned submersible work (and these are from a few years ago). The Harbor Branch Oceanographic Institutions (HBOI) charges used to be around \$12 000 a day for ship transit time, plus ~\$4 500 a day for diving with the submersible. This would approximate to one major dive (or two shallower ones) for around 4-5 hours of collection time. Since a significant part of the cost of diving in the tropics away from their base in Florida would be actual transit time, one can perhaps understand why a large amount of the collection work by HBOI is in the Caribbean, which is on their front door step.

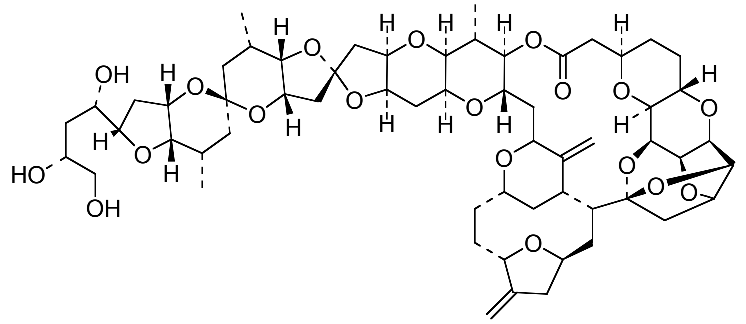
However, the use of submersibles of one type or another has led to discoveries that have significant drug potential. Thus, the HBOI were able to isolate the interesting molecule, discodermolide (Figure 1) from the previously undescribed sponge *Discodermia dissolut*, and this compound is now in Phase I clinical trials for cancer because of its similarity in mechanism of action to Taxol® as a drug that "freezes" the microtubule system in tumor cells. We should add however, that discodermolide, unlike Taxol® is now made by total synthesis, a tribute to the skill of the synthetic organic chemist once shown a "chemical mountain to conquer".

FIGURE 1
Discodermolide



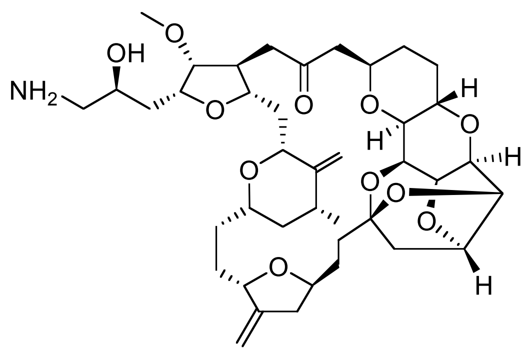
Similarly, the compound known as halichondrin B (Figure 2), which was originally discovered from a shallow water sponge off Japan in small amounts, and then was rediscovered by the University of Canterbury group of Munro and Blunt from a deepwater *Lyssodendorix* sp. off the Kaikoura shelf at >100 metres, was recovered by dredging and following a series of complex political and legal discussions, a joint venture between the University of Canterbury, NIWA (and indirectly the NZ government) with the NCI enabled a tonne of sponge to be collected by dredging, from which 300 mg of pure halichondrin B was recovered by chemical purification. The total costs of this operation were over $500 000 (with 50 percent from the NCI in direct payments to the joint-venture).

FIGURE 2
Halichondrin B



Concomitantly, NCI funded both the synthesis of halichondrin B via its grants mechanism and the aquaculture work performed by Battershill (then at NIWA) on growth in shallow waters. All of these endeavors were successful and have led to the trials of the modified halichondrin, E 7389 (Figure 3) which was developed by Eisai from the synthetic work performed by the NCI-funded group of Kishi at Harvard. No composition of matter patents could be taken out on halichondrin B as the structure had been published previously, but the Eisai company was able to patent the "half-hali" and Harvard had the patent on the synthesis, which was licensed to Eisai.

FIGURE 3
E 7389



5. DRUG DISCOVERY AND MARINE SOURCES

The potential for novel active structures from accessible waters is well documented with many hundreds of publications, particularly the annual reports written by the late John Faulkner for 17 of the past 18 years (and now carried on by a consortia of New Zealand marine natural products chemists led by Blunt and Munro) showing the production of either completely unknown structural classes or of compounds that have striking similarities to those produced by terrestrial microbes. The link between microbes and marine natural products had long been hypothesized by marine natural products chemists and marine microbiologists as the phylum *Porifera*, which has provided close to 50 percent of all reported structures, can be considered to be a solid-state fermentor operating in a saline environment, as in a large number of cases, sponges contain massive amounts of all classes of microbial life.

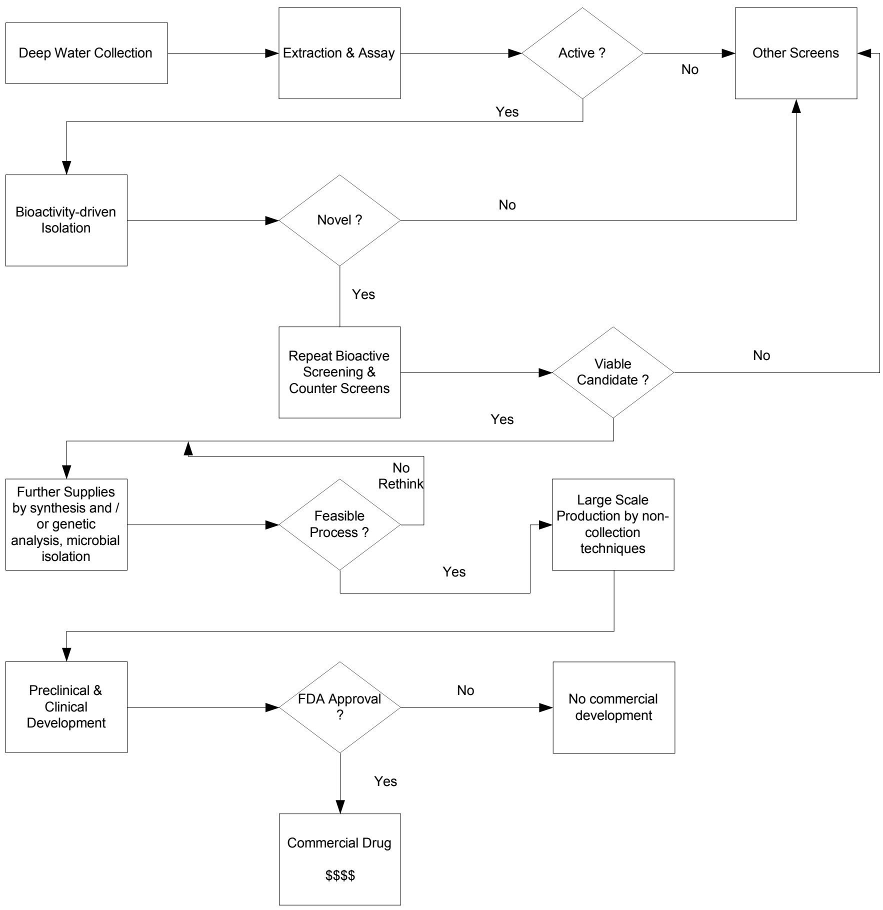
The "smoking gun" was finally discovered by a consortium from the Center for Marine Biotechnology (COMB) in Baltimore and the Pharmacy Department at the University of Mississippi, when work by Hill at COMB on the isolation of a *Micromonospora* from an Indonesian sponge that produced the manzamine alkaloids (well known from a number of sponges) also produced the basic manzamine and a derivative when cultured in some media but did not produce it when cultured in others. The microbe is now being further investigated for the producing gene clusters and the compounds are being developed as anti-tuberculosis compounds at this moment.

The basic problem from this area of science has always been “supply of materials” when a successful structure has been discovered. Initially, the objectives were to produce enough material by aquaculture or mariculture (and this is a successful strategy in a number of cases), and can be utilized in areas of the world where the infrastructure is not optimal for more advanced studies. However, the current paradigm might be expressed as a continuum as shown in Scheme 1.

Thus the marine invertebrate (from whatever depth) is collected, an extract is made and a new, active structure determined. This is a patentable invention as there is novelty and utility, but usually it is not patented at this point as a stronger case can be made if there is *in vivo* data. To obtain enough material for further work in animals and to establish what other pharmacological possibilities there are, one has to consider all types of “production”.

Nowdays, the route is often concurrent with attempts at synthesis (either complete or the putative pharmacophore), investigation of the invertebrate’s microbial flora by both classical isolation and by searching for putative gene clusters that might be involved in the biosynthesis of the metabolite, or potentially cell culture of the invertebrate cells if a suitable line from the source organism can be established. The speed with which synthetic and biosynthetic and genetic experiments can be performed nowdays is orders of magnitude faster than even five years ago.

SCHEME 1
Collection and evaluation process



Examples are in the chemical and biochemical literature almost weekly, so the initial rate- limiting step (of further supply) that significantly held up marine drug discovery in the past is now not as much of a problem; but the real rate limiter is the actual acquisition of enough viable sample to proceed.

6. LEGAL ISSUES OF COLLECTIONS

Shallow water collections (and this could include waters out to the 200 nautical mile EEZ), though usually one only considers territorial waters (12 nautical miles), are easily covered by the NCI's letter of collection or by simple agreements between collectors and the relevant agencies in the country.

When one considers the seabed beyond the EEZ, or even within the EEZ, but at depths below 200 m, then the legal statues are highly debatable. The 1982 Convention on the Law of the Sea (LOSC) has been signed by the vast majority of countries in the world, but the USA is notable in that it has only ratified the LOSC provisions covering migratory fish stocks, though the Department of State did present testimony at the United Nations on 21 November 2001 stating that the Bush administration was recommending acceptance of the modified 1994 agreement on deep seabed mining. Due to the fact that the US Senate must ratify any such agreement, even though the President has signed such a document, as yet, the agreement has not been ratified.

Recently the Department of State has notified US-funded researchers that they need to consider the CBD when collections are being made, particularly from a genetic perspective and they point to the CBD secretariat's website as a source of further information.

Where marine bioprospecting in the deep-sea falls (if it even does) in the LOSC is debatable as it is not deep-sea mining. Only three or four countries have the technical capability to perform such collection programmes, Japan, The Russian Federation, the USA and perhaps France to some extent if one considers manned exploration. Other methods such as ROV explorations and deep dredging with some recovery do not require such levels of technical expertise. However, when it comes to investigation of the samples and then particularly the further development to a drug, there is only one country, the USA, where the government funds materials through to clinical trials (and then only in the case of cancer and AIDS). In all other cases, industrial involvement is necessary and, again, only a few groups can go all the way without involving others.

Thus, the legal waters are indeed deep and cloudy in these respects. Suggestions have been made that if materials are recovered from international waters and ultimately lead to a commercial drug, some form of international trust fund could be set up and administered by a suitable body. However, this suggestion is fraught with political problems, but might be solvable with a minimum of legal entanglements and a maximum of scientific input. For example, a fund that deals with "orphan diseases", such as malaria or tuberculosis and under WHO auspices, might be possible and the CBD has a biodiversity trust fund that is also a possibility, but it would have to be modified as it is "country-biased".

7. CONCLUSION

The search for novel structures that can be used to produce compounds that are active against diseases of interest to man is a laborious process. The marine invertebrates (and their associated microbial flora) have definitely demonstrated their potential to produce novel structures that frequently have no comparison from terrestrial sources. However, it would be remiss of us not to put some form of odds on finding a novel drug. Although one can only do these calculations in their entirety once a drug has become a commercial product, there are enough data in the public domain to be able to make the following generalizations across all disease states.

For every 100 preclinical candidates (defined below), only ten will reach Phase I clinical trials and for every ten that enter clinical trials, one or two will become commercial drugs. A preclinical lead is a compound that has novelty and efficacy and does not effect any biological activity other than the one desired; it can also be produced in sufficient quantity to be tested in the preclinical and clinical processes.

If asked how many compounds and extracts have to be tested to get one preclinical lead, the answer is from greater than 1 000 to less than a 1 000 000 in most cases. These figures are extremely difficult to obtain as they are in the archives of pharmaceutical companies, but from our experience it is usually somewhere in excess of 10 000. Thus the process can best be described as a "numbers game" but with high rewards if one is successful. Obviously, the more screens that a given extract or compound can be assayed in, the better the overall odds of success.

Bioprospecting and the genetic resources of hydrothermal vents on the high seas. What is the existing legal position? Where are we heading and what are our options?

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> *"It's sort of frustrating…Because there's this wonderful world down there, and it's just so hard to get to. It's an inaccessible place nobody ever goes to- so nobody cares, because nobody knows anything about it. It's kind of depressing".*
> G. Richard Harbison, Woods Hole Oceanographic Institute, quoted in Kunzig (2000).

1. INTRODUCTION: FROM SEA MONSTERS TO COMMERCIAL OPPORTUNITY

For many thousands of years humanity's attitude to the deep sea was shaped largely by myth and fuelled by ignorance. Across recorded history, across all cultures and continents, humanity has traditionally characterized the deep sea as an evil foreboding place (Sweeney 1972). Throughout time one word has been used to describe the deep sea more than any other. That word, "resonating with sinister energy" is the "abyss" from the Greek words *a*, without, and *byssos*, bottom – a synonym for dark infinities and primal chaos. It was unknown and unknowable, unconnected to anything remotely human (Broad 1997). It was the home of sea monsters.

While it is a cold and dark place, contrary to popular myth it is a truly beautiful and amazing place. There are no sea monsters, just an amazing diversity of truly ingenious and adaptive life. The deep sea is the largest area of the planet that supports complex life, constituting somewhere between 78.5 percent and 97 percent of the global biosphere (Broad 1997). As such it constitutes the most typical environment and its inhabitants, the typical life forms of planet earth (Gage and Tyler 1991).

As technology has developed so has our understanding of the biodiversity of the deep sea. Increasingly the deep sea, and beyond it the deep biosphere, are of increasing interest to both science and industry. Until recently most bioprospecting[1] in the oceans had been confined to the shallower waters of the coastal and near coastal zones. A lack

[1]There have been many attempts to define 'bioprospecting'. As Jeffery notes all "such definitions denote an activity that involves the search of biodiversity (sometimes termed nature or natural sources) for resources, be they genetic or biochemical or both, for use in purely scientific and or commercial endeavours". This is a useful description for the purposes of this paper (Jeffery 2002).

of knowledge of the biodiversity of the deep sea[2], together with logistical difficulties of working in environments of high pressure and total darkness associated with the deep sea, have meant that bioprospecting in the deep sea was unknown.

A range of biological communities and habitats in the deep sea including hydrothermal vents, deep-sea sediments, methane seeps and even the deepest points in the ocean such as the Mariana Trench (a depth of 11 035 m), are of interest to science and industry alike and have been sampled with an eye to their biotechnology potential.

This paper focuses on one particularly important deep-sea habitat, namely hydrothermal vents or deep-sea hot springs. It examines a number of key questions in relation to bioprospecting at hydrothermal vents and addresses a number of questions on the high seas with a view to making a contribution to the ongoing debate as to whether, if, and how we can or should regulate access to hydrothermal vents on the high seas. It begins by briefly introducing the hydrothermal vent ecosystem. The paper then outlines the nature and extent of bioprospecting and commercial research activity in relation to the genetic resources of hydrothermal vents. Who is this research being carried out by? Is it primarily industry, academia or a combination of both? To what extent has such research been commercialized? What products derived from hydrothermal vent genetic resources are on the market?

The paper then examines the extent to which existing international law regulates bioprospecting at hydrothermal vent sites on the high seas. This includes an examination of the recent Study of the Relationship between the Convention on Biological Diversity (CBD)[3] and the 1982 United Nations Convention on the Law of the Sea (LOSC)[4] with regard to the conservation and sustainable use of genetic resources on the deep seabed. This study was considered at the CBD Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) meeting in Montreal in March 2003. The ongoing work of the International Seabed Authority (ISA) in relation to biodiversity of the deep-sea and hydrothermal vents is also reviewed.

To the extent that there are gaps in the law the paper goes on to consider the need for regulation. In essence why should we bother? Some of these broader issues are introduced in general terms and some alternate sources of relevant law are discussed. Although there are clearly significant gaps in the major treaties, the LOSC and the CBD, it is argued that there are other sources of law that, to a limited extent, have the potential to provide for regulation of bioprospecting and other activities at hydrothermal vent sites on the high seas.

2. THE HYDROTHERMAL VENT ECOSYSTEM

2.1 Formation of hydrothermal vents

More than 100 hydrothermal vent sites have been identified around the world (Ré 2000). The most studied sites are located in the eastern Pacific (principally the East Pacific Rise and the Juan de Fuca, Gorda, and Explorer Ridges) and the north-central Atlantic (principally the Mid-Atlantic Ridge) (Van Dover 2000). Recently hydrothermal vents have been discovered at twelve sites located on the Gakkel Ridge (which runs under the Artic Ocean from north of Greenland to Siberia) (Reuters 2001) and thirteen sites have also been identified within northern waters of New Zealand's

[2]Although several different definitions of the deep sea have been proposed, for present purposes a useful definition is that which has been provided by Butler and Koslow *et al.* (2001) who suggest that the deep sea can be defined as the area beyond the edge of the continental shelf, greater than 200 m in depth, including the continental slopes, continental rises, and abyssal plains as well as topographic features such as seamounts, volcanic ridges and trenches.

[3]Convention on Biological Diversity, Rio de Janeiro, 5 June 1992, entered into force 29 December 1993, 31 I.L.M. (1992).

[4]United Nations Convention on the Law of the Sea, Montego Bay, 10 December, 1982 entered into force 16 November 1994, 21 I.L.M. (1982).

Exclusive Economic Zone (EEZ) (New Zealand Institute of Geological and Nuclear Sciences 2002). Given that the mid-ocean ridges are known to circle the globe for some 75 000 km it is reasonable to speculate that many more, possibly thousands, of hydrothermal vent sites lie hidden below the deep sea, waiting to be discovered. Little work, if any, has been done in the southern oceans close to Antarctica. Given the size of the ridge system associated with the Antarctic and Australian Plates it is reasonable to expect that significant numbers of hydrothermal vent sites lie on, or are adjacent to, the boundaries of these plates.

Hydrothermal vents generally form at mid-oceanic ridges[5] due to interaction of sea water with magma associated with the generation of new lithosphere. They are formed due to the close proximity of heat-laden magma chambers to the seafloor in conjunction with tectonic plate movement, which causes the convective circulation of dense, cold seawater through the cracked and fissured upper portions of the lithosphere (Lutz and Kennish 1993). Sea water penetrates down to the magma chamber and heats up (Ré 2000). The seawater is believed to penetrate to between 1.6 and 2.4 km below the sea floor (Humphris *et al.* (Eds) 1995). Heat transfers from the magma to the water. As the fluid circulates within the crust it interacts with basaltic rock at high temperatures. This causes clay and sulfate minerals to precipitate from the seawater resulting in a modified fluid with little to no magnesium or sulphate. As temperatures increase metals, silica and sulfide are leached from the rock, resulting in a hot, acidic fluid rich in silica, hydrogen, sulfide and metals relative to seawater (Tivey 1991).

Due to intense pressure on the deep ocean floor the temperature of the fluid can be as high as 350°C without boiling. At such an extreme temperature the water is buoyant and when it finds a path through the sea floor it rises rapidly to the surface of the ocean floor (Tivey 1991). As the fluid exits, it passes from the seafloor to the surrounding seawater at high velocity. The mixing of the fluid with the surrounding seawater causes changes in pH and temperature and the precipitation of minerals (Tivey 1991). Sulphide minerals crystallize onto the volcanic rocks forming a columnar chimney-like structure on the fissure (Ré 2000). At the same time fine-grained sulfide and oxide minerals precipitate from the resulting solution, appearing as black smoke (Tivey 1991). Hence these columnar chimney structures are often called "black smokers" (Van Dover 2000).

Although columnar chimney black-smoker forms are common, not all hydrothermal vents fit this description. Apart from black smokers, complex sulphide mounds are perhaps the most impressive form of hydrothermal vent structure. These are typically huge structures, often towering metres above the adjacent ridge axis. Examples include several located at the Endeavour hydrothermal field on the Juan de Fuca Ridge. These are freestanding sulphide mounds 10 – 30 m in diameter and up to 40 m or more in height. One such mound known as "Godzilla", because of its height, towers some 45 m above the ocean floor. These huge structures also typically have multiple black smoker chimneys projecting from them (Van Dover 2000).

There are several other variations of morphology and mineral composition, including white smokers, beehives, flanges and massive sulfide deposits. Massive in a geological sense means material made up entirely of sulphide minerals. The term massive does not

[5]Some sites have also been identified at back-arc and fore-arc spreading centres. Back-arc spreading centres form behind island arcs where old lithosphere is subducted beneath a continental plate moving in the same direction. The sinking slab [sic] of lithosphere pulls on the edge of the overlying plate splitting it open and forming a zone of extension. If sufficient heat is generated magma wells up in this zone, providing the heat source required for the formation of hydrothermal vents. Hydrothermal vents have also been found associated with seamounts. This occurs where there is sufficient heat and porosity to drive hydrothermal convection. Similarly they have been found in the centre of plates where there are active submarine volcanoes. Several sites have also been found associated with areas of high sediment deposition including those in the Guaynas Basin in the Gulf of California, Middle Valley of the Juan de Fuca Ridge and in the Escanaba Trough of the Gorda Ridge (Van Dover 2000).

refer to the size or volume of such a deposit. As such, a small-black smoker chimney can be a massive sulphide deposit (Van Dover 2000).

2.2 A species-rich ecosystem

The deep sea is a species rich environment, although many of these species are spread over amongst the vast expanse of the soft sediments of the sea floor (Butler *et al.* 2001). In contrast to the sparsely populated soft-sediments of other areas of the deep sea, hydrothermal vents have been found to literally teem with life (Van Dover 2000), hosting one of the highest levels of animal abundance on earth (WWF & IUCN 2001), as well as one of the highest levels of microbial diversity on earth (Dept of Fisheries and Ocean Canada 2001). It is hardly surprising, therefore, that terms such as "oases of the abyss" (Ré 2000), the "Oceanic Gardens of Eden" (Allen 2001), and "biological islands"(Baker *et al.* 2001) have been applied to describe these amazing deep-sea communities.

Hydrothermal vents exhibit a unique range of habitat diversity with species so adapted to their particular niches that they are not paralleled at other sites on earth (Baker *et al.* 2001). They support amazingly diverse and rich ecosystems with high levels of biodiversity and high levels of endemism. Of the approximately 500 species discovered around hydrothermal vents to date between 80 percent (Dando and Juniper 2001) to 90 percent (Baker *et al.* 2001) are endemic to hydrothermal vents and new to science.

Three phyla dominate vent fauna and constitute 92 percent of the species identified: molluscs (34 percent), anthropods (35 percent) and annelids (23 percent) (Tunnicliffe, McArthur and McHugh 1998). In addition 32 octopus and fish species have also been observed in and around hydrothermal vents (Baker *et al.* 2001). Other species include giant clams, mussels, the giant tube worm, brachyuran crabs, galatheid crabs, turrid gastropods, limpets, polychaetes, pink bythitid vent fish, barnacles, brittle stars, sea stars, anemones, sponges, soft corals (Lutz and Kennish 1993) and jellyfish (Ballard 2000).

While the total number of new species discovered is high, at individual vent sites local species diversity is typically low with dominance by only a few species. Over 75 percent of vent species occur at only one site (Butler *et al.* 2001). This endemism may mean that species are restricted to individual vent sites. It also appears as if different oceans support quite different biological communities. For example, vent sites in the Atlantic Ocean are characterized by an abundance of shrimp whereas those in the Pacific are dominated by vestimentiferan tubeworms. Few species have been found in more than one ocean (Baker *et al.* 2001).

2.3 The base of the ecosystem: Bacteria and Archaea

The food chain of hydrothermal vent ecosystems is based upon chemosynthetic microbial processes rather than photosynthesis (Baross and Hoffman 1986). In essence it is the geological and geochemical processes responsible for forming the mid-oceanic ridges and hydrothermal vents that provide the food upon which the associated ecosystem thrives.

At hydrothermal vents these microbial forms of life oxidize sulphides, together with other chemicals released from hydrothermal vents, such as hydrogen, iron or manganese. These microbes thus serve as the base of the hydrothermal vent food chain (Prieur, Erauso and Jeanthon 1995). Many of these microbes have formed symbiotic relationships with several other species. Examples of such species include the tubeworms and some species of clams and mussels (Van Dover 2000). The tubeworm, which has no eyes, mouth or digestive tract, relies on these symbiotic bacteria to survive. They absorb oxygen and other inorganic compounds from the water, with the microbes living inside them then using the absorbed compounds for chemosynthesis.

Tubeworms, therefore, are often found just above vent openings clustering in thickets to direct the exiting fluids past their tubes tips (Ballard 2000).

Black smokers are also known to generate plumes that provide an additional distinctive microbial habitat. Plumes are important as zones of chemical reaction between vent fluids and seawater and as habitat and resources for micro-organisms zooplankton. They also have a role to play in dispersal stages of vent biota (Van Dover 2000).

3. BIOPROSPECTING, RESEARCH AND PRODUCT DEVELOPMENT

Biotechnology interest in hydrothermal vents centres mainly on these microbes. It has been suggested that these organisms and their derivatives have a range of applications from molecular biology, to the food processing, fabric and chemical industries. The ability of some of these organisms to survive extreme temperature and other extreme conditions make them prime candidates for research with potential for discovery of new DNA repair mechanisms that could be of use in medicine. In addition, it is suggested that they offer new opportunities in developing biotechnology with beneficial applications in bioremediation (Butler and Koslow 2001).

So far sample collection from hydrothermal vents is exclusively conducted by scientific research institutions. There are numerous national research institutions involved in research in relation to hydrothermal vents. These include the Japan Marine Science and Technology Centre (JAMSTEC), Australia's Commonwealth Scientific Industrial and Research Organisation (CSIRO), Institut français de recherche (IFREMER), the Korean Ocean Research and Development Institute (KORDI), the Woods Hole Oceanographic Institute, and the New Zealand Institute of Geological and Nuclear Sciences to name a few.

Commercial interests gain access to samples either collected through research collaboration with such institutions, or through national culture collections where samples are deposited by research institutions. There are a number of examples of scientific research institutions, universities, and national culture collections that are involved in collaborative research with industry. For example, the Frontier Research programme for extremophiles at JAMSTEC collaborates with industry on the development of biotechnology from extremophiles collected by JAMSTEC through its Bioventure Centre.

There is no substantiated evidence that any company has mounted their own dive to hydrothermal vents for sample collection purposes (as distinct from those in collaboration with scientific research institutions). There is anecdotal evidence, though, that at least one company is planning its own series of dives, independent from any research institution. It is unknown what the purposes of these dives are or indeed whether such dives have taken place (A. Adamczewska, InterRidge Tokyo interview 17 September 2003).

While both the full extent of scientific and commercial research interest in extremophiles from the deep sea (including hydrothermal vents) has not yet been quantified, there is a substantial body of evidence to show strong scientific and commercial interest in relation to the commercial and industrial uses of extremophiles more generally, and hydrothermal vent thermophiles and hyperthermophiles in particular. At a superficial level the interest in this field is clearly demonstrated by the wealth of scientific literature, including a specialized journal **Extremophiles**. In 2003 alone two major international conferences, the 6th International Marine Biotechnology Conference in Chiba, Japan (and its associated satellite symposia Marine Microbes and Extremophiles) (<*http://www.tuat.ac.jp/%7emarine/*>) and Thermophiles 2003 (<*http://www.ex.ac.uk/thermophiles/ welcome.htm*>) considered papers and presentations in relation to marine biotechnology and extremophiles from the deep sea in particular.

Derivatives from thermophiles and hyperthermophiles from sources other than hydrothermal vents, such as terrestrial hot springs, are already utilized in a wide range of industrial processes. Of particular significance have been a number of enzymes useful in industrial processes requiring high temperatures. Examples of some of the known uses of thermophile and hyperthermophile derivatives are listed in Table 1.

TABLE 1
Examples of thermophile and hyperthermophile dervivatives and their applications Adapted from Maloney (2003), Schiraldi and De Rosa, (2002), Aguilar, Ingemansson and Magnien. (1998), Blochl *et al.* (1995), Cowan (1995) and Deming 1998)

Thermophile and hyperthermophile products	Industrial/commercial applications
DNA polymerases	DNA amplification by PCR used in research and diagnostics, especially genetic engineering
Lipases, pullulanases and proteases	Detergents, food processing and waste water treatment
Amylases	Baking and brewing
Xylanases	Paper bleaching, pulp and paper processing
Cellulases	Pulp and paper recycling

Research and product development in similar fields is also under way with respect to hydrothermal vent thermophile and hyperthermophile derivatives. To date research and product development have centred mainly on development of novel enzymes for use in a range of industrial and manufacturing process, and DNA polymerases for use in research and diagnostics. More recently, research has been directed towards pharmaceutical and therapeutic applications such as antifungals.

A least seven biotechnology companies are currently involved in collaboration with research institutions with a view to product development of derivatives of thermophiles and hyperthermophiles from hydrothermal vents. Three of these companies, Diversa Corporation, New England Biolabs Inc., and Invitrogen Corporation already market products derived from hydrothermal vent thermophiles and hyperthermophiles. Other companies are also involved in research in relation to biotechnology involving hydrothermal vents species other than bacteria and archaea. (Table 2).

4. EXISTING POSITION OF HYDROTHERMAL VENTS UNDER INTERNATIONAL LAW

4.1 The 1982 Convention on the Law of the Sea

Two major international treaties are relevant to the legal status of hydrothermal vents and access to their associated genetic resources for bioprospecting, the 1982 Convention of the Law of the Sea (as modified by the 1994 Agreement on the Implementation of Part XI of the LOSC) and the CBD.

The LOSC divides ocean space into a number of jurisdictional zones. For present purposes the most significant zones are the 12 nautical mile territorial sea, the 200 nautical mile EEZ, the Continental Shelf, the High Seas and that portion of the seabed beyond national jurisdiction on the High Seas known as the Area. The Area is defined in Article 1(1) of the LOSC as the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction.

Within the territorial sea, coastal states posses sovereign rights to regulate all access to and exploitation of all resources located within the territorial sea and seabed. Within the EEZ, coastal states possess sovereign rights for the purposes of exploring, exploiting, conserving and managing the natural resources, whether living or non-living, of the waters superjacent to the seabed and its subsoil, and with regard to other activities for the economic exploitation and exploration of the EEZ. Within the EEZ, coastal states also have jurisdiction with respect to, *inter alia*, marine scientific research and the protection and preservation of the marine environment.

TABLE 2

Biotechnology companies involved in research and/or product development in relation to hydrothermal vents: potential applications of ongoing research and products developed and currently on the market

(Information from individual company web sites, annual reports and literature as cited)

Company	Areas of research interest and product development from thermophiles and hyperthermophiles from terrestrial and marine sources and other relevant areas	Products currently on the market developed from hydrothermal vent thermophile or hyperthermophile derivatives
Diversa Corporation *(www.diversa.com)*	Agricultural, chemical processing, industrial and pharmaceutical applications. Especially interested in potential uses of thermophiles in animal feed additives, agricultural product processing enzymes, industrial and consumer product enzymes and high performance specialty chemicals and polymers.	• **Pyrolase™ 160** enzyme, which can be employed in industrial applications at pH 5–9 and at high temperatures.
Innovase LLC (50/50 joint venture of Diversa Corporation and The Dow Chemical Company)	Industrial enzymes including applications such as detergents, starch processing, textile manufacturing, oil and gas production, pulp and paper processing, and the production of baked goods, beer, wine and dairy products. Also investigating applications in water treatment, industrial cleaning and biofilm removal.	
Invitrogen Corporation *(www.invitrogen.com)* Under licence from Diversa Corporation.	Commercialisation of three of Diversa Corporation's thermostable DNA-modifying enzymes.	•**ThermalAce™ DNA** Polymerase, a novel enzyme that improves the performance of DNA amplification for the widely used polymerase chain reaction.
New England Biolabs Inc. *(www.neb.com)*	Restriction endonucleases and other related products for molecular biology research/ recombinant DNA technology	• **Vent$_R$ ® DNA Polymerase** a high-fidelity thermophilic DNA polymerase, which is purified from a strain of *E. coli* that carries the Vent DNA Polymerase gene from the archaea *Thermococcus litoralis* isolated from a submarine hydrothermal vent near Lucrino, Bay of Naples, Italy (Perler *et.al.* 1992). The native organism is capable of growth at up to 98°C (New England Biolabs Inc. 2002a). • **Vent$_R$ ® (exo$^-$) DNA Polymerase** genetically engineered version of Vent $_R$ DNA Polymerase that carries the Vent DNA Polymerase gene from the archaea **Thermococcus litoralis** isolated from the hydrothermal vent site noted above (New England Biolabs 2002b). • **Deep Vent$_R$ ® DNA Polymerase** a more stable form of Vent ®$_R$ DNA Polymerase. Purified from a strain of *E.coli* that carries the Deep Vent$_R$ DNA Polymerase gene from *Pyrococcus* species GB-D(1) (New England Biolabs 2002c). The native organism was isolated from a submarine thermal vent in the Guaymas Basin at 2010 meters (Jannasch *et. al.* 1992). • **Deep Vent $_R$® (exo$^-$) DNA Polymerase** genetically engineered version of Deep Vent $_R$® DNA Polymerase purified from a strain of *E. coli* that carries the Deep Vent$_R$ DNA Polmerase gene from *Pyrococcus* species GB-D(1) (New England Biolabs 2002d). The native organism was isolated from the location noted above.

TABLE 2 (cont.)

Company	Areas of research interest and product development from thermophiles and hyperthermophiles from terrestrial and marine sources and other relevant areas	Products currently on the market developed from hydrothermal vent thermophile or hyperthermophile derivatives
		• **$9°N_m$™ DNA Polymerase** purified from a strain of *E. coli*. that carries a modified $9°N_m$ DNA Polymerase gene from the extremely thermophilic marine archaea *Thermococcus* sp. Isolated from a submarine hydrothermal vent at a depth of 2,500 meters, 9° north of the equator at the East Pacific Rise (New England Biolabs 2002e). • **Therminator™ DNA Polymerase** (New England Biolabs 2002f).
Prokaria ehf *(www.prokaria.com)*	Development of products for biotechnology/genomics industry for research and diagnostics, for food, agricultural, chemical companies and the pharmaceutical industry, including thermostable DNA polymerases and ss RNA/DNA ligases. Prokaria is currently the sole company licensed to access and sample Iceland's offshore submarine hydrothermal vents, and also has sole access to some of Iceland's terrestrial hot springs and geothermal areas.	
Genencor International Inc. *(www.genencor.com)*	Enzymes for use in applications such as detergents, converting starch to sweeteners, producing ethanol, "stone-washing" blue jeans and enhancing the nutritional value of animal feed.	
Montana Biotech Corporation & Mycologics Inc. (www.mycologics.com)	Discovery and isolation of novel antifungal compounds for therapeutic use. Especially interested in identification of extremophiles and thermophiles that have potent activity against human fungal pathogens. Joint Research by these two companies resulted in the first reported screening of extremophiles for antifungal activity. Although most research has focussed on extremophiles from terrestrial sources, the potential for hydrothermal vent extremophiles has been identified in such research (Phoebe *et al.* 2001).	
Biopolymer Engineering Inc. *(www.biopolymer.com)*	Research in relation to polysaccharides, especially chitin for use in a range of applications including consumer products such as recycled paper, household sponges, diapers and feminine napkins and tampons, and medical uses such as wound dressings, hospital bedding, gowns and other medical products. Chitin is found in the shells of crustaceans, the exoskeletons of insects and the cell walls of fungi. Biodegradation of these materials in nature involves processes similar to those used commercially to produce popular nutraceuticals. The progress of biodegradation has been modelled and quantified in various studies including the evolution of chitin and protein contents of the shells of a hydrothermal vent crab exposed to marine soil (www.biopolymer.com) (Gaill *et al.* 1995).	

This means that the coastal state has the right under international law to regulate activities at hydrothermal vent fields within their EEZ and territorial sea. Thus measures such as those implemented at the Endeavour hydrothermal field within Canada's EEZ (Leary 2002), at the Lucky Strike and Menez Gwen hydrothermal fields within the Portuguese EEZ, and the access regime currently being developed by Papua New Guinea, are entirely consistent with those countries' rights and obligations under the LOSC and the CBD as discussed below (Leary 2003b).

The extent to which a coastal state can regulate bioprospecting at hydrothermal vents on its continental shelf is unclear. Pursuant to Article 77(1), the coastal state has sovereign rights to explore and exploit the natural resources of the continental shelf. The term "natural resources" as used in Part VI is defined in Article 77(4) of the 1982 Convention as the "mineral and other non-living resources of the seabed and subsoil together with living organisms belonging to the sedentary species". That is, "organisms which, at the harvestable stage, either are immobile on or under the seabed or are unable to move except in constant physical contact with the seabed or the subsoil."

In considering the rights of the coastal state to regulate access to hydrothermal vent sites on the Continental Shelf (including for bioprospecting), a key issue therefore is whether or not species (and importantly bacteria and archaea) associated with hydrothermal vents are sedentary species. However, as Allen (2001) notes, the definition of sedentary species "has little or no relationship to biological taxonomy". Working out whether hydrothermal vent species fall within the definition of sedentary species presents a number of problems. First, there are clearly difficulties in identifying the harvestable stage of many hydrothermal vent species. Indeed bacteria and archaea are not collected in a way that can be regarded as harvesting (Allen 2001).

More problematic is the requirement that such species be either immobile on, or under, the seabed, or unable to move except in constant physical contact with the seabed or the subsoil. Some species found at hydrothermal vent arguably meet this requirement (e.g. molluscs, gastropods and possibly tubeworms), while others such as fish and octopus species, are clearly capable of movement through the water without being in constant physical contact with the seabed and therefore fall outside the definition (Allen 2001).

Given the different miens in which microbes are found at vents sites some, such as those found in hydrothermal plumes, arguably fall outside the definition of sedentary species while others, such as those under the seabed, may arguably fall within the definition of 'immobile at the harvestable stage'. Therefore, within the one ecosystem there will be both macrofauna and microfauna that meet the test for sedentary species and fall within the Continental Shelf Regime, as well as macrofauna and microfauna that will not fulfil the definition of sedentary species, and thus fall outside the Continental Shelf Regime (Allen 2001).

Korn, Friedrich and Feit (2003) have suggested that since many species fall outside the sedentary species definition, this leads to a "fractured regulatory approach regarding management and conservation" of hydrothermal vents and their associated biological resources. Does the failure of some macrofauna and microfauna to fall within the definition of sedentary species really matter? Is the consequence as significant as Korn, Friedrich and Feit. and Allen's detailed analyses suggest? Perhaps not when one looks at the consequences for the ability of the coastal state to regulate activities in relation to hydrothermal vents.

If the particular macrofauna or microfauna do not fall within the definition of sedentary species, but are located within the coastal states EEZ, then the coastal state nonetheless has the sovereign right to explore, exploit, conserve and manage such macrofauna or microfauna as natural resources under Article 56(1)(a) of the LOSC, and the jurisdiction to take measures, such as requiring benefit sharing, and measures for the protection and preservation of such living resources, as part of the marine environment under Article 56(1)(iii). That is to say, if such species are found within the EEZ and are not sedentary species, then the EEZ regime applies.

If the particular macrofauna or microfauna fall within the definition of sedentary species and are located within the coastal states EEZ and its continental shelf, then the coastal state has the sovereign right to explore and exploit such natural resources under Article 77. These rights are expressed as sovereign rights. Such sovereign rights include the right to prohibit any form of exploitation and, or, the right to make exploitation for any purpose subject to, or conditional on, compliance with measures to protect and preserve individual vent sites or to minimize the environmental impact of such activities. Although such measures are not specifically mentioned, they would constitute a legitimate exercize of sovereign rights with respect to such resources.

The only situation where the distinction might matter is where a hydrothermal vent site is found outside the EEZ but on the continental shelf. That is, where a state claims a continental shelf that extends beyond the limit of the EEZ. However, by operation of Article 76(3) of the LOSC, hydrothermal vent sites associated with the mid-ocean ridges (where the majority of hydrothermal vent sites discovered have been located) would be excluded from the Continental Shelf Regime anyway as Article 76(3) specifically excludes oceanic ridges of the deep ocean floor from the Continental Shelf Regime.

4.2 Hydrothermal vents and Part XI of the 1982 UN Convention on the Law of the Sea

Pursuant to Article 136 of the LOSC the Area and its "resources" are declared the common heritage of mankind [sic]. In addition Article 137 of the LOSC provides:

"1. No State shall claim or exercize sovereignty or sovereign rights over any part of the Area or its resources, nor shall any State or natural or juridical person appropriate any part thereof. No such claim or exercize of sovereignty or sovereign rights nor such appropriation shall be recognized.

2. All rights in the resources of the Area are vested in mankind [sic] as a whole, on whose behalf the [International Seabed] Authority shall act. These resources are not subject to alienation. The minerals recovered from the Area, however, may only be alienated in accordance with [Part XI] and the rules, regulations and procedures of the [International Seabed Authority].

3. No State or natural or juridical person shall claim, acquire or exercize rights with respect to the minerals recovered from the Area except in accordance with [Part XI]. Otherwise, no such claim, acquisition or exercize of such rights shall be recognized [sic]."

Article 138 provides that the general conduct of all States in relation to the Area must be in accordance with the provisions of Part XI, "the principles embodied in the Charter of the United Nations and other rules of international law in the interests of maintaining peace and security and promoting international co-operation and mutual understanding". Article 140 also requires that such activities be carried out for the "benefit of mankind" and Article 141 requires the Area to be used exclusively for peaceful purposes.

A novel feature of Part XI of the LOSC is that, under Article 156, it created a specific entity with responsibility for regulating activities associated with deepsea mining in the Area, namely the ISA. Under Article 156(2), all parties to the LOSC are *ipso facto* members of the ISA. Article 157(1) of the LOSC specifically provides that the ISA is the organization through which state parties shall "organize and control activities in the Area, particularly with a view to administering the resources of the

Area". However the expression "activities in the Area" used so liberally in many provisions of Part XI[6] is narrowly defined in Part 1, Article 1(3) to mean

"all activities of exploration for, and exploitation of, the resources of the Area".

More significantly, "resources" are defined under Article 133(a) of the LOSC as

"all solid, liquid or gaseous mineral resources in situ in the Area at or beneath the seabed, including polymetallic nodules".

This means that, until such time as a wider mandate is conferred on the ISA, the ISA's current mandate with respect to regulation of activities in the Area extends only to regulating activities associated with the exploration for, and exploitation of, the mineral resources of the Area. As Glowka (1996) has pointed out the ISA's current mandate does not extend to bioprospecting.

The situation is further complicated by the fact that the LOSC and the Part XI Agreement specifically recognize the rights of all state parties and scientific research institutions to carry out research on the High Seas and in the Area. The right to carry out research on the high seas is expressly recognized as a high seas Freedom under Article 87(1)(f) of the LOSC. Similarly Article 256 recognizes that all States have the right to conduct research in the water column beyond the limits of the EEZ. Article 257 recognizes that all States and competent international organisations have the right to conduct research in the Area, provided such research is conducted in conformity with the provisions of Part XI of the LOSC. This right is also recognized by Article 143(3).

Under Article 143(2) the ISA is entitled to carry out research in the Area and in relation to its resources (as that term is defined in Article 133(a)) the ISA may enter into contracts for that purpose. Where research involves prospecting and exploration for mineral resources such applied research would be subject to the approval and control of the ISA (Churchill and Lowe 1999). Under Article 240(d) the ISA clearly has the mandate to implement measures to regulate research associated with the mineral resources of the Area. Such activity clearly falls within the definition of "activities in the area" contained in Article 1(3).

However, this authority does not appear to extend to other forms of research including bioprospecting associated with such research. Given that research cruises in relation to hydrothermal vents often involve research relating to mineral deposits, biology, microbiology and bioprospecting, then some research will be regulated and some will not. The possible exception to this is where such research interferes with "activities in the area", that is to the extent of interference with activities for the exploration for, and exploitation of, the mineral resources of the Area. Thus, not only does the 1982 Convention fail to give a mandate to the ISA to regulate bioprospecting, in fact, specific provisions clearly recognize states and national research institutions as having the right to carry out research including bioprospecting in the Area.

4.3 United Nations Convention on Biological Diversity

The provisions of the LOSC and the Part XI Agreement must also be read in conjunction with the provisions of the CBD. Article 22 of the CBD makes clear that in the event of conflict between the provisions of the CBD and the LOSC, the 1982 Convention prevails.

The CBD has three main objectives: the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources. It establishes a framework of

[6]These provisions include the requirement that activities in the Area be conducted for the benefit of mankind [sic] under Article 140(1), the requirement of equitable sharing of financial and other economic benefits derived from activities in the Area under Article 140(2), and provisions dealing with transfer of technology and scientific knowledge under Article 144(1)(a).

general flexible obligations aimed at implementing these objectives. These include obligations to create plans, strategies, or programmes for conservation and sustainable use of biodiversity (Article 6). States must also identify and monitor components of biodiversity important for its conservation and sustainable use, and identify processes and categories of activities which have, or are likely to have, significant adverse impacts on the conservation and sustainable use of biodiversity (Article 7). States also have an obligation to take steps to regulate activities that threaten biodiversity, including measures such as systems of protected areas to conserve biodiversity (Articles 8, 9, 10 and 11).

Article 15 of the CBD is of particular relevance to bioprospecting and deals with access to genetic materials, including a requirement that access shall be on mutually agreed terms and subject to prior informed consent. The implementation of these provisions has been further clarified following the adoption of the Bonn Guidelines on Access to Genetic Resources and the Fair and Equitable Sharing of the Benefits Arising out of their Utilisation (Jeffery 2002). However, these obligations are subject to several significant qualifications. First, the CBD is a framework treaty. It sets out overall goals and policies and general obligations with respect to biodiversity conservation and only provides a limited structure for technical and financial cooperation. Responsibility for achieving its goals is left to the individual state parties.

This view is reinforced by Article 3 of the CBD, which recognizes that:

> *"States have in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction."*

Obligations under the CBD are subject to, and therefore secondary to, each state's sovereign right to exploit their own resources and set their own environmental policies. Of even more significance is the limitation imposed by Article 4 under which the Convention's provisions only apply, in relation to each contracting party:

"(a) In the case of components of biological diversity, in areas within the limits of its national jurisdiction; and

(b) In the case of processes and activities, regardless of where their effects occur, carried out under its jurisdiction or control, within the area of its national jurisdiction or beyond the limits of national jurisdiction."

This means that the coastal state is obliged to implement its obligations under the CBD in its inland waters, territorial sea, contiguous zone, within its EEZ and parts of its continental shelf (de Fontaubert, Downes and Agardy 1998). Beyond their national jurisdictions the state parties may only regulate the activities of their own nationals to achieve the objectives of the CBD. Thus, under the existing provisions of the CBD access to, and use of, the genetic resources of the oceans and the deep sea beyond national jurisdiction is unregulated except where individual states regulate the activities of their nationals. So far, no state has implemented measures specifically regulating activities of their nationals at hydrothermal vents on the high seas.

As Glowka (1996) notes, this is ironic because the most immediately exploitable and lucrative resources of the deep sea are arguably its genetic resources, yet such resources fall outside of the main legal regime applicable to the deep sea, the deep-sea mining regime under Part XI of the LOSC, and the main treaty dealing with biodiversity conservation - the CBD.

Despite this significant lacuna in the law, this issue has been subject to only scant consideration by the main organs of the CBD. The two most important meetings that have considered the genetic resources of the deep sea (including those associated with hydrothermal vents) were the meetings of the Conference of Parties (COP) in Jakarta in November 1995 and the meeting of the SBSTTA in Montreal in March 2003.

4.4 Jakarta 1995

At the Jakarta meeting in 1995 the COP agreed on a programme of action for implementing the CBD with respect to marine and costal biodiversity now known as the Jakarta Mandate on Marine and Coastal Biological Diversity (de Fontaubert, Downes and Agardy 1998).

A number of states consistent with the Jakarta Mandate, including Canada, Portugal and Papua New Guinea, have begun to design and implement measures regulating access to particular hydrothermal vent sites within their territorial sea and EEZ. In the case of Canada this has included the establishment of the Endevour Hydrothermal Vent Marine Protected Area, which was formally proclaimed in March 2003. However, Canada's regulation of access to the Endeavour Hydrothermal Vent Marine Protected Area does not include any specific provision regulating bioprospecting and there is no requirement for benefit sharing (Leary 2002).

Portugal proposes to prohibit bioprospecting in the proposed marine protected area for the Lucky Strike and Menez Gwen hydrothermal vents. Research will be permitted, but subject to regulation. It is unclear what are the implications where samples collected are subsequently provided to third parties and the derivatives are commercialized (Leary 2003b). Papua New Guinea is currently developing an access and consent regime for research and bioprospecting that will involve informed prior consent for access for research, bioprospecting and benefit sharing (Leary 2003b).

Significantly, in paragraph 12 of decision II/10 adopted at the COP meeting in Jakarta in 1995, the COP requested the Executive Secretary of the CBD, in conjunction with the United Nations Office for Ocean Affairs and the Law of the Sea, to:

> *"undertake a study of the relationship between the Convention on Biological Diversity and the United Nations Convention on the Law of the Seas with regard to the conservation and sustainable use of genetic resources on the deep seabed, with a view to enabling the Subsidiary Body on Scientific, Technical and Technological Advice to address at future meetings, as appropriate, the scientific, technical, and technological issues relating to bioprospecting of genetic resources on the deep seabed."*

The study requested by COP II/10 took nearly eight years to prepare and was finally published in February 2003. Prior to the report's preparation a preliminary assessment of the areas that might be considered in the final study was published in an unofficial report in 1996. In some respects this preliminary assessment reflects the ultimate conclusions and recommendations of the study requested by COP II/10 released in 2003. In particular, the preliminary assessment concurred with Glowka's assessment noted above, recognising that the genetic resources of the deep seabed are "unregulated resources". However, given the lack of information on the commercial potential of deep-sea genetic resources, the preliminary assessment concluded that the knowledge base on which to make informed and appropriate decisions about how this area might be controlled was then almost non-existent (CBD SBSTTA 1996).

Despite this obvious and significant absence of a knowledge base the preliminary report suggested several "foreseeable scenarios" as to how bioprospecting in relation to these resources could develop. These are:

(a) "leaving marine genetic resources unregulated and freely available to those who spend the resources to collect them;
(b) bringing them within the regime governing the Area and the [International Seabed Authority's] authority;
(c) bringing them within the CBD regime; and
(d) establishing an entirely new regime to deal with these special and new resources" (CBD SBSTTA 1996).

These "foreseeable scenarios", with the exception of the last one, were endorsed by the final study released in 2003.

4.5 The SBSTTA Study on the relationship between the LOSC and the CBD

The SBSTTA study released in early 2003 confirmed the existence of a lacuna in the law with respect to the genetic resources of the deep sea as first identified by Glowka. The study concluded that there are three options available for a regime to manage activities relating to genetic resources beyond national jurisdiction. They are:

i. maintaining the statu quo

ii. application of the regime under Part XI of [the LOSC], currently limited to the management of mineral resources and

iii. application of the regime of conservation and sustainable use of genetic resources under the Convention on Biological Diversity.

The study noted that the last two of these options are not mutually exclusive and could be integrated (CBD SBSTTA 2003).

The SBSTTA study also noted two additional options for regulation that were not examined in detail or referred to in the study's conclusion and recommendations. These were the potential roles of marine protected areas on the high seas and intellectual property rights as incentives for benefit sharing and sustainable use of deepsea genetic resources. It is unclear from the report why these alternatives were ruled out without further consideration. It seems inappropriate for a study of options to rule out two possible options without detailed consideration. This is especially so given the wealth of literature and interest in both options. Marine protected areas, especially on the high seas, have been the subject of detailed consideration at a number of international forums recently (Gjerde and Breide 2003).

The SBSTTA study stops short of endorsing any one option, but it appears from the tone of the report that it supports an expanded mandate for the ISA as a preferred option. There are immediately obvious benefits associated with such an option. Expanding the mandate of an existing international institution might be more efficient than establishing an entirely new institution with possibly overlapping mandates. Although it has only been operational since 1994, the ISA has accumulated a considerable level of expertise and data on the deepsea environment.

Significant issues would need to be considered before proceeding with such an option. Some, but by no means all, of these issues, include the following.

i. To what extent will there need to be changes to the ISA's existing structure? The ISA has been designed to regulate a deepsea mining industry and its structure reflects many interests including producers and consumers of minerals.[7] This structure effectively ensures that no decisions can be pushed through the Council of the ISA against the will of any one interest group. This is further complicated by the general rule decision-making in the organs of the ISBA (French 2002).

[7] The Council of the ISA consists of 36 members of the ISA who are elected in accordance with a formula set out in the Part XI Agreement. This formula (Annex, Section 3, paragraph 15) provides for the Council to be composed of 36 members elected as follows:

- Four members from among the states that are the major consumers of the categories of minerals to be derived from the Area. These four members must include one state which is the largest consumer in Eastern Europe (effectively Russia) and upon its accession to the LOSC, the USA
- Four members from among the eight state parties who have made the largest investment in preparation for mining
- Four members from among state parties that are the major net exporters of the categories of minerals to be derived from the Area, including at least two who are developing states whose exports of such minerals have a substantial bearing upon their economies
- Six members from developing state parties representing special interests. The special interests are defined as states with large populations, landlocked or geographically disadvantaged states, island states, states that are major importers of the categories of minerals to be derived from the Area, states which are potential producers of such minerals and least developed states and
- Eighteen members elected according to the principle of ensuring an equitable representation for each geographical region of the world. The regions are Africa, Asia, Eastern Europe, Latin America and the Caribbean and Western Europe and Others.

ii. To what extent do the interests of the biotechnology industry and the scientific community differ from those reflected in the ISA's existing structure?
iii. To what extent will the principles embodied in the CBD and the principals of international environmental law more generally be reflected in any amended structure?
iv. How will the proposed regime deal with the question of benefit sharing?
v. Should the genetic resources of the deep sea be regarded as the common heritage of mankind?
vi. Finally, to what extent would a new regime attempt to distinguish between research and bioprospecting? Is it even feasible to attempt such a distinction in law when at times it is almost impossible to distinguish the two in practice?

Such issues will need to be addressed if such a proposal is to be advanced. However, this presupposes the ISA, and in particular member states, are willing to consider an expanded mandate for the ISA in the first place. However, as recent discussion on the issue of biodiversity at the ISA seems to indicate that an expanded mandate for the ISA currently has minimal support.

4.6 Repeating the mistake of the sedentary species definition?

The SBSTTA study contained an important qualification in the following terms:

> *"that the studies recommendations addresses only the "biological resources **attached to the ocean floor** and not the free swimming fish above, which fall within the regime of fisheries on the high seas, covered by Articles 116 – 119 of the Convention, as well as by the United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (the 1995) Fish Stocks Agreement) where appropriate"* (CBD SBSTTA 2003).

COP Decision II/10, which authorized the preparation of the study, made no mention of resources "attached to the ocean floor". It speaks only of the "genetic resources on the deep seabed". Is there any difference between genetic resources "on" or "attached to" the deep seabed? Perhaps, parts of the above extract suggests the intention is merely to exclude fisheries and this particular statement may have been included to allay concerns that this report had any relevance to high-seas fisheries, a contentious issue.

However, there will be a significant defect in any future regime if it only applies to the resources "attached to the ocean floor". A regime along those lines would exclude integral components of the hydrothermal vent ecosystem. For example, it would exclude the genetic resources associated with microbes found in the hydrothermal plume. Likewise microbes that have formed symbiotic relationships with other species not necessarily attached to the seabed such as shrimp, crabs, etc. would also be excluded. It seems a somewhat arbitrary distinction that fails to take account of the entire ecosystem, of which those resources attached to the seabed only form part. It is inconsistent with an ecosystem based approach and is reminiscent of the sedentary species definition under the continental shelf regime discussed above.

4.7 The environmental mandate of the ISA

It is significant that the study implies that the ISA currently has a wide mandate to regulate the environmental impact of human activities in the deep sea. In that respect the study notes:

> *"A substantial proportion of the regulatory responsibility of the Authority relates to the protection and preservation of the marine environment. The mandate for the Authority's work in this field is established both by the United Nations Convention on the Law of the Sea, which stipulates that the Authority shall adopt*

> *appropriate rules, regulations and procedures to ensure the effective protection of the marine environment and by the Authority's Regulations for Prospecting and Exploration for polymetalic Nodules in the Area, which also require the adoption of rules, regulations and procedures for environmental protection" (CBD SBSTTA 2003).*

Similar comments are made elsewhere in the study, such as in the context of considering the advantages of utilising the ISA's existing structure because it

> *"is already operational and has already a mandate relating to the protection and preservation of the Area's marine environment" (CBD SBSTTA 2003).*

In light of these comments it is useful to consider the mandate of the ISA with respect to the deep-sea environment, and its work in this regard to date.

The relevant provision of the LOSC is Article 145, which requires that necessary measures be taken with respect to activities in the Area to "ensure effective protection for the marine environment from harmful effects which may arise from such activities". Under Article 145 the ISA is specifically required to adopt appropriate rules, regulations and procedures with respect to:

> *"(a) the prevention, reduction and control of pollution and other hazards to the marine environment, including the coastline, and of interference with the ecological balance of the marine environment, particular attention being paid to the need for protection from harmful effects of such activities as drilling, dredging, excavation, disposal of waste, construction and operation and maintenance of installations, pipelines and other devices related to such activities*
>
> *(b) the protection and conservation of the natural resources of the Area and the prevention of damage to the flora and fauna of the marine environment".*

A similar requirement is also found in the LOSC, Annex III, Article 17, paragraph 1(b) (xii), which requires the ISA to adopt and apply rules, regulations and procedures for the exercise of its functions in relation to *"mining standards and practices, including those relating to operational safety, conservation of the [mineral] resources and protection of the marine environment".*

Likewise Annex III, Article 17, paragraph 2(f) of the LOSC requires rules regulations and procedures to be drawn up:

> *"in order to secure effective protection of the marine environment from harmful effects directly resulting from activities in the Area or from shipboard processing immediately above a mine site of minerals derived from that mine site, taking into account the extent to which such harmful effects may directly result from drilling, dredging, coring and excavation and from disposal, dumping and discharge into the marine environment of sediment, wastes or other effluents".*

The provisions of the Part XI Agreement have further elaborated these requirements. In the interim period from the entry into force[8] of the deep-sea mining regime until the approval of the first plan of work for exploration, the ISA is required to, *inter alia*, focus on the adoption of rules, regulations and procedures incorporating applicable standards for the protection and preservation of the marine environment pursuant to Part XI Agreement, Annex, Section 1, Paragraph 5 (g).

So far the only regulations adopted by the ISA dealing specifically with environmental issues are the Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area (Nodule Prospecting Regulations) (ISA 2000). Adoption of the Nodule Prospecting Regulations cleared the way for the ISA to enter into the first contracts for exploration. The first contract was signed with the state enterprise Yuzhmorgeologia (Russian Federation) on 29 March 2001. Since then similar exploration contracts have been signed with Interoceanmetal Joint Organization (a consortium formed by Bulgaria, Cuba, the Czech Republic, Poland, the Russian Federation and Slovakia), the

[8] The regime entered into force on 28 July 1996.

Republic of Korea, the China Ocean Mineral Resources Research and Development Association (China), Deep Ocean Resources Development Company (Japan), Institut français de recherche pour l'exploitation de la mer Association français pour l'étude et la recherche des nodules (France) and the government of India (ISA 2002).

These regulations include some curious provisions. For example, Regulation 2(2) provides that "*Prospecting shall not be undertaken if substantial evidence indicates the risk of serious harm to the marine environment*". Serious harm to the marine environment is defined in the Regulations as "*any effect from activities in the Area on the marine environment which represents a significant adverse change in the marine environment determined according to the rules, regulations and procedures adopted by the Authority on the basis of internationally recognized standards and practices*". So far no such rules or regulations or procedures have been prepared.

The requirements for "*substantial evidence*", "serious harm" and "*significant adverse change*" would appear to be at odds with a precautionary approach, as reflected in Principle 15 of the Rio Declaration and subsequent instruments. The use of these terms is even more curious given that specific provisions of the regulations dealing with protection and preservation of the marine environment contained in Part V of the Regulations seem to make application of a precautionary approach mandatory. Thus Regulation 31(2) provides:

> "*In order to ensure effective protection for the marine environment from harmful effects which may arise from activities in the Area, the Authority and sponsoring states shall apply a precautionary approach, as reflected in principle 15 of the Rio Declaration, to such activities*".

4.8 Regulations for prospecting at hydrothermal vents

The ISA has recently commenced consideration of the appropriate type of regulation for prospecting for polymetalic sulphides associated with hydrothermal vents and cobalt-rich ferromanganese crusts following a request from the Russian Federation. It is not yet clear to what extent provisions of these regulations will mirror the Nodule Prospecting Regulations.

The Legal and Technical Commission of the ISA is currently working on drafts of these regulations. In accordance with its programme of work agreed upon during the eighth session of the ISA, the members of the Legal and Technical Commission convened informal working groups to consider certain aspects of the rules and regulations including one working group charged with analyzing

> "*Considerations relating to the development of environmental rules, regulations and procedures relating to prospecting and exploration for polymetalic sulphides and cobalt-rich crusts*" (ISA 2003a).

This working group has produced a preliminary draft of regulations relating to the protection and preservation of the marine environment during prospecting and exploration, which will be considered further at the Commission's next session in 2004. In the course of its work, the working group indicated that it is appropriate for the draft regulations to reflect

> "*developments in international environmental law achieved since the adoption of the Convention in 1982" (ISA 2003a)*

The Legal and Technical Commission, in the context of its work on these regulations and "*working within its mandate*", has acknowledged that it needs to know more about seabed and deep-ocean biodiversity. Accordingly, at its most recent meeting the commission has requested one of its members, Helmut Beiersdorf, to draw up a proposal for a seminar on seabed and deep-ocean biodiversity relevant to mineral resource prospecting and exploration with participation by members of the Legal and Technical Commission and experts in the field. Another member of the Legal and Technical Commission, Frida Mara Armas Pfirter is to co-ordinate the preparation of a paper on legal issues "to ensure the Commission remained within its mandate" under the LOSC. The Legal and Technical Commission will also review the idea of establishing a working group to study the issue further (ISA 2003b).

With environmental issues, and particularly protection of deep-sea biodiversity including hydrothermal vents, are increasingly of interest to the ISA, it is also clear that the ISA (and most member states) appear to want to confine its work within is existing mandate. Indeed, at its most recent session concerns were expressed by several states lest the ISA go beyond this mandate and in debate during the closing session of the Assembly of the ISA, a number of states expressed their concern that the ISA not exceed its mandate.

For now it appears as if the ISA intends to confine its consideration of deep-sea biodiversity strictly to the terms of its existing mandate. The implications of this were summarized by the Secretary-General of the ISA to the meeting of the final session of the Assembly in 2003. In relation to the ISA's work on biodiversity Ambassador Nandan stated:

> *"Our purpose is not to deal with it in a comprehensive way; our purpose is to deal with it in a manner which would be of interest to the authority" [i.e. in regard to the regulation of deep-sea mining] "We are not looking to control or manage or regulate marine scientific research. We are not looking to licence bioprospectors or to deal with the patent rights of bioprospectors"* (ISA 2003c).

Thus, while the SBSTTA study suggests an expanded mandate for the ISA as a preferred option for regulating access to hydrothermal vents for bioprospecting, it appears that such a proposal currently lacks support amongst members of the ISA.

4.9 SBSTTA Meeting Montreal, March 2003

The SBSTTA study was presented for consideration at the eighth meeting of the SBSTTA in Montreal from 10 to 14 March 2003. The subsequent debate on the report at the meeting revealed further significant differences on this issue. For example, Brazil, Argentina, Columbia, Peru and several other developing states objected to the competence of both the SBSTTA and the CBD to deal with issues related to the deep seabed beyond national jurisdiction (Earth Negotiations Bulletin 2003). In contrast the European Union, Greece and the Seychelles felt these issues fell within the CBD's mandate under Articles 3 and 4. In addition, they noted that the SBSTTA was competent to deal with its scientific aspects under Decision II/10 on marine and coastal diversity (Earth Negotiations Bulletin 2003). Canada objected to a recommendation encouraging Parties to start working through the ISA on issues related to conservation and sustainable use of genetic resources as they felt this may prejudice the outcome of more considered deliberations (Earth Negotiations Bulletin 2003).

The Montreal meeting made three main recommendations to the COP. These recommendations were as follows.

i. That the Executive Secretary, in consultation with parties and other governments and in collaboration with relevant international organisations[9], compile and synthesize information on the status and trends of deep seabed genetic resources and on methods to identify, assess and monitor genetic resources of the deep seabed in areas beyond the limits of national jurisdiction. This is to include identification of threats to such genetic resources and the means for their protection, with a view to addressing processes and activities under Article 4(b) of the CBD, and to report on progress thereon to the SBSTTA, which will prepare recommendations for the consideration of the COP at its eighth meeting.

[9] Namely the United Nations Division for Ocean Affairs and the Law of the Sea, the United Nations Environment Programme, the ISA and the Intergovernmental Oceanographic Commission of the United Nations Educational, Cultural and Scientific Organization.

ii Invite the UN General Assembly to call upon relevant organisations[10] to review issues relating to the conservation and sustainable use of genetic resources of the deep seabed beyond the limits of national jurisdiction and make appropriate recommendations to the General Assembly regarding appropriate actions.

iii. Invite parties and other states to identify activities and processes under their jurisdiction or control which may have significant adverse impacts on deep seabed ecosystems and species beyond the limits of national jurisdiction, in order to comply with Article 3 of the CBD.

These recommendations are to be considered at the seventh meeting of the COP in Kuala Lumpur, Malaysia in March 2004.

5. WHY BOTHER?

> *"Hyperthermophiles are not likely to generate the passionate lobbying support enjoyed by charismatic mega-vertebrates, like whales or elephants"* **(Sochaczewski and Hyvarinen 1996).**

5.1 Defining the problem for the law to address

After an eight year study it is disappointing that the SBSTTA study has not advanced in the consideration of this issue. The study has largely done no more than re-state what was first identified by Glowka, i.e. there is a significant gap in international law. Add to that the significant qualification contained in the SBSTTA report, i.e. the ISA appears to be reluctant to consider an expanded mandate at the moment, and it appears that little real progress has been made in the last eight years.

A significant problem in the approach of both the SBSTTA and the ISA to this issue is that they both narrowly define the problem that they seek to address. For SBSTTA, the issue is defined in terms of regulating access to hydrothermal vents by bioprospectors seeking genetic resources, albeit with the underlying goal of conservation of biodiversity. In the case of the ISA, the issue is minimizing the environmental impact of mining on the biodiversity of the deep sea.

The issue of regulating access to hydrothermal vents on the high seas, and within territorial waters and the EEZ, is far more complicated than just these two issues, and deep-sea mining and bioprospecting are only two of several, at times conflicting, uses of the deep sea. Human activities at hydrothermal vents include research, bioprospecting, mining and tourism. These activities pose a vaguely quantified threat to the biodiversity of hydrothermal vents (Dando and Juniper 2001, Leary 2002). Add to these impacts pollution and the risk of introducing alien invasive species and the question of regulating access to hydrothermal vents becomes more complicated.

5.2 The economic value of hydrothermal vents

Hydrothermal vents are of interest because of their associated mineral deposits. As for the biotechnology potential of hydrothermal vents, it is difficult to speculate on the economic significance of mineral deposits such as polymetalic sulphide deposits associated with hydrothermal vents based on existing data. Based on the limited information now available, it has been suggested that such deposits may contain concentrations of metals that are comparable to those found in ores from massive sulphide mines on land. (Herzig, Peterson and Hannington 2002).

Approximately 200 sites of seafloor hydrothermal mineralisation have been identified. Of these, only about ten sites may have sufficient size and grade justify

[10]Specifically the United Nations Environment Programme, the International Maritime Organisation, the ISA, the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization, the International Hydrographic Organisation, the World Meteorological Organisation, the Secretariat of the Convention on Biological Diversity, and the United Nations Division for Ocean Affairs and the Law of the Sea.

future mining (Herzig, Peterson and Hannington 2002). Most of these sites are located within the territorial sea and, or, the EEZs of coastal states, areas that are outside the jurisdiction of the ISA.

Thus, most commercial interest has been confined to sites located within the territorial waters or the EEZ of coastal states. Both Papua New Guinea and New Zealand have granted exploration and prospecting permits in relation to hydrothermal vent mineral deposits within their territorial waters and EEZ. Proposals for mining at the site in PNG are advanced with prefeasibility studies and selection of mining technology now complete (Heydon 2003b) so that the first deep-sea mining associated with hydrothermal vents may not be in an area subject to control by the ISA.

One permit granted to Nautilus Minerals Limited for deposits in the Manus basin in Papua New Guinea has lead to concerns within the scientific community as to their impact on the ability to conduct research in PNG waters subject to the permit (Leary 2003a). This is but one example of the potential conflict between multiple users of hydrothermal vents. Companies signature to this agreement have also applied for similar exploration licences in the territorial waters of Fiji and Tonga (Heydon 2003a). So far no mining, exploration or prospecting activities have been licensed by the ISA with respect to such minerals. This is mainly because the ISA has not yet developed regulations governing prospecting at hydrothermal vents.

Hydrothermal vents as a tourist destination.

The deep sea is not typically regarded as a prime holiday destination. For those tourists jaded by the world's other travel destinations until recently the only remaining frontier destinations were Antarctic and outer space. Now thousands of tourists visit Antarctica each year. The deep sea, and in particular hydrothermal vents, are also emerging as an adventure tourist destination. A number of research vessels have taken tourists to hydrothermal vent sites, though so far the numbers appear to be small. One example was a cruise offered in June 2002 which, for $55 000 offered deep-sea tourists a month long cruise on the **R.V. Akademik Keldysh**, a Russian research vessel, and dives to several hydrothermal vent sites near the Azores (<*http://www.halyava.ru/ bioch/ mikehydrot2.htm*>). The $55 000 fee included participation as an observer on three **Mir** submersible scientific dives to three different hydrothermal vent sites which included Snake Pit, TAG, Broken Spur, Lost City and Lucky Strike hydrothermal vent sites. Russian scientists are also known to have taken deepsea tourists to the Rainbow hydrothermal vent site (Dando and Juniper 2001).

It appears that so far the tourist dives are only operated by scientific research vessels and are intended as a source of additional funding for the research undertaken by these vessels. As these dives are a recent phenomena it is unclear what their economic value will be, but they do represent a potentially new economic activity associated with hydrothermal vents.

Geothermal energy

A further theoretical, but as yet unrealized, economic resource associated with hydrothermal vents is their potential used for generating hydrogen fuel (Bubis and Molochnikov 1993).

5.3 Marine Scientific Research and hydrothermal vents

Apart from bioprospecting, hydrothermal vents are also of great value to other fields of science. Conflict has arisen between the objectives of different forms of research at hydrothermal vents. In some areas as research shifts towards long term observation these conflicts have become more pronounced (Mullineaux, Desbruyeres and Juniper 1998). In designing a legal regime to regulate research at hydrothermal vents such conflicting objectives must be reconciled. Some of the ongoing research is outlined briefly below.

Earth sciences

Geological and geochemical research at hydrothermal vent sites is providing better understanding of the genesis of ore deposits and providing improved models for exploration for ore on land. Such research may also provide new geological knowledge about the formation, structural deformation and ageing of the Earth's volcanic ocean crust and associated sediments (Dando and Juniper 2001).

Biological sciences

Research into hydrothermal vent biology, microbiology and ecology has already lead to exciting discoveries and further research will expand knowledge of biological systems and physiological processes of vent species and other species living in extreme environments (Dando and Juniper 2001). Coastal species living at shallow vent sites have adapted to toxic conditions and high temperatures. Study of these organisms could help predict how coastal ecosystems may respond to increasing anthropogenic pollution and global warming (Dando and Juniper 2001).

Research into the role of hydrothermal vents in maintaining the chemistry of the oceans

Hydrothermal vents play an important role in maintaining the geochemical balance of the planet as a result of their output of chemicals. Dando and Juniper (2001) estimate that all seawater re-circulates through the vents on average every $10^7 – 10^8$ years. They also suggest that hydrothermal vents contribute to ocean productivity and the local circulation of seawater.

Scientific research on the origin of life

One interesting development to have arisen as a consequence of the discovery of hydrothermal vent ecosystems is the debate as to the origin of life on earth and the search for possible life elsewhere in the universe. The question remains unanswered, but the discovery of hydrothermal vent ecosystems, driven by chemosynthetic microrganisms, has prompted an interesting theory that life on earth could have originated and evolved in association with hydrothermal vents in the primeval ocean during the early Archaean period approximately 4 000 million years ago (Baross and Hoffman 1986).

This theory is supported by comparison of the RNA sequences of hydrothermal vent thermophiles, which suggests that the heat-loving bacteria and archaea associated with hydrothermal vents are nearest to the common ancestor of all life on earth. This suggests that hydrothermal systems may have been a cradle for early biosphere evolution. Modern hydrothermal vents therefore may serve as refuges for close relatives of ancient forms of life (Farmer 2002). The implications for humanity in discovering how life began would be profound. That hydrothermal vent species and, in particular, bacteria and archaea, may answer these questions means that hydrothermal vents and the microbes that inhabit them are organisms of potentially great importance! This provides strong justification for a strict application of a precautionary approach - hydrothermal vents and their associated microbial communities may be the common heritage of all life!

5.4 Hydrothermal vents and conservation of marine biodiversity

The conservation of biodiversity has been recognized as a desirable objective in its own right. This is a fundamental principle underlying the CBD. The CBD recognizes the intrinsic value of biological diversity. The recognition of the intrinsic value of biological diversity is significant because it may be seen as acknowledging the inherent right of all components of biodiversity to exist independent of their value to humankind (Glowka, Burhenne-Guilmin and Synge1994).

As the deep sea constitutes the most typical habitat on earth and is where literally millions of species live, we should take steps to conserve the biodiversity of this habitat, particularly where specific threats have been identified. Simply put, we should be concerned about the loss of species in the deep sea and at hydrothermal vents just as much as in any other region or habitat on earth. With an emerging awareness that threats do exist, the agreed objectives of biodiversity conservation and the intrinsic right of such species to exist recognized by the CBD and other international instruments, provides a strong justification for a shift in focus to the deep sea and hydrothermal vent ecosystems in particular.

6. SOME ALTERNATE SOURCES OF LAW

6.1 Light and noise pollution in the deep sea

One impact of human activities in the deep sea is the introduction of light to an otherwise totally dark environment. There is evidence that the introduction of light to the deep-sea hydrothermal-vent environment may lead to blindness in the associated shrimp species whose eyes are adapted to total darkness (Herring and Gaten 1998). Light is introduced by research in the deep sea, by bioprospecting and in the course of deepsea tourism. Although deep-sea mining has not yet commenced, the introduction of light energy into the deepsea environment may also be an associated environmental impact. Likewise, little is yet known about the impact of noise pollution in the deep sea and on hydrothermal vent ecosystems in particular. A precautionary approach should be adopted pending further scientific research.

The most comprehensive provisions of the 1982 Convention dealing with protection of the marine environment relate to pollution. Article 1(4) of the LOSC defines "pollution of the marine environment" as:

> *"the introduction by man [sic], directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities."*

While this definition includes more typical pollution such as oil, polychlorinated biphenyls and heavy metals (Churchill and Lowe 1999), the definition has a potentially wider scope. The reference to "energy" could cover all forms of energy including noise (Dotinga 2000) and light. The definition of pollution in Article 1(4) is based on an earlier version prepared by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) (Dotinga 2000). The original definition referred only to the introduction of substances, but the term "energy" was added following concerns about thermal pollution (Dotinga 2000). The definition was therefore not drafted with either noise or light pollution in mind, but a wide interpretation of the term "energy" could include such types of pollution as they are forms of energy.

The use of the expression "results or is likely to result" in Article 1(4) indicates that the deleterious effects need not have manifested yet, but can be expected to occur (Dotinga 2000). Even in the absence of certainty as to whether deleterious effects have occurred or are about to occur, there is a need to act with caution and not delay preventative action where the circumstances require such (Dotinga 2000) as is consistent with the precautionary principle.

So far, no steps taken to implement measures to regulate the introduction of light or noise into the deepsea environment. However, the use of the term "energy" in Article 1(4) provides a basis for the adoption of such regulations in the future, either pursuant to Article 209 of the LOSC in respect of mining activities in the Area, or under the obligation imposed on States to adopt measures to prevent, reduce and control pollution of the marine environment under Article 194 of the 1982 Convention.

In addition to the LOSC, Article 1(4) has been incorporated into many other instruments dealing with the protection of the marine environment (Dotinga 2000). These include the OSPAR Convention, the 1974 Convention on the Protection of the Marine Environment of the Baltic Sea Area, the 1992 Convention of the same name, and most of the framework treaties adopted under the UNEP Regional Seas Programme including some protocols dealing with specific sources of marine pollution (Dotinga 2000). There is, therefore, currently a sound legal basis under the LOSC and many of these treaties for adoption of specific measures to deal with light and noise pollution in the deep sea.

6.2 Can the ISA create *de facto* marine protected areas under Article 162 of the LOSC and Regulation 31(7) of the Nodule Prospecting Regulations?

Article 162(2) (x) of the LOSC provides that the Council of the ISA may

> *"disapprove areas for exploitation by contractors or the Enterprise in cases where substantial evidence indicates the risk of serious harm to the marine environment"*

In his recent statement to the Fourth Meeting of the United Nations Open-ended Informal Consultative Process on Oceans and Law of the Sea. the Secretary-General of the ISA suggested that

> *"There is no reason why, pursuant to this provision, the Council [of the ISA] should not develop criteria for the identification of particularly sensitive areas to be reserved for detailed scientific study as environmental baselines or as reference areas" (ISA 2003d)*

The Secretary-General's comments suggested that the Council could designate sensitive areas that would act as environmental baselines and also as *de facto* marine protected areas. This is re-enforced by the provisions of Regulation 31(7) of the Nodule Prospecting regulations, which provides:

> *"If the Contractor applies for exploitation rights, it shall propose areas to be set aside and used exclusively as impact reference zones and preservation reference zones. Impact reference zones means areas to be used for assessing the effect of each contractor's activities in the Area on the marine environment and which are representative of the environmental characteristics of the area. Preservation reference zones means areas in which no mining shall occur to ensure representative and stable biota of the seabed in order to assess any changes in the flora and fauna of the marine environment."*

It can also be argued that the ISA has a discretionary power to designate particular parts of the Area as sensitive no-mining areas in the context of fulfilling its mandate under Article 145 of the LOSC to protect and preserve the marine environment from the impact of deepsea mining (Leary 2003b), also effectively creating *de facto* marine protected areas. Indeed one site has already been suggested as a possible candidate site by WWF. This is the Logatchev vent field in the mid-Atlantic (Schmidt *et al.* 2003).

6.3 Convention for the Protection of the Marine Environment of the North-East Atlantic (The OSPAR Convention)

Under Article 1 the OSPAR Convention applies to a significant portion of the maritime area of the North East Atlantic and Artic Oceans including the internal waters and the territorial seas of the Contracting Parties. It also applies to the sea beyond and adjacent to the territorial sea under the jurisdiction of the coastal state to the extent recognized by international law, and to the high seas, including the sea bed of all those waters and its sub-soil within certain defined limits. There are at least four known hydrothermal vent fields in the OSPAR maritime area; the Menez Gwen, Lucky Strike, Saldanha and Rainbow vent fields (Gubbay *et. al* 2002).

Under Article 2(1)(a) of the OSPAR Convention contracting parties are obliged to

> *"take all possible steps to prevent and eliminate pollution and [obliges parties to] take the necessary measures to protect the maritime area against the adverse effects of human activities so as to safeguard human health and to conserve marine ecosystems and, when practicable, restore marine areas which have been adversely affected"*.

Under Article 2(1)(b) contracting parties are obliged, individually and jointly, to adopt programmes and measures and to harmonize their policies and strategies. In that context the parties are also obliged to apply the precautionary principle and *"the polluter pays principle"*.

Annex V of the Convention deals specifically with the protection and conservation of the ecosystems and biological diversity of the maritime areas to which the OSPAR Convention applies. Annex V and the accompanying Sintra Statement, which provides a strategy for implementation of Annex V, includes provisions requiring an assessment of the species and habitats that may need protection as well as human activities that are likely to adversely effect such species and habitats (Gubbay *et al.* 2002).

Following the Sintra Statement OSPAR has committed to promoting "the establishment of a network of marine protected areas to ensure the sustainable use and protection and conservation of marine biological diversity and ecosystems." Work is now being carried out by parties to the OSPAR Convention and other interested parties such as the WWF, to design mechanisms to implement these obligations. The most significant of these is development of an overall framework for marine protected areas (MPAs) within the context of the OSPAR Convention (Leary 2001). Possible marine protected areas candidate sites within the area of the Convention include the Lucky Strike (Christiansen 2001) and Rainbow fields (Christiansen and Gjerde 2002).

Measures could be adopted under these provisions to regulate activities at hydrothermal vents such as bioprospecting given that it has been suggested bioprospecting is one threat to hydrothermal vent ecosystems. A range of activities including bioprospecting at these hydrothermal vent sites could be regulated in the context of a system of MPAs. The obvious problem with any such measures will be that they could not apply to nationals of non state parties to the OSPAR Convention on the high seas.

6.4 Noumea Convention

The Convention for the Protection of the Natural Resources and Environment of the South Pacific Region (Noumea Convention)[11] aimed contributing to the care and responsible management of the special hydrological, geological and ecological characteristics of the South Pacific Region. It also recognizes the threats to the marine and coastal environment, their ecological equilibrium, resources and legitimate uses posed by pollution and by the insufficient integration of an environmental dimension into the development process (Noumea Convention, Preamble).

Article 2 of the Noumea Convention defines the Convention Area as the EEZs of American Samoa, Australia (East Coast and Islands to eastward including Macquarie Island), Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia and Dependencies, New Zealand, Niue, Northern Mariana Islands, Palau, Papua New Guinea, Pitcairn Islands, Toeklau, Tonga, Tuvalu, Vanuatu, Wallis and Futuna and Western Samoa. The Convention Area also extends to include the areas of the high seas that are enclosed from all sides by the

[11] Convention for the Protection of the Natural Resources and Environment of the South Pacific Region, Noumea, 24 November 1986, in force 22 August 1990, (1990) ATS 31.

EEZs of these States. Within the Convention Area, Papua New Guinea, New Zealand, Fiji, Solomon Islands and Tonga are at various stages of considering development of resources, especially mineral resources, associated with hydrothermal vents within their territorial sea and, or, EEZ.

Under the Noumea Convention the state parties have assumed a number of significant obligations which provide the legal basis to conserve, sustainably manage and use the resources of hydrothermal vent fields found within the Convention Area. Under Article 4 of the Noumea Convention the parties are obliged to endeavour to conclude bilateral or multilateral agreements, including regional or sub-regional agreements, for the protection, development and management of the marine and coastal environments of the Convention Area. Similarly under Article 5, the parties are obliged, either individually or jointly, to take appropriate measures in conformity with international law and the provisions of the Noumea Convention to prevent, reduce and control pollution of the Convention Area from any source and to ensure sound environmental management and development of natural resources.

Article 8 specifically addresses pollution from seabed activities, obliging all parties to take

> *"all appropriate measures to prevent, reduce and control pollution in the Convention Area, resulting directly or indirectly from exploration and exploitation of the sea-bed and its subsoil."*

The provisions of Article 8 are re-enforced by Article 13, which obliges parties to take

> *"all appropriate measures to prevent, reduce, and control environmental damage in the Convention Area, in particular coastal erosion caused by coastal engineering, mining activities, sand removal, land reclamation and dredging."*

The Noumea Convention also recognizes specially protected areas as a means of biodiversity conservation. Thus Article 14 provides

> *"The Parties shall, individually or jointly, take all appropriate measures to protect and preserve rare or fragile ecosystems, depleted, threatened or endangered flora and fauna as well as their habitat in the Convention Area. To this end, the Parties shall, as appropriate, establish protected areas, such as parks and reserves, and prohibit or regulate any activity likely to have adverse effects on the species, ecosystem or biological processes that such areas are designed to protect."*

Article 16 contains provisions requiring assessment of the environmental impact of "major projects" on the marine environment so that appropriate measures can be taken to prevent any substantial pollution of, or significant and harmful changes within, the Convention Area. While these provisions provide some basis to act at the regional level, the obligations are subject to a number of qualifications. For example, the obligation to reduce and control pollution under Article 5(1) is subject to individual state's capabilities. Even more significantly, Article 4(6) provides that nothing in the Convention shall affect the sovereign rights of states to exploit, develop and manage their own natural resources pursuant to their own policies, taking into account their duty to protect and preserve the environment. Nonetheless, the Noumea Convention might provide, at a regional level, the legal basis for measures to regulate access to hydrothermal vents.

6.5 The Antarctic Treaty system

So far no hydrothermal vent sites have been identified in the vicinity of Antarctica or within Antarctic waters. Nonetheless the possible discovery of such sites cannot be ruled out. If so, the Antarctic Treaty system may provide a means of regulating access and activities in relation to hydrothermal vents. The most relevant instruments are the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR)[12] and the Protocol on Environmental Protection to the Antarctic Treaty (Madrid Protocol).[13]

CCAMLR

Under Article I (1) the CCAMLR applies to

> *"the Antarctic marine living resources of the area south of 60º South latitude and to the Antarctic marine living resources of the area between that latitude and the Antarctic Convergence which form part of the Antarctic marine ecosystem".*

Article II (2) defines Antarctic marine living resources to mean

> *"the population of fin fish, molluscs, crustaceans and all other species of living organisms, including birds, found south of the Antarctic Convergence."*

Arguably, species of molluscs and crustaceans associated with hydrothermal vents would fall within this definition. Other species, including bacteria and archaea found at hydrothermal vents, fall within the definition of "other species of living organisms". These species, if they exist within the area defined in Article I(1), would form part of the Antarctic marine ecosystem, which is defined in Article I(3) as

> *"the complex of relationships of Antarctic marine living resources with each other and with their physical environment."*

Therefore CCAMLR should apply to hydrothermal vents in areas covered by the treaty.

Article II(1) states that the objective of CCAMLR is the conservation of Antarctic marine living resources. Conservation is defined in Article II(2) as including "rational use" of Antarctic marine living resources. As such, harvesting of marine living resources and any associated activities must be conducted in accordance with a number of principles of conservation set out in Article II (3) of CCAMLR. These are

- prevention of decrease in the size of any harvested population to levels below those which ensures its stable recruitment
- maintenance of the ecological relationships between harvested, dependent and related populations of Antarctic marine living resources and the restoration of depleted populations to defined levels and
- prevention of changes or minimisation of the risk of changes in the marine ecosystem, which are not potentially reversible over two or three decades, taking into account the state of available knowledge of the direct and indirect impact of harvesting, the effects of the introduction of alien species, the effects of associated activities on the marine ecosystem and the effects of environmental changes, with the goal of sustained conservation of Antarctic marine living resources.

To give effect to these principles CCAMLR established the Commission for the Conservation of Antarctic Marine Living Resources. Among powers conferred on the Commission, Article IX(1)(f) grants the Commission power to formulate, adopt and revise conservation measures on the basis of the best scientific evidence available, subject to compliance with the Agreed Measures for the Conservation of Antarctic Fauna and Flora adopted by the Consultative Parties to the Antarctic Treaty. Pursuant to Article IX(2) these conservation measures can include

- designation of the quantity of any species which may be harvested in the area to which CCAMLR applies

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[12]Convention on the Conservation of Antarctic Marine Living Resources, Canberra, 20 May 1980, in force 7 April 1982; 19 I.L.M (1980).

[13]Protocol on Environmental Protection to the Antarctic Treaty, Madrid, 4 October 1991, entered into force 14 January 1998; 30 I.L.M. (1991).

- designation of regions and sub-regions based on the distribution of populations of Antarctic marine living resources
- designation of the quantity which may be harvested from the populations of regions and sub-regions
- designation of protected species
- designation of the size, age and, as appropriate, sex of species which may be harvested
- designation of open and closed seasons for harvesting
- designation of the opening and closing of areas, regions or sub-regions for the purposes of scientific study or conservation, including special areas for protection and scientific study
- regulation of the effort employed and methods of harvesting, including fishing gear, with a view, *inter alia*, to avoiding undue concentration of harvesting in any region or sub-region and
- taking of such other conservation measures as the Commission considers necessary for the fulfilment of the objectives of CCAMLR, including measures concerning the effects of harvesting and associated activities on components of the marine ecosystem other than harvested populations.

If hydrothermal vents were found within the CCAMLR area then the provisions of this treaty could be applied to regulate activities associated with them. However, as with the continental shelf regime under the LOSC, there may be a number of problems presented by the terminology used in this convention. For example, in the context of hydrothermal vent species, do terms such as "harvesting", "harvested population" and "fishing gear" have any real meaning?

More significantly, given that so little is known about the hydrothermal vent ecosystem and the life span of individual hydrothermal vent fields, is it possible to identify "changes in the marine ecosystem which are not potentially reversible over two or three decades" as required by the principles of Conservation under Article II(3) of CCAMLR ?

Similarly, questions would remain about the applicability of such measures to non-party states on the high seas. However, unlike fisheries measures, most of the states active in hydrothermal vent research and bioprospecting are parties to CCAMLR. This includes countries such as South Korea, France, Australia,Germany, United Kingdom, Japan, USA and New Zealand. CCAMLAR therefore may offer a further source of law and an institution that could regulate activities at hydrothermal vents.

Madrid Protocol

The Madrid Protocol serves as a framework convention, which provides the basic features of the regime for environmental protection in Antarctica (Redgwell 1994).

Article 3(1) of the Madrid Protocol provides

> *"the protection of the Antarctic environment and dependent and associated ecosystems and the intrinsic value of Antarctica, including its wilderness and aesthetic values and its value as an area for the conduct of scientific research, in particular research essential to understanding the global environment, shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area."*

To this end Article 3(2) requires that activities in the Antarctic Treaty area shall be

> *"planned and conducted so as to limit adverse impacts on the Antarctic environment and dependent and associated ecosystems".*

As such, pursuant to Article 3(2)(b), activities in the Antarctic Treaty Area must be planned and conducted so as to avoid *inter alia*:

- significant changes in atmospheric, terrestrial (including aquatic), glacial or marine environments

- detrimental changes in the distribution, abundance or productivity of species or populations of species of fauna and flora or
- degradation of, or substantial risk to, areas of biological, scientific, historic, aesthetic or wilderness significance.

Significantly, Article 3(2)(c) also requires all activities to be "planned and conducted on the basis of information sufficient to allow prior assessments of, and informed judgements about their possible impacts on the Antarctic Environment". These principles apply to all activities in Antarctica (Harris and Meadows 1992). To the extent that specific activities are not regulated by the Annexes to the Protocol, these fundamental principles provide a benchmark against which all activity must be assessed.

One significant innovation of the Madrid Protocol is the requirement for environmental impact assessments to be undertaken for activities in Antarctica. Under Article 8 activities undertaken in the Antarctic Treaty Area pursuant to scientific research programmes, tourism and all other governmental activities are subject to prior assessment of the "impacts of those activities on the Antarctic environment or on dependent or associated ecosystems according to whether those activities are identified as having

(a) less than a minor transitory impact
(b) a minor or transitory impact; or
(c) more than a minor or transitory impact".

The procedure for this prior assessment is set out in Annex I to the Madrid Protocol and requires that the environmental impacts of proposed activities be considered in accordance with appropriate national procedures. By virtue of Annex I, Article 1(2), if an activity has less than a minor or transitory impact such activity may proceed. However, if a proposed activity will have more than a minor or transitory impact then compliance with the environmental impact assessment provisions of Articles 2 and 3 of Annex I become mandatory.

Article 2 of Annex 1 requires that, unless an activity will have less than a minor or transitory impact or unless a Comprehensive Environmental Evaluation is prepared under Annex I, Article 3, an Initial Environmental Evaluation (IEE) must be prepared. An IEE must contain sufficient detail to assess whether a proposed activity may have more than a minor or transitory impact. By virtue of Article 2(2) of Annex I if the IEE indicates that the proposed activity is likely to have no more than a minor or transitory impact then the activity can proceed. However, this is subject to implementation of appropriate procedures, including monitoring, to assess and verify the impact of the activity. Annex 3(1) of Annex I requires that if an IEE indicates or if it is otherwise determined that a proposed activity is likely to have more than a minor or transitory impact, a Comprehensive Environmental Evaluation (CEE) must be prepared.

The final decision on whether to allow an activity to proceed rests with the Antarctic Treaty Consultative Parties acting on the advice of the Committee for Environmental Protection, a permanent body established pursuant to Articles 11 and 12 of the Madrid Protocol. The comprehensive provisions requiring environmental impact assessment would provide a sound basis for assessing the potential environmental impact of activities such as bioprospecting and research at hydrothermal vents and for regulating such activities.

In addition, Annex V to the Madrid Protocol provides a mechanism for establishing protected areas and the regulation of activities in particular areas, which could also be used to regulate access to hydrothermal vents. Thus Article 2 of Annex V provides that any area

> *"including any marine area, may be designated as an Antarctic Specially Protected Area or an Antarctic Specially Managed Area".*

Antarctic Specially Protected Areas (ASPAs) can be designated to protect outstanding environmental, scientific, historic, aesthetic or wilderness values, any combination of those values, or ongoing or planned scientific research under Annex V Article 3(1). Article 3 of Annex V specifically requires parties to identify within a systematic environmental and geographical framework specific categories of areas to be established as ASPAs. Categories that are relevant to hydrothermal vents include

- representative examples of major terrestrial and marine ecosystems (Annex V, Article 3(2)(b))
- the only known habitat of any species (Annex V, Article 3(2)(d))
- areas of particular interest to ongoing or planned scientific research (Annex V, Article 3(2)(e)) and
- and examples of outstanding geological or geomorphological features (Annex V, Article 3(2)(f)).

Under Annex V Article 4(1) Antarctic Specially Managed Areas can be established in areas where activities are being conducted or may be conducted in the future so as to assist in the planning and co-ordination of activities, avoid possible conflicts, improve co-operation between parties or minimize environmental impacts. ASMAs may also include areas where activities pose risks of mutual interference or cumulative environmental impacts (Article 4(2) (a)).

Antarctica as a model for regulating bioprospecting on the high seas.

The similarities between Antarctica and the deep ocean floor of the high seas are striking. Both are harsh environments. The ecosystems of both are heavily dependent on one form of life; in the case of Antarctica it is krill, for hydrothermal vents it is bacteria and archea. Both occur in areas beyond national jurisdiction, both are of interest to science and both have resources that many wish to exploit.

So far no measures have been implemented to specifically regulate bioprospecting in Antarctica or within Antarctic waters (Rothwell 2003). However, the legal instruments discussed above could be used in designing a regime to regulate bioprospecting in Antarctica. Any future high-seas regime could draw on the experience in Antarctica. Developments in relation to regulating bioprospecting in Antarctica should be watched closely as they may provide an example for regulating activities in other parts of the high seas including at hydrothermal vents

7. CONCLUSIONS

Access for bioprospecting at hydrothermal vents on the high seas is currently unregulated. The CBD (and contracting states) appear to have made little progress on this issue. Despite an eight-year study the response to the SBSSTA has resulted in only further recommendations for yet further studies. On the other hand, the ISA and some member states seem to be reluctant to contemplate anything more than operating within the limits of the existing mandate of the ISA.

There are many reasons why activities at hydrothermal vents should be regulated, not least the importance of their biodiversity and the threats posed by human activity in the deep sea. This paper has outlined a number of possible options beyond the ISA and the CBD that could be explored. As activities such as bioprospecting occur more frequently in the deep sea, we need to take effective measures to ensure protection of the unique biodiversity of one component of the most typical habitat of our planet. As interest in the potential of biotechnology from the deep sea grows, so the need to take effective measures is becoming ever more urgent.

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FAO FISHERIES PROCEEDINGS **3/2**

Deep Sea 2003: Conference on the Governance and Management of Deep-sea Fisheries

Part 2: Conference poster papers and workshop papers

Queenstown, New Zealand, 1–5 December 2003
Dunedin, New Zealand, 27–29 November 2003

This second volume of the Proceedings of the Conference on the Governance and Management of Deep-sea Fisheries, held in Queenstown, New Zealand, from 1 to 5 December 2003, contains papers developed from many of the presentations in the Poster Session of the Conference. Poster-papers presented in this volume address issues of deep-sea oceanography, ecology, fisheries management and governance.
The second part of this volume of the Proceedings contains papers that were presented at the workshops held in Dunedin, New Zealand, from 27 to 29 November, just prior to Deep Sea 2003. There were four workshops that addressed the topics of: (i) Assessment and Management of Deepwater Fisheries; (ii) Management of Small-scale Deep-sea Fisheries; (iii) Conservation and Management of Deepwater Chondrichthyan Fishes; and (iv) Bioprospecting in the High Seas.

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