Ecology of the barracudinas (*Aulopiformes: Paralepididae*), a ubiquitous but understudied mesopelagic predatory fish family, in the Gulf of Mexico

by

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Abstract

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The *Deepwater Horizon* oil spill in 2010 prompted an enormous survey effort to assess the under-studied, deep-ocean ecosystems of the Gulf of Mexico. The resulting samples and datasets afforded a unique opportunity to study the ecology of a poorly known group of mesopelagic fishes, the barracudinas (Aulopiformes: Paralepididae). Here we address several important data gaps regarding the ecology of the Paralepididae. Our results indicate that a majority of barracudina species are efficient at avoiding research-sized nets, suggesting that their overall abundance has been historically under-estimated. Notable differences in vertical distribution, seasonal abundances of sizes classes, and diets were observed among the three major sub-groups of the family, with potential implications to ecosystem-based management of deep-pelagic fisheries. This thesis is dedicated to all the fish, squids, and shrimps that gave their lives to make these data and to those that endured the hardship of the *Deepwater Horizon* oil spill.

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Chapter One: Introduction

Small swimmers, big problems

Barracudina (Paralepididae) are a family of small to medium sized, Aulopiformes fishes found in deep pelagic waters of temperate and tropical oceans globally. Barracudina are most frequently documented in the mesopelagic (the area of the water column where photosynthesis is no longer possible but low levels of light still persist) and are relatively large members of an assemblage of “small-swimmers”, or micro-nekton. They are uncommon mesopelagic fishes compared with the super-abundant lanternfishes (Myctophidae) and bristlemouths (Gonostomatidae) and their diversity is also comparatively low (Rofen, 1966; Sutton, 2013). It is thought that they do not participate in diel vertical migration and may frequently evade most trawling net types because they are fast swimmers (Rofen, 1966) which have led them to be largely overlooked by research-sized landing gear.

Despite their rarity in fisheries independent sampling, barracudina are frequently found in the stomachs of deep diving tunas (Fourmanoir *et al*., 1971; Matthews *et al*., 1977; Kornilova, 1980; Moteki *et al*., 2001; Pusineri *et al*., 2005; Portier *et al*.,2007; Battaglia *et al*., 2013), swordfish (Scott & Tibbo, 1968; Stillwell & Kohler, 1985; Moteki *et al*., 2001; Chancollon *et al*., 2006; Navarro *et al*., 2017), and Opah (Choy *et al*., 2013), which implicates them as an important food source to these economically valuable pelagic predators. Very little is known regarding the ecology of barracudina, however, and many taxa are currently difficult to identify to species. With increasing pressure on deep-pelagic ecosystems from expanding fisheries (Norse, *et al*., 2012; St. John, *et al*., 2016), climate change (Robinson et al., 2010; St. John, *et al*., 2016) and oil spills (Fisher *et al*., 2016), it is increasingly important for managers and researchers to have access to a greater base of ecological knowledge regarding intermediate consumers, such as barracudina, as developing ecosystem-based management schemes becomes an apparent necessity to protecting the sustainability of marine resources.

The diversity of mid-water "forage fishes", those abundant small varieties which act as food for bigger varieties, is critical to the stability of many economically important fisheries and pelagic ecosystems generally. Small, yet abundant and speciose, nekton comprise an important trophic link in deep pelagic ecosystems where the higher trophic levels of food webs are heavily influenced by the metabolism, species richness, and community dynamics of intermediate consumers at a regional scale (Cury *et al*., 2000; Fock *et al*., 2002; Duarte & Garcia 2004; Porteir et al., 2007; Dambacher *et al*., 2010; Robinson et al., 2010; Griffiths *et al*., 2012; Madigan *et al*., 2012; Engelhard *et al*., 2013; Pikitch *et al*., 2013). It has even been theorized that the collective biomass and activities of these assemblages may contribute to oceanic carbon cycling and, in turn, global climate dynamics (Wilson *et al*., 2009; Robinson et al.,2010; St. John *et al*., 2016).

Most of the habitable space on the planet is in the deep ocean and it is estimated that 10 – 15% of global fish diversity resides there (Haedrich, 1996; Sutton, 2013; St John *et al*., 2016). In these deep pelagic ecosystems, where primary production occurs only remotely, and food webs are comprised of myriads of consumers, species composition and richness of trophically intermediate assemblages can have far reaching implications (Cury *et al*., 2000; Dambacher *et al*., 2010; Sutton, 2013). Trophodynamic modelling efforts of epipelagic waters (Cury *et al*., 2000; Giacomini *et al*., 2012) have demonstrated that in low-productivity pelagic environments biomass accumulation by small fishes is slow, but consistent, and therefore compatible with high levels of species richness as functional responses are slowly or incompletely saturated. Study of the topological features of such food-webs have highlighted the importance of “highly centralized” intermediate consumers (such as shrimp; see Navia *et al*., 2016) but also the importance of functional complementarity to the overall resilience of those ecosystems (Lindegren *et al*., 2015). Such ecological interrelationships are clearly important in understanding the cross-roads of climate change and fisheries resources (Young *et al*., 2015). Especially in mid-latitude pelagic habitats, such as the GoMx, the complex interactions of “top-down” and “bottom-up” tropho-dynamics seems to indicate that the intermediate assemblages are a likely driver of overall fishery productivity (Frank *et al*., 2006).

While the dimly lit waters of the mesopelagic remain comparatively little studied, it is probable that organisms there represent a sizable portion of pelagic biomass globally (Irigoien *et al*., 2014), and this, in turn, is likely facilitated by that habitat’s unique array of species richness (Robinson *et al*., 2010). This shadowy biomass presents new opportunities for fisheries expansion and nutraceutical resources with the promise of untold levels of deep-sea biomass attracting certain market interests to meet the rising global demand for fish meal and oil (St. John *et al*., 2016). However, these proposed fisheries are likely to be inherently unsustainable because, while many deep-sea taxa may be locally or seasonally abundant (i.e. near sea mounts), their comparatively slow rates of growth make them susceptible to overexploitation that could result in complete ecosystem collapse (Norse *et al.*, 2012; St. John *et al*., 2016).

As exploitation of the deep pelagic environment increases, human induced stressors on those environments from both the top-down and the bottom-up are likely to compound and exacerbate degradation in ecosystem function and composition. In an environment where very little is known regarding even the most basic aspects of the biological community, uncertainty about sustainability of this exploitation is high. What is known seems to indicate that the midwater, intermediate trophic assemblages likely have numerous direct and indirect relationships with economically important fisheries in surface waters. Evidence is mounting that much of the small nekton foraged by migratory predators in tropical oceans resides in the mesopelagic. Gut surveys of tunas and billfiishes (Manooch & Hogarth, 1983; Williams *et al*., 2015; Portier *et al*., 2007; Huse *et al*., 2013) support that certain epipelagic fishery targets are regularly diving to forage on mesopelagic nekton. Furthermore, efforts in tracking the movements of such fishes (Brunnschweiler *et al*., 2009; Gore *et al*., 2008; Bonfil *et al*., 2005; Theisen & Baldwin, 2012; Wilson & Block, 2009; Lawson *et al*., 2010) have shown that diving to mesopelagic depths is common. Increasing fishery pressure on these large migratory predators has brought about a demonstrable reduction in biomass in their largest size classes over the past 100 years (Sibert *et al*., 2006; Christenen *et al*., 2014) which has led to increased concern regarding the impact of trophic cascades in open ocean ecosystems. As stocks of the megafaunal fisheries of the central Pacific have declined, for example, evidence is growing that mesopredators, such as lancetfish (*Alepisaurus* spp.), are becoming more abundant while megapredators, such as tuna, dwindle (Choy *et a*l., 2013).

The actual ecological impacts of these cascades are complex and presently unclear. In this context, without foundational ecological knowledge regarding the basic components and relationships of deep-pelagic ecosystems on a regional basis, there is no meaningful way to predict whether pelagic resources are sustainable or not and at what spatio-temporal scales.

The *Deepwater Horizon* and the Gulf of Mexico

Such concerns were brought abruptly to the center of attention for managers in the Gulf of Mexico (GoMx) when the *Deepwater Horizon* (*DWH*) oil spill occurred during the summer of 2010. The *DWH* blowout originated deeper and directly affected a much greater volume of water than any previous marine oil spill (Fisher *et al*., 2016). Collectively, 90% of the volume in the Gulf of Mexico (GoMx) is deeper than 200 meters and, since the Macondo well-head blew at 1500 meters, the deep pelagic was the first and largest ecosystem impacted by the disaster. Furthermore, it is likely that a sizable portion of the oil formed a plume and remained deep for several months after the spill due to the physical properties of oil at depth, the direct injection of dispersant at the wellhead, and the local geomorphology near the *DWH* site (Valentine *et al*., 2014). Owing to the extreme and remote nature of this habitat, data on basic ecological phenomena were poorly characterized at the time of the spill, therefore, understanding the short and long-term impacts of this disaster on the deep-pelagic habitat was impossible without more data. To this end, the disaster inspired new research into the deep pelagic of this fascinating ocean region, of which the present work is a small constituent.

It is generally understood that, when compared with higher latitudes, mid and low latitude pelagic ecosystems tend to have relatively low primary production yet high species richness (Angel, 1993). Unlike most oligotrophic pelagic systems, however, the GoMx exhibits a suite of physical dynamics and primary production is seasonally driven by outflow from the Atchafalaya and Mississippi Rivers over the continental shelf and seasonal gyres in more pelagic waters offshore. While the rate of fish endemism in the GoMx is technically too low to categorize it as a distinct bioregion (McEachran, 2009) the unique overlap of temperate-Atlantic and tropical-Caribbean taxa define the GoMx as a pelagic ecotone with mixtures of species richness not found elsewhere (Richards *et al.*, 1993; McEachran and Fechhelm, 1998). At the base of this system, massive input of nutrients from riverine outflow drives phytoplankton blooms which later contribute to organic carbon in deep pelagic waters (Walsh *et al*., 2015; Daly *et al*., 2016; Fisher *et al*., 2016). After the *DWH* spill, the abrupt input of dispersant and oil resulted in an increase in biomass of heterotrophic prokaryotes and a decrease in ciliates and dissolved oxygen, indicating a reduction in grazing pressure and a potential decrease in transfer of carbon to higher trophic levels (Ortmann *et al*., 2012; Du and Kessler, 2012). Additional hydrocarbons were transported to depth by way of suspended oil droplets in marine snow as well as in oiled Sargassum mats which sank to the bottom, creating large anoxic areas on the sea floor (Powers *et al*., 2013; Fisher *et al*., 2016).

While much of the direct fall-out from the *DWH* has been documented, a comprehensive understanding of the effects of the fall-out on the deep ecology of the GoMx has remained elusive. The complexity of the GoMx oceanography provides further frustration on this issue and is worth taking time to briefly describe. In the epipelagic GoMx, anticyclonic activities of the Loop Current define the GoMx and greatly influences the ichthyofaunal assemblages by entraining larval recruits from Caribbean waters with nutrient rich coastal waters, then distributing both throughout the Gulf and, eventually, through the Florida straits and Gulf Stream (McEachran and Fechhelm, 1998). After the *DWH* accident, much of the surfaced oil was entrained in a similar fashion but its horizontal distribution in the epipelagic was muted partly due to the prodigious use of oil dispersant and partly to the persistence of anticyclonic eddies spawned by the loop current at that time, which helped to trap much of the oil in the Northern GoMx (Joye *et al*., 2016). Knowledge of seasonal phytoplanktonic production in this area based on satellite imaging holds that the GoMx trends toward regular, spatio-temporal variability with minimum productivity occurring between May and July, greater variability in the western region compared to eastern, and entrainment of riverine water mass along the cyclonic edges of the loop current (Müller-Karger *et al*., 1991). Early biophysical modelling of these oceanographic trends suggested that the most important factor controlling the seasonal cycle in surface phytoplankton concentrations is the depth of the mixed layer (Müller-Karger, *et al*., 1991). More recent research in modelling fisheries independent stock assessment highlights the potential import of this horizontal heterogeneity to tunas and billfishes as spawning and nursery habitat (Muhling *et al*., 2010; Simms *et al*., 2010; Hazen *et al*., 2016). Despite the potentially negative implications, the impact of the spill on these important epipelagic fish assemblages is tentatively null. Rooker *et al*. (2013) in assessing the larval composition of commercially important, epipelagic fish taxa (namely tunas and billfishes) found no significant differences in abundances before and after the *DWH* event, however, the authors cited monthly variability as a potential factor obscuring the visibility of deleterious trends following the spill.

Assessment of deep-pelagic hydrocarbons and dissolved oxygen levels after the *DWH* spill (Du & Kessler, 2012), as well as work with polycyclic-aromatic hydrocarbon concentrations in common mesopelagic fishes (Romero, I. pers. comm.), indicate that the effects of a sustained plume of oil between 1000 and 1200 meters persisted for several years after the incident (see also Valentine *et al*., 2013). A high degree of vertical migration has been characterized among taxa found in this depth range in the GoMx (Hopkins *et al*., 1996). Therefore, it is likely that many of these fishes were chronically exposed to this plume and transporting its effects through the water column over the course of their life histories. In considering the specific impacts of the *DWH* spill on the deep GoMx, quantifiable baseline data, notably time series information on biological composition, abundance, and connectivity to surface assemblages, are essential. Because the pelagic GoMx is such a complex ecosystem that supports economically important fisheries and ecosystem health regionally (Adams *et al*., 2004), it is imperative that this complexity is characterized with the greatest resolution available.

Barracudina: Shots in the Dark

The specter of compounding anthropogenic stressors (overfishing, climate change, plastic pollution, oil spills) underscores the importance of accumulating granular, baseline ecological data to inform management criteria and decisions. However, the study of mid-water nektonic assemblages remains challenging. Direct, fisheries independent sampling of that environment is difficult, expensive, and often plagued by inconsistencies in data collection and sampling biases (Klevjer *et al*., 2016). Recent hydroacoustic surveys have demonstrated that a sizable portion of the mid-water fauna may be under-represented by research-grade trawling methods due to net evasion by nekton (Kaartvedt *et al*., 2012; Handegard *et al*., 2013; Klevjer *et al*., 2016). A few researchers have even argued that this bias should be understood to skew worldwide projections of deep pelagic biomass by at least an order of magnitude (Webb *et al*., 2010; Irigoien, *et al*., 2014). At such depths, it is difficult to run most net-types at speeds greater than a few knots, and so, net evasion is possible for the more capable swimmers. The extent to which this sampling bias pervades is slowly being untangled thanks to modern hydro-acoustic technologies (Kaartvedt *et al*., 2012; Handegard *et al*., 2013; Klevjer *et al*., 2016). However, at the time of this writing, this technology is only capable of quantifying abundances at a fairly course taxonomic level (e.g. all large fish without swim-bladders are categorized together; see D'Elina, *et al.,* 2016). While this technology is extremely important to reducing the costs and increasing the precision of mid-water nekton surveys, it must be paired with detailed taxonomic resolution of those assemblages to provide the most accurate information for management criteria.

Barracudina exhibit several advanced adaptations typical to many nektons of the deep pelagic, such as the lack of a swim-bladder, simultaneous hermaphroditism, and bioluminescence (only in some species). However, unlike many of their mesopelagic counterparts, barracudina retain a general body morphology that allows for a certain amount of sustained speed, and it has long been known that most barracudina species easily evade trawling nets (Harry, 1953), likely due to their stream-lined body form. Extremely rare observations of live barracudina behavior underscore this potential for net evasion and hints to other aspects of their ecology. Observations from the voyage of the French Navy's *Bathyscaphe Trieste I* in the early 1950s (Furnetin, 1955; Pere et al., 1957; Tregouboff, 1958; Houot, 1958) provided several first-hand accounts of barracudina. One such observation published in National Geographic (Houot, 1958) likely describes a bioluminescent Lestidiinae species (either *Lestidium atlanticum* or *Lestrolepis intermedia*), swimming like "rapid streaks, long and slender and very brilliant". At about 600 – 700 meters depth, the bathyscaphe encountered numerous fast swimming fishes "like silvery javelins…slender creatures in the abyssal blackness, darting up and down in lightning spurts like…high-speed elevator[s] or drifting slowly beside the gondola, stiffly erect like asparagus" (Houot, 1958). In other reports, *Arctozenus* (=*Notolepis*) *rissoi* were seen from the *Trieste I* in the mesopelagic of the Mediterranean where the silvery fishes were noted to hold themselves "rigidly upright, at times motionless but with fins vibrating, and then darts rapidly away oriented horizontally" (Furnestin, 1955; Peres *et al.*, 1957; Tregouboff, 1958). Later observations by surface researchers in the Mediterranean reported that adult (~40 cm SL) *Sudis hyalina* attacked mooring cables they may have confused with prey, partially severing the lines in the process by glancing them with their extremely sharp teeth (Haedrich 1965).

Figure 1- Photograph of an adult duck-billed barracudina (*Magnisudis atlantica*) In situ floating in an oblique orientation. Taken by the Okeanos Explorer ROV in the Gulf of Mexico, 2017.

Later reports from the *Deepstar 4000* submersible diving off the coast of San Diego observed unidentified, vertically oriented barracudina in “a highly active state” (Barham, 1970).

Given these rare behavioral observations, it should not be surprising that barracudina, especially the larger size classes, are infrequently represented in fisheries independent sampling yet frequently found in the guts of fast swimming apex predators. It is quite possible that overall abundances of barracudina are grossly misrepresented by fisheries independent sampling and are a sizable portion of that biomass documented to evade deep trawls by hydroacoustic techniques. However, it is also possible that barracudina are only abundant at certain localities or times, or that they are simply infrequent. Too little information exists to make these inferences with certainty.

In any case, the ecology of most species of barracudina has been poorly or incompletely considered in all ocean basins with little interest to drive research and few data to inform characterizations. During the entire 20th century, only a half dozen or so researchers can be credited with developing the current scientific understandings of the Paralepididae. Perhaps the most useful to managers has been the work of Rofen (1966), who published an exhaustive array of morphological, taxonomic, ecological, and behavioral information on this poorly studied group in his contribution to the preeminent *Fishes of The Western North Atlantic* series and his work still stands out in its extensive treatment of these fishes. Rofen eloquently and extensively delineated many interrelationships still accepted today but he had categorized the various families of Aulopiformes as part of the anachronistic order Iniomi which, at the time, also included lanternfishes (now Myctophiformes). The Iniomi order has since been dissolved and undergone extensive reclassification. Much of the data Rofen worked with concerning barracudina came from an eclectic group of disparate sampling efforts, chief of which being the reports by Ege (Ege, 1930) on the results of the circumglobal mid-water surveys by the Danish research vessel the *Dana*. From data such as these Rofen was able to compile an exhaustive description of the known barracudina species, including morphometric, meristic, dietary, vertical and geographic distributions. However, the size classes represented in his data were largely composed of small (<40 mm SL) individuals, and often data was informed by samples sizes that were as small as one or two, post-larval specimens per sampling location. While the work by Rofen was instrumental to defining this group, it was far from complete.

After Rofen, only occasional and scattered publications appeared treating the Paralepididae over the past 50 years, either describing range expansions (e.g. Post, 1971; Lear & May, 1970; Uyeno *et al*., 1983; Moore, et al., 2003; Kim, *et al*., 2007; Ali, *et al*., 2014), presence in the guts of large, predatory fishes (e.g. Matthews *et al*., 1977; Kornilova, 1980; Moteki *et al*., 1993; Pusineri *et al*., 2005; Portier *et al*.,2007; Battaglia *et al*., 2013; Scott & Tibbo, 1968; Stillwell & Kohler, 1985; Moteki *et al*., 2001; Chancollon *et al*., 2006; Navarro *et al*., 2017; Choy *et al*., 2013), or describing new species (e.g. Rofen, 1963; Post, 1969(a); Post, 1969(b); Post, 1970; Kartha, 1970; Post, 1978). Much of the more extensive work with Paralepididae that followed Rofen involved the taxonomic treatment of the order. Notably, Baldwin and Johnson (1996) tentatively described Alepisauroidei as a distinct clade of Aulopiformes that represented a pelagic divergence from demersal lizardfishes (i.e. Synodontidae, Bathysauridae). Baldwin and Johnson cited several shared, derived characters of Alepisauroids in their skulls and pigmentation, however, they did not rule out the possibility of homoplasy within Alepisauroidei, and they were especially inconclusive regarding the interrelationships of the Paralepididae (Baldwin & Johnson, 1996). Following this work, Davis and Fielitz (2010) and Davis (2010) utilized diagnostic characteristics, molecular and mitochondrial markers, and fossil records among select taxa of Aulopiformes to conduct a Bayesian driven analysis of known, systematic relationships and to establish a more definitive taxonomy of interrelationships. Their findings confirmed the monophyly described by Baldwin and Johnson (1996) between *Alepisaurus* and *Omosudis* as well as that of *Anotopterus* and some Paralepidid genera but rejected the established interrelationships of Paralepidids and *Sudis*, a genus which Davis and Fielitz determined predated all other taxa within that clade, including Alepisauridae, and likely warranted family status (Sudidae). This discourse resulted in a relatively solidified understanding of Aulopiformes overall but a newly confused understanding of the previously monophyletic family of Paralepididae. Davis and Fielitz (2010) and Davis (2010) results indicate that many previously recognized synapomorphies, such as lack of squamation, are not necessarily plesiomorphic within Alepisauroidei as previously suspected. Most recently, Ghedotti *et al*. (2015) assessed the histology of bioluminescent cells derived from hepatopancreatic tissues in the “naked barracudina” (Lestidiinae), as well as seven molecular markers and one mitochondrial marker, to establish a clade that addresses this ambiguity regarding the more derived barracudina. Their findings supported the notion that the more derived Paralepidids (i.e. *Lestidiops*) warrant a unique family status (Lestidiidae) as well.

Nelson *et al*. (2016) cited these varied perspectives of Alepisauroidei taxa in their most recent edition of *Fishes of The World* and this represents the most contemporary understanding of the group. This synthesis defines the suborder Alepisauroidei as having six family groups: pearleyes (Scopelarchidae), sabertooth fishes (Evermannellidae), lancetfish and hammerjaws (Alepisauridae), and the respective barracudina families (Sudidae, Paralepididae and Lestidiidae; as per Nelson et al., 2016). While the evidence for this classification is compelling, a more conservative view will be employed for the purposes of the present work and the original sub-family distinctions will be maintained (i.e. the Paralepidinae, Lestidiinae, and Sudinae). This is meant to limit the scope of the present analysis to the barracudinas while excluding the larger and ecologically distinct *Alepisaurids*. Given the phylogeny described by Davis & Fielitz (2010) nearly the entire Alepisauroidei grouping would need to be assessed as “barracudinas” if the contemporary perspective is held. However, this present work is chiefly concerned with the subtle differences in ecological functionality and natural history of the closely allied taxa of the original “Paralepididae”. Furthermore, when barracudina are mentioned in contemporary publications, whether in fishery independent sampling or as stomach contents in fishery target taxa, the species belonging to the three families (Sudinae, Paralepididae, Lestidiidae) are still usually referred to as the single “Paralepididae” which underscores the utility of treating these fishes as a contiguous group. As a slight exception, *Anotopterus pharoa* will be included here, even though in older classifications it was allotted its own family status. Morphological evidence places *Anotopterus* within the Paralepididae (Baldwin & Johnson, 1996).

Objectives

As large-scale, systemic pressures continue to compound on pelagic environments from both the top and the bottom of ecosystems, the need for understanding the basic natural histories of intermediate, deep-pelagic assemblages has become an increasing necessity for defining management priorities and goals in the pelagic realm. The *DWH* oil spill presented a unique opportunity, and an urgent need, to develop baseline data on those assemblages in the GoMx as a first step toward such goal setting. Barracudina, while under-represented and not as abundant nor diverse as some other deep-pelagic fish groups within the catches, may prove to be useful indicators of the pelagic environment’s ability to support the large migratory predators which prey upon them. The comparative rarity of barracudina may make them a potentially effective sentinel of change, and subtle differences in the natural history of the various taxa may prove to reflect topological features of the greater ecosystem.

Using an extensive database collected in the years following the *DWH* spill, this work hopes to provide a usable “field guide” to the barracudina species of the GoMx and information on their natural histories for future management purposes. To this end, the first and most important goal of the present thesis is to publish what species were found by these sampling efforts, in what abundances, and to provide a convenient key to their identification. For each of the respective species, in turn, the objectives to describe them become three-fold: 1) provide complete descriptions of adult specimens to ease identification, 2) publish new records of greatest known sizes, as well as geographic, seasonal, diel, and vertical extents in the GoMx (compare with Thompson, 2003; fishbase.org; gulfbase.org), and 3) describe the dietary habits of adults, which have previously been only modestly treated in the region (see Hopkins *et al.*, 1996). Describing ontogenetic and/or reproductive trends observed, which has not been assessed for most of these taxa as far as this author is aware, is another, related goal of dietary surveys. Ideally, this work will be a compendium of baseline information on this obscure, but potentially ecologically relevant, group in the GoMx and a tool for future researchers. Another objective of this work will be to characterize the degree and extent of net evasion among these fishes. Also, of interest is any change the data may show between the sampling events closer to the spill and those years later, however, this objective is difficult to query or accurately characterize without sufficient pre-spill baseline data to compare with and a myriad of concomitant oceanographic variability to consider. Ultimately, the ability to operationalize these varied objectives will be limited by sample sizes and their respective dispersions in time and space.

The first objective will require a series of morphometric investigations on larger specimens, which are rare among published works on barracudina. This will not, necessarily, involve testable hypotheses, but rather accounts of species descriptions will be made following precedent of previous work (see Methods section) and multiple measurements of multiple specimens will be used to create ranges for key diagnostic measurements which will be compared to previously published numbers. Similarly, the maximum standard lengths of specimens captured by these efforts will be compared with maximum recorded standard lengths in the available literature to determine any record breaking specimens in this dataset.

The second objective involves a series of discrete, but related, statistical tests regarding sample distributions in time and space. While the interactive effects of environmental variables in the pelagic realm can be enormously complicated and impactful on the distributions of micronekton, for the purposes of the present work, explicating basic trends at a regional level is acceptable. In constructing hypotheses for the geographic distributions of the various taxa, it has been previously reported that horizontal distributions are far less predictive of species occurrences than vertical distributions among mesopelagic fishes in the GoMx (Hopkins, *et al.*, 1996). However, findings by USGS icthyoplankton sampling in the northern GoMx have demonstrated a possible trend for larval *Lestidiops affinis* to be more abundant along the margins of the continental shelf during spring months (Lyczkowski-Shultz, *et a*l., 2004). Additionally, analysis of larval fish composition along edge water masses of the Loop Current by Richards, *et al*. (1993), found Paralepididae larva to be highly associated with pelagic-demersal and neritic larval types, indicating a similar area of origin possibly near areas of up-welling (i.e. the continental shelf). Quite often the Loop Current has a distinct effect on the pelagic northern GoMx. However, for much of the year in 2011, when most of the samples concerned in this work were collected, the Loop Current was far out to sea and mostly beyond the range of the sampling transect (see Figure 2). Furthermore, as a guiding purpose of this work is to begin to characterize even a basic understanding of Paralepdididae distributions in the GoMx, answering the basic question of “where have they been found?” will be informative, and these hypotheses will help in distinguishing any regional patterns of distribution documented.

As can be seen in Figure 2 (compare with Figure 3) most of the warm water masses of the Loop Current are far from shore but may approach the southeastern extent of the study area to a varying degree. Additionally, Richards, *et al*., (1993) noted evidence of Paralepididae larva being more abundant along the western fronts of the Loop Current. When they sampled in the 1990s, the longitudinal position of the Loop Current was roughly approximate to where it was during 2011.

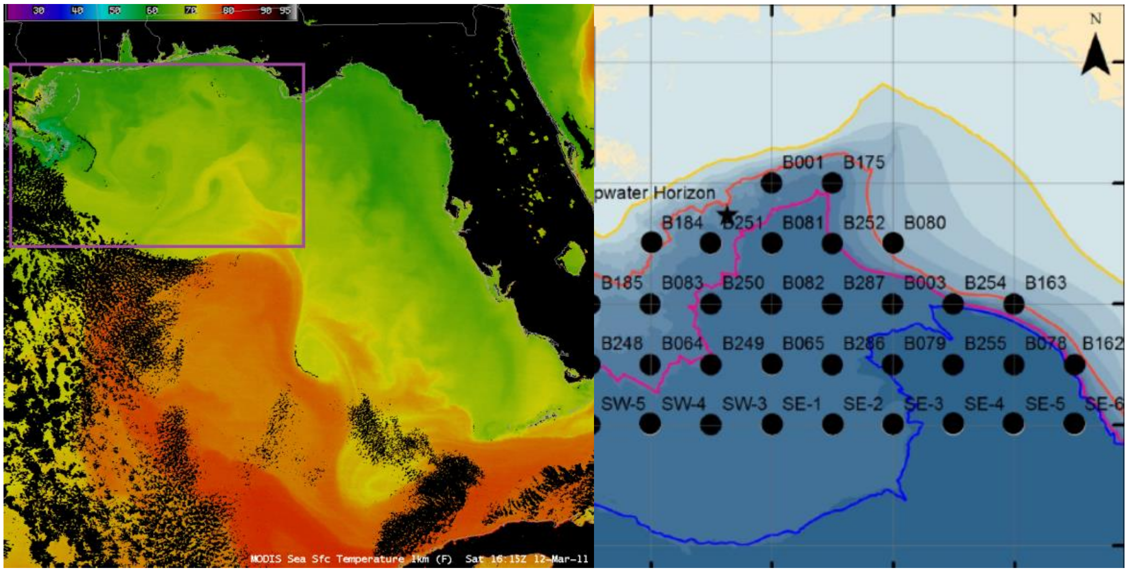


Figure 2 - A satellite derived Sea Surface Temperature map (left) of the eastern half of the study area (right) during March of 2011. The Purple box in the image to the left is a rough outline of the extent of the study area map on the right. The orange and red colors indicate comparatively warmer surface temperatures, which are approximate of the water masses associated with the Loop Current and its warm-cell filaments. The lowest latitudinal extent of the stations sampled extended to about the northernmost extent of this water mass and it is likely the Loop Current had little effect on the sampling area at that time.

“Seasons”, in this context, have been defined based on previously determined trends in seasonal variation of sea surface temperature and coastal phytoplanktonic production and concomitant export offshore (Müller-Karger *et al*., 1991). Sampling cruises assessed here have been roughly categorized under this broader context into “Winter” (December – February), “Spring” (March – June), and “Summer” (July – September) for the purpose of testing the hypotheses that species abundances and frequencies of size classes differ by season.

The third objective of this work is to describe the diets of adult specimens collected. Very little work has been done regarding the adult diets of barracudina in the GoMx, although what has been done indicates that mesopelagic fishes are likely an important aspect (Hopkins, *et al*., 1996). The assessment here of dietary patterns will be quite basic and be based purely on gut dissection surveys of adult specimens (no specimens had tissue samples taken before fixation in formalin, curtailing the implementation of stable isotopic analysis).

Describing the ontogenetic and reproductive aspects of barracudina will be another component of this work and will be comprised of a two-part approach: 1) assess if the observed distributions of size class frequencies differ by season, depth, or time of day, with different size classes treated as discrete populations and 2) determine if the presence of mature eggs in specimens is associated with an average standard length and/or season. All the aforementioned objectives will be organized into a “field guide” type format in the Results section, where each hypothesis is treated individually by species. The following sub-headings will organize the varied hypotheses in this format: Description, Similar Species in the Gulf of Mexico, Distribution (Geographic, Seasonal, Diel, and Vertical), Diet, Ontogeny and Reproduction.

Lastly, a comparison of the number of barracudina species and their respective abundances collected by the *Meg Skansi* surveys in 2011 and the *Point Sur* surveys in the years following will be attempted. These two vessels will be compared because they used the same trawling gear and sampling protocol, making comparisons of standardized abundances more applicable. Because the Loop Current had a greater extent in the study area during the years following 2011, geographic distributions are not easily comparable between the two cruise efforts. Therefore, standardized abundances will be assessed with special consideration given to specimens collected in “common water” by the *Point Sur* (water masses outside the influence of the Loop Current and its eddies) because it is assumed that all of the areas surveyed by the *Meg Skansi* in 2011 were also common water. It is likely that the best results possible from comparison of the two cruises will be to characterize some amount of inter-annual variation in barracudina assemblages and stocks and not, necessarily, to measure the impact of the *DWH* oil spill, as not enough baseline information is currently available to make that distinction with confidence.

Chapter Two: Methods and Hypotheses

Collection Methods

To counter the paucity of baseline, biological data at the time of the *DWH* oil spill, the NOAA Office of Response and Restoration facilitated the rapid creation of the Offshore Nekton Sampling and Analysis Program (ONSAP) through a series of academic and private sector agreements immediately following the *DWH* accident in 2010 (Fisher *et al*., 2016). The goal of this program was to provide independent data for use during the *DWH* Natural Resource Damage Assessment (NRDA) process. More recently DEEPEND (Deep Pelagic Nekton Dynamics of the Gulf of Mexico), a research consortium under the auspices of the Gulf of Mexico Research Initiative, has continued a time series trawl sampling of the GoMx into the present (2018).

Under the auspices of NOAA NRDA, the R/V *Pisces* conducted four cruises in the GoMx during 2010 and 2011 using a modified Irish Herring, High-Speed Rope Trawl (HSRT) which included a flow meter to record the volume filtered per tow/sample. The station grid chosen for sampling was a subset of the planktonic sampling grid called SEAMAP (Eldridge, 1988; see Figure 3), with stations occurring at whole and half degree latitude-longitude crossings in the GoMx, at approximately 25 km intervals, bounded by the 1000-meter isobath to the north, and the 27°N line of latitude to the south (~61,000 km^2). Sampling at each station was conducted day and night sequentially at each station to capture diel migration dynamics, with deployments centered around solar noon and solar midnight, respectively. Due to the nature of the *Pisces* modified trawling net, which had no closing mechanism, discrete depth bins were restricted to “shallow” and “deep” with trawls reaching depths between 0 to 700 and 0 to 1500 meters, respectively.

Additional sampling was later conducted on the merchant vessel *Meg Skansi*, with the same sampling grid as the *Pisces*, instead using a 10-m^2 rigid mouth area, 3-mm mesh, 6-net Multiple Opening Closing Midwater Net and Environmental Sampling System (MOCNESS) midwater trawl, a flow meter attached to the frame recorded the volume filtered at each respective depth strata and ship-board computers operated the opening and closing of the respective nets based on depth data collected at the net location (see Weibe *et al.*, 1985 for detailed description of unit). The MOCNESS sampling protocol was standardized at all locations (see Figure 4): net 0 fished from the surface to the maximum depth (usually 1500 m, bottom depth permitting); net 1 fished from 1500-1200 m depth; net 2 fished from 1200-1000 m; net 3 fished from 1000-600 m; net 4 fished from 600-200 m; and net 5 fished from 200-0 m. The NOAA NRDA rationale for sampling these depth strata was to characterize depths below, at, and above the depth range of a large hydrocarbon plume that had been reported to be persisting at 1000 – 1200 meters (Camilli *et al.*, 2010), as well as to characterize potential trends in vertical distribution of migrating and non-migrating taxa as reported by Sutton (2013). Subtracting the net 0 “oblique” samples (surface to maximum depth) from samples for which reliable flow data were not available provided a corrected dataset of quantifiable samples to be used in analyses. The M/V *Meg Skansi* trawling surveys were divided into three major campaigns: MS6 (Jan 25 – Apr 1 2011), MS7 (Apr 19 – Jun 30, 2011) and

MS8 (Jul 18 – Sep 30, 2011). MS7 coincided almost exactly with the time the DWH oil spill occurred one year prior.

An additional research vessel, the R/V *Point Sur*, was employed by the DEEPEND project with similar MOCNESS equipment and deployed to the same grid for seasonal sampling from 2015 up to the present year (2018). There has been a total of five DEEPEND cruises to date: DP01 (May 1 – 8 2015), DP02 (Aug 8 - 22 2015), DP03 (May 1 – 16 2016), DP04 (Aug 5 – 20 2016) and DP05 (Apr 29 – May 12, 2017), (see Figure 15) with a sixth planned for the summer of 2018. While the sampling periods were shorter than those conducted during the *Meg Skansi* campaigns, efforts were made to standardize sampling periods to similar seasonal ranges. Attention was also given to capturing notable oceanographic features of water masses associated within and without of the Loop Current and its eddies, and combined CTD, satellite, and AUV information was collated to inform and define key oceanographic features.

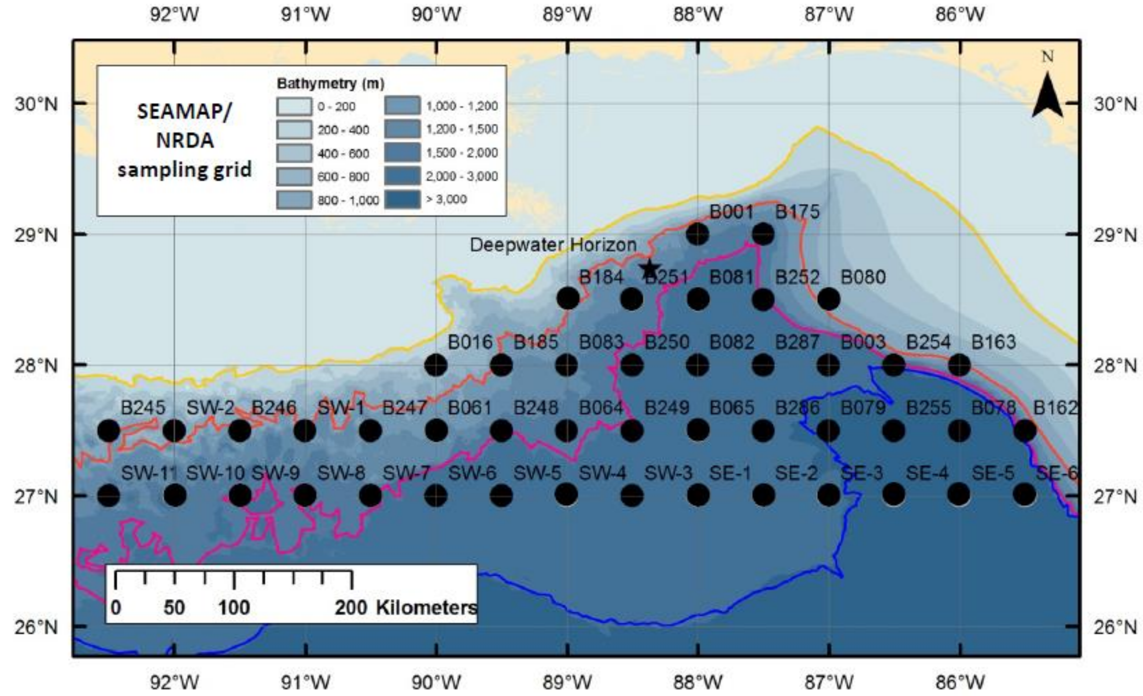
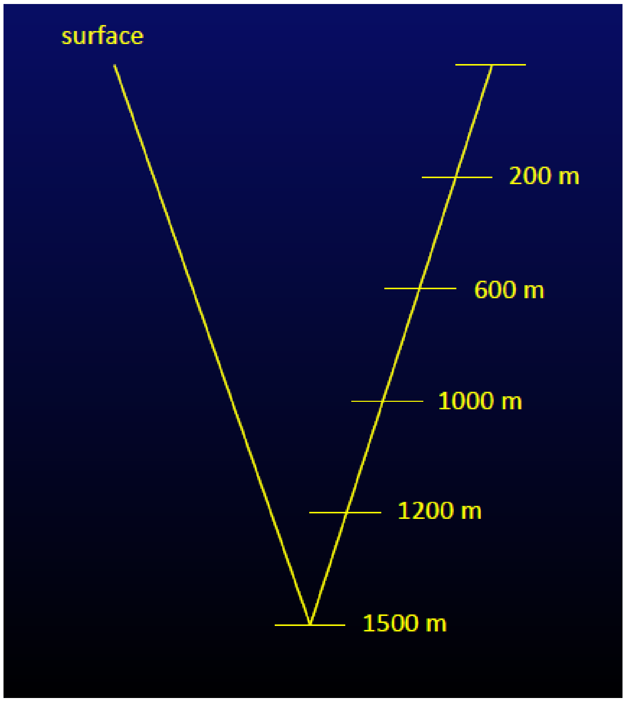


Figure 3 - SEAMAP sampling grid used by both NOAA NRDA and DEEPEND cruises (Eldridge, 1988); Note the location of the DWH marked by a star in the upper, left of the sampling area.



0 – 1500 meters	Net 0 (Set Begins)
1500 – 1200 meters	Net 1
1200 – 1000 meters	Net 2
1000 – 600 meters	Net 3
600 – 200 meters	Net 4
0-200 meters	Net 5 (set ends)

Figure 4 - Standardized depth strata for MOC10 sets, utilized by the NOAA NRDA M/V *Meg Skansi* and DEEPEND R/V *Point Sur*. The "V" in the figure to the left roughly represents the path of a typical set. The MOCNESS is deployed on the surface (top left) and takes an oblique sample of the entire water column (Net 0). Once the MOCNESS has reached a maximum depth, Net 1 opens and then closes at a specific depth, followed by the opening of the next consecutive net. Flow meters were used with each net.

All samples collected during the 2011 ONSAP field campaigns were archived at Alpha Analytical (Cambridge, MA) under Trustee custody. Parcels were shipped to Virginia Institute of Marine Sciences (VIMS) and later to Nova Southeastern University (NSU) for quantitative processing, and shipped back when processing was complete, with chain-of-custody procedures observed at every step of transport and during all stages of processing. During processing, all subsample split identifiers were linked to the parent sample per protocols approved by the NOAA NRDA Data Management Team. This data was later collated and compiled along with data from the DEEPEND cruises into the Gulf of Mexico Research Initiative Information and Data Cooperative (GRIIDC) network.

All specimens collected were identified to the lowest possible taxonomic level using standard meristic techniques (Strauss & Bond, 1990). The biomass of each taxon in each sample was determined by direct weighing (±0.01 g) after formalin fixation and/or after 70% ethanol:water curation. The relationship between post-formalin weight (x) and post-ethanol weight (y) was determined using paired measurements from samples and fit with a linear regression of $y = 0.8366x$ ($R^2 = 0.99$). This regression was used to standardize the biomass of all fish taxa in all samples to facilitate inter-sample comparisons. Size-frequency data were collected for all taxa by measuring up to 25 individuals of every taxon from every sample. Representative specimens of all lowest identifiable taxa were kept as species vouchers and photographed as a digital reference for taxonomic identification.

Abundances collected by discrete nets were standardized by taking the raw counts per net and dividing this number by the volume filtered through that net in meters cubed, then multiplying the resultant number by 1,000,000. This will be referred to throughout this paper as “abundance” or “standardized abundance” and is a method for comparing numbers caught across samples while accounting for catch per unit effort.

Morphometrics and Descriptions

Once NSU researchers had finished compiling the data as described above, specimens identified as “Paralepididae” were shipped to Florida Atlantic University (FAU) for further analyses. As most size classes represented in these data were juvenile or adult specimens, size classes were categorized by relevance to previously known ontogenetic changes in adult pigmentation and phenotype as described in particularly great detail by Rofen (1966), and to a lesser extent by Post (1984, 1987), McEachran and

Fechhelm (1998), and Ditty (2005). However, the bulk of the specimens in these data were above the size ranges Rofen had considered in his treatment of the group. Nonetheless, efforts were made to fit the spread of standard length present in these data to a level of categorization that would reflect meaningful size classes observed. Three specimens were measured for each species for each of these size classes when available. Efforts were made to include the smallest and largest specimens available in measurements. Morphometrics considered were measurements that had been previously described by Ege (1930) and further by Rofen (1966) namely "…those of head, snout, average length of large depressible teeth in lower jaw, diameter of eye, interorbital width, predorsal length, 'preanal length' (distance from tip of snout to anus), distance between pelvic fin origin and dorsal fin insertion, length of dorsal base, and distance between adipose fin and end of vertebral column" (Harry, 1953). Many of these characters are expressed as a percent of standard length (SL) to facilitate comparison across size classes. Standard length (SL) is the measured distance from the apex of the snout of a specimen to the terminus of the caudal body, in this case, the most posterior extent of hypural bone elements. Commonly used abbreviations in the species descriptions below include AFO (anal fin origin), AFR (anal fin rays), DFO (dorsal fin origin), DFR (anal fin rays), PVO (pelvic fin origin), and SL (standard length).

In addition to these morphometrics, characters that we found most useful in diagnosing taxa were also noted. To that end, pigment type, number and orientation were often most useful for identifying Paralepididae and, as such, notes were taken for representative samples regarding the presence/absence of those identifying characters at the respective specimens given size range. If characters or measurements fell outside the range of SL as described by Rofen (1966) then his ranges were amended with the new data. If they were the same or fell within his defined ranges, then no amendments were made and his were maintained. Only characters that proved helpful to identification were included in the Description section. Maximum known SL were referenced by McEachran and Fechhelm (1998), Fishbase.org, or in other works (in the below species descriptions, any new record max. SL represented in these data are indicated by an *; otherwise source for max SL is cited).

A section on "similar species" was added to directly address confusion among certain difficult-to-distinguish taxa. Idealized illustrations of adult specimens for each taxon are provided by Dr. Ray Simpson of the Yale Peabody Museum to aid in quick reference to the overall physiognomy.

Statistical Analyses

Before analyses were conducted, standardized abundances were calculated by dividing the raw number of counts per species per net by the volume filtered by those respective nets and multiplying the resultant value by 10^6. This standardized the count data to facilitate comparison across deployments. Throughout this thesis, when the term "abundance" or "standardized abundance" is used, it refers to the number of individuals per million cubic meters of ocean water in that depth strata. Occasionally, nets would fail, and no specimens were collected, or flow meters would fail, and volume filtered was not measured. For deployments where such accidents occurred, a note was made about it and those deployments were necessarily excluded from these analyses. (All the data, whether standardized or not, are presented in tables 1, 2, and 3 in the Results section).

While this dataset is extensive given the paucity of previous collections and efforts, it is still far too meager to treat every species with rigorous, parametric analysis for any given set of hypotheses. In most cases with these data, species abundances transformed to more idealized distributions (e.g. Log10) were still highly skewed with long tails which, in themselves, represented important data. Furthermore, applying more advanced multivariate methods (such as diversity indices or generalized linear models) would likely have added error terms that may be prevalent among samples likely to be committing some degree of pseudoreplication anyway.

Therefore, a nonparametric approach was applied to each respective hypothesis to compartmentalize sample populations by variables of interest. For each applicable hypothesis, a Wilcoxon method for comparison of means (Wilcoxon, 1945) was applied to standardized abundances using the statistical program JMP (JMP®, 2007). For hypotheses concerned with two "treatments" (i.e. near or far from shelf, day and night trawls, etc.) the statistical test administered was a Mann-Whitney test (Mann & Whitney, 1947). For hypotheses concerned with three or more "treatments" (i.e. seasonality, MOCNESS depth codes, etc.) the statistical test administered was a Kruskall-Wallis test (Kruskall & Wallis, 1952). These sign-ranked, nonparametric tests preclude the necessity to transform this non-normal data and make results somewhat more robust to breaches in parametric assumptions. However, since heterogeneity of variance was especially high among these data, a Levene's test (Levene, 1960) for heterogeneity of variance was performed for each hypothesis as well. If the null of Levene's test was rejected for a given hypothesis (at an alpha of 0.05), the Welch's permutational t-test/ANOVA method (Welch, 1990) was applied at an alpha of 0.025 to account for family-wise error.

The dietary hypotheses were treated by a different approach. Comparisons of gut contents were presented as percentages of number, frequency, and wet weight (see Dietary Analyses section) and combined into an index of relative importance for approximate comparisons. These results should not be interpreted as rigorous statistical analysis. Assessments of feeding chronology were tested implementing a ranked system of digestibility for gut contents and, again, should be interpreted as rough estimates rather than statistical test results (again, see the Dietary Analyses section for a more detailed description of these methods).

Ontogenetic analyses were queried using the nonparametric tests described above but the dependent variables assessed were the frequency of standard lengths rather than standardized abundances. All statistical methods in this work were treated by the methods described above and conducted with the SAS statistical program JMP (JMP®, 2007) unless stated otherwise.

Assessment of Net Evasion

As mentioned previously, it is thought that evasion of research-grade trawling nets has led to the gross under-representation of mid-water, nektonic assemblages in deep-sea research (Kaartvedt *et al*., 2012; Irigoien, *et al*., 2014) and that this is likely especially true of the Paralepididae (Harry, 1953). These data presented a unique opportunity to compare the catch per unit effort difference between standard, mid-water, research grade trawls (e.g. MOCNESS) and high volume, high speed rope trawls (HSRT) within the same spatio-temporal context.

$H1^0$

There is no difference in lengths of barracudina caught by MOCNESS and HSRT gear in the same sampling year (2011).

When this null is rejected it can be said that the different gear types capture differing numbers and differing lengths. This analysis was meant to define the tendency of net evasion by larger individuals with a single, accessible metric applicable to all species. The Mann-Whitney U test will be used to assess the differences of size classes above 70 mm and below by gear type along with graphed frequencies of specimens by length in millimeters by each species and gear type using the R statistical program (R Core Team, 2013) to provide context lengths caught by gear. If total sample numbers were lower than 15 for the given gear type or size classes of species assessed, simple descriptions of numbers caught were reported instead. The tendency of net evasion for all species of Paralepididae, collectively, were assessed by plotting the log 10 transformed mean standard lengths caught by gear type in a histogram and calculating statistical differences by t test with the R statistical program (R Core Team, 2013).

Distributional Analyses

The geographic, seasonal, diel, and vertical distributions of species collected in the 2011 sampling efforts were characterized, respectively (see the Statistical Analyses sub-section). The goal of these discrete analyses was to provide simple elucidations regarding possible population differences among species based on previously defined trends (see Objectives section). With the understanding that pelagic distributions normally have numerous confounding variables, and that these taxa are known to be pelagic, the following hypotheses are given as null but were constructed to test very general regional and meso-scale variations in observed abundances with respect to each species and trawling gear-type by sample.

H2^0

There are no differences in sample abundances of the respective barracudina species at stations within 25 km of the 1000-meter isobath and at those further from it.

This hypothesis considered all samples of a given species within a single sampling year. Because standardized abundances are the metric assessed, statistical treatment was further compartmentalized by trawling gear type which differed in rate of capture and volume filtered. When greater numbers were found farther from the shelf, this finding was approximated to that of null because the effects of the Loop Current are assumed to be muted during the sampling period (2011) and the purpose of this hypothesis was to test the potential degree of pseudoceanic (see Merrett, 1986) tendencies of these species which are otherwise assumed to be fully pelagic. Samples near and far from the shelf werre likely to vary depending on many factors, which is why an additional hypothesis arises considering season (see H5 for definition of "season"):

H3^0

There are no differences in sample abundance of the respective barracudina species at stations within 25 km of the 1000-meter isobath and those further from it by given season.

Sample "treatments" were defined here by region and season and lowered the respective sample sizes considerably but also reduced the degree of inter-seasonal variability in observed geographic distributions. Interpretations of H3 being accepted could vary and may depend on other available data and conclusions (e.g. standard length at season). The regional geographic question being assessed here concerns whether the latitudinal distributions of a given species change on a seasonal basis over all size classes.

A similar set of hypotheses was tested to assess a general, longitudinal division in the study area with special concern for the potential influence of water masses from the Loop Current (see Figure 2) or association with the Desoto canyon on the eastern portion of the study area during 2011:

H4^{0}

There are no differences in sample abundances of the respective barracudina species at stations on or east of the 88^{o} *line of longitude compared to abundances at stations west of it.*

The 88-degree line of longitude roughly divides the study area in half and compartmentalizes the eastern portion of the area in Figure 2 into regional subsets of stations from which samples are compared. Like the previous two hypotheses, these samples were further compartmentalized for seasonal variability:

H5^{0}

There are no differences in sample abundances of the respective barracudina species at stations on or east of the 88^{o} *line of longitude compared to abundances at stations west of it among seasons.*

Differences in abundances by season were tested and the null hypothesis for all size classes was:

H6^{0}

There is no difference in observed abundances among samples from the three, pre-defined seasons.

This hypothesis was to broadly compare the standardized abundances (by respective species and gear type) collected over the three seasons (see Objectives section for definition of seasons).

Paralepididae are understood, at this time, to not partake in diel vertical migration, the largest daily, mass migration of animal life on the planet (Rofen, 1966; Sutton, 2013). However, it is assumed that there is a high degree of net evasion among these fishes (Harry, 1953). As such, comparing abundances sampled during day time trawls and those during night was done to address the potential for visual-based net avoidance among barracudina and may help to understand the degree to which their abundances are under-represented.

$H7^0$

There are no differences in abundances observed during day time sampling and during night time sampling.

Again, this hypothesis was assessed within the data of each given gear type. When the null is rejected, and greater abundances are found at certain times of the solar cycle, comparison of standardized abundance with depth distribution data at solar sampling period visually help to address whether diel vertical migration is a factor in a given species' natural history. To this end, loop plots of standard abundance at MOCNESS depth were generated using the open source statistical program R (R Core Team, 2013). If the null was rejected and diel depth patterns are noted, it could mean that abundances congregate into a narrower depth range at a given time of day to feed than the data resolution can capture. Or it can be inferred that visual acuity of the sampling net is a factor which biases sampling of barracudina abundances.

H8^{0}

There are no differences in abundances among the different depth strata trawled.

This hypothesis was used to assess respective gear types for abundances by depth code. The analysis will differ based on the number of depth codes defined for a given trawling net. Further compartmentalization can be made of depth code data to query the differences in abundances by season, geography, or time of day. However, the sample numbers did not support statistical testing for each of these hypotheses and, as such, were often left to purely descriptive accounts of raw counts by depth distribution.

Dietary Analyses

Intact specimens collected by the R/V *Pisces* (HSRT) were surveyed for gut contents by dissection. Specimens from the *Pisces* were selected because there were far more subadult and adult specimens with apparently full guts than from either of the other vessels. While the HSRT collected far more and far larger specimens than did the MOCNESS, many of the delicate barracudina captured by the *Pisces* were too badly damaged from capture for gut surveying. A common injury sustained by barracudina captured in the HSRT was evisceration of the stomach. “Intact” specimens were pre-defined as specimens with no apparent evisceration and most of their body tissues remaining. Standard Length (SL) was measured for each specimen to the nearest millimeter and specimens were individually weighed; the entire digestive tract was removed; the stomach and intestines were separated. The scale used for weight measurements was an A&D Company, Ltd., FX-300i, with accurate weights measured to the nearest hundredth of a gram. Excised stomachs were also weighed to the nearest hundredth of a gram whereupon they were dissected, any food items removed, which were then weighed separately to the nearest hundredth of a gram. All large food particles and identifiable prey parts were placed in separate vials of 70% ethanol, whereas smaller particles were mounted on glass slides for later identification under compound microscope. Prey items were identified to the lowest possible taxonomic unit (LTU), either from whole prey or from diagnostic hard structures, micrographs were taken with a dissecting microscope for prey items which required more expert identification. The total number of prey was estimated by counting the total number of diagnostic structures and dividing by the appropriate number of structures per animal (e.g. all eyes counted and total divided by 2 to estimate number of prey). In cases where diagnostic hard structures could not be counted, a prey number of 1 was assigned to that prey category. For every prey category of each species of barracudina, three measurement units were calculated: percentage in number (%N), percentage in wet weight (%WW) and frequency of occurrence (%F).

%N = (total number of prey item *i* / total number of all prey items) x 100

%F = (number of stomachs including prey item I / total number of positive stomachs) x 100

%WW = (total wet (post fixation) weight of prey item I /
total wet (post fixation) weight of all prey items) x 100

The measure of wet weight (WW) can be considered an underestimate because each time a specimen is frozen, thawed, fixed, and/or placed in ethanol, some percentage of water and organic matter is likely lost (Sutton & Hopkins 1996). However, given that all taxa were subjected to the same methodology, predator/prey biomass comparisons should be relatively unaffected.

These percentages were combined into an index of relative importance (IRI, Pinkas et al., 1971), calculated for each prey category:

IRI = (%N + %WW) x %F

This index values presents all three metrics in a value between 0 and 1 and is meant to function as a rough estimate of importance rather than a rigorous statistical characterization. Given this index value, stomach content were ranked in tables to facilitate comparisons of total values and values by day and night were interpreted further separately:

$H9^0$

The prey taxa of greatest relative importance for the different barracudina species does not vary among them by major taxonomic level (Phylum).

The implication of this null hypothesis is that all barracudina eat mesopelagic fishes. Evidence from Rofen's work indicates that there is potentially variety at the species level. However, this previous work was based on very small samplings of specimens from disparate regions. The utility of cataloguing the respective diets of the different species of barracudina in a single region and period from numerous specimens is the possibility of teasing apart the myriad of confounding variables that could impact diet by space and time. In comparing the results of hypotheses 1 – 7 for the respective species of barracudina with the findings of this hypothesis for those same species, tentative patterns were elucidated regarding factors which influence the dietary habits of those species. Conversely, gut dissections that revealed even small amounts of contents that could be identified to taxonomic units lower than the family level provided information regarding other aspects of that species life history may be possible to infer (i.e. presence of epipelagic fishes in guts indicate utilization of the epipelagic). However, not enough data were available from these gut dissections to have taxonomic resolution lower than the Phylum level with much certainty for the majority of taxa.

In addition to this hypothesis, a hypothesis on the chronology of feeding was tested. To determine when, and how many times, barracudina feed relative to the diel cycle, excised stomachs were ranked on a scale of stomach fullness from 0 to 4, with 0 = empty, 1 = traces of prey present, 2 = a partially to half-filled stomach, 3 = mostly full but not stretched, and 4 = a full and stretched stomach. Additionally, every prey item recovered was ranked on a scale of 1 to 4, representing the degree of digestion. The scale was as follows: 1 = no visible sign of digestion, prey whole and complete; 2 = prey partially digested, not complete; 3 = prey highly digested, only pieces remaining; and 4 = almost completely digested, only traces remaining.

$H10^0$

There is no difference in the stomach fullness and the degree of digestion of gut contents between day and night sampled specimens of respective species.

The intention of this hypothesis was to test during which period of the solar cycle various species are feeding. While knowledge on the rates of digestion and evacuation is lacking for these species at this time such rough estimates can be used to approximate feeding ecology assuming other variables remain constant.

Ontogenetic Analyses

In querying the potential effects of ontogeny on given distributions standard length was utilized as a proxy for defined life stages. It is important to note that most of the data assessed here involved juvenile and adult specimens and it can be assumed that the results of H2 – H8 largely reflect juvenile and adult habits and not larval. However, to further reduce the potential for certain large or small individuals in the dataset to act as effective outliers, standard abundances were further compartmentalized by “large” (>70 mm SL) and “small” (<70 mm SL) specimens. As mentioned previously (see Objectives section) the present thesis is most concerned with seasonal, diel, and vertical patterns in terms of ontogenetic changes, since these likely have the greatest ecological implications. As such, only three hypotheses on SL/ontogeny were tested here in the same fashion as H2 – H8:

H11^{0}

Standard lengths do not differ among pre-defined seasons.

H12^{0}

Standard lengths do not differ among day and night time trawls.

and

H13^{0}

Standard lengths do not differ among depth strata of the respective trawling gear.

By compartmentalizing If enough data is available for a given species, differences in frequency of SL were graphed as cumulative density curves for respective depth strata, where data supported it, and these charts were used to contextualize statistical findings of size by depth and season.

The differences in SL among depth strata (H13) is perhaps the most ecologically important query of these data because if the null is rejected, and most small specimens are found in different depths from larger ones, different size classes are potentially occupying different depths and indicative of a vertical ontogeny. This will have implications as to which apex predators adult barracudina are potential prey for.

In the early era of deep sea exploration, some conjecture arose as to the observed relationship between fish size and depth with the hypothesis of “bigger is found deeper”, or “Heincke’s Law”, emerging as a compelling explanation for observations (Polloni *et al*., 1979). Heincke’s “Law” generally states that smaller, larval and juvenile fish are found at shallower depths while larger, mature individuals of the same species are generally found deeper. It has been argued that this trend can be explained by the physiology of planktonic fish eggs and the requirement of larvae with limited mobility to have access to quantities of planktonic food, which is more consistently available in the epipelagic, followed by a vertical descent with age to avoid predation by large epipelagic predators (Sutton, 2013). Research in the 1980s and ‘90s provided a mixed view of this hypothesis. With some areas and some taxa it was supported (Gordon & Mauchline, 1996; Koslow, *et al*., 1997; Smith and Brown, 2002) and in others it was not (Pearcy *et al*., 1986; Merrett *et al*., 1991; Stefanescu *et al*., 1992; Moranta *et al*., 2004). More recently, physiological modelling, such as that with pacific salmon (*Oncorhynchus spp*.) by Morita *et al*. (2010), has demonstrated that ideal growth temperatures decrease with age hinting to ontogenetically determined habitat preferences (as colder waters are found deeper). Opponents of Hienke’s “Law” have often sited sample bias, arguing that larger fish may be more easily caught at depth where visual cues of a trawl’s presence are obscured while individuals of the same size closer to the surface are more capable of seeing the net and avoiding it, while their smaller counterparts lack the swimming strength (Haedrich *et al*., 1997; Kaardvedt *et al*., 2012; Handegard *et al*., 2013; Klevjer *et al*., 2016).

Given the paucity of available evidence, it would be reasonable to generally allow for either possibility, especially in the case of poorly studied taxa. A rejection of the null for H13 for both gear types can be interpreted as a tentative acceptance of the Heincke's hypothesis if different size classes are occupying significantly separate depth strata, while a rejection of the null may be interpreted as a tentative acceptance of the net avoidance hypothesis and rejection of bigger=deeper.

To this author's knowledge, no information is currently available in the scientific literature regarding size at maturity and the gonadal development of barracudina. While a gonadosomatic index would have been most instructive toward addressing this question, it would be highly susceptible to error in these data because all specimens have been fixed in formalin and preserved in ethanol for several years prior to dissection. Instead, basic assessment of gonads for mature eggs, based on color and size, was employed in tandem with the gut content surveys of adult specimens. It has long been known that many species of Paralepididae exhibit hermaphroditism based on the presence of both gametes in the gonads of some specimens (Rofen, 1966). Recent work by Davis and Fielitz (2010) have shown that the genetic disposition for simultaneous hermaphroditism is common to the entire Alepisauroidei suborder. For this reason, no distinction is made between sexes in the data and the simple presence or absence of pigment in eggs, and eggs greater than or equal to 1 mm in diameter, are compared with standard length and season to assess size at maturity and the potential seasonality of reproduction.

Meg Skansi vs. *Point Sur*

While they both utilized the same sampling gear and protocol, the sampling transects of the *Point Sur* were far different from those of the *Meg Skansi*. Over the entire 2011 sampling year, the *Meg Skansi* was able to sample every station at least once, and many stations 3 times, to account for seasonal variability. The *Point Sur*, on the other hand, sampled a semi-random assortment of stations along a track for any given cruise. The transect tracts were semi-random because time was more limited for the DEEPEND campaign, and efforts were made to generate an equal spread of samples within and without of water masses associated with the Loop Current. Due to limitations in sea days, far fewer stations were sampled by the *Point Sur* for any given sampling season than were done by the *Meg Skansi* in 2011. For this reason, comparison of abundances documented by the respective cruises must be considered with context and with respect to the associated water masses of a given sample. As mentioned previously, the sample region is assumed to have been almost entirely composed of "common water" (water masses not associated with the Loop Current) during the 2011 sampling year. As such, comparisons between the two cruise campaigns were restricted to sample stations defined as "common water" in the *Point Sur* data.

Chapter Three: Results

Overview

Over all NOAA NRDA and some DEEPEND sampling cruises, spanning from 2011 to 2017, a total of 2,141 Paralepididae specimens were collected representing 19 different species. Of these, 6 species represented first records for the Gulf of Mexico basin: *Anotopterus pharoa*, *Stemonosudis siliquiventer*, *S. rothschildi*, *Paralepis brevirostris*, *P. coregonoides*, and *Lestidiops mirabilis* (McEachran and Fechhelm, 1998; McEachran, 2009). All specimens caught deeper than 1000 meters represented first-ever records in the gulf by occurrence at depth (McEachran and Fecchlem, 1998). T - test comparisons of standardized abundances of Paralepididae by the three sampling vessels showed that the *Pisces* caught significantly greater numbers of barracudina (N=1582) than either the *Meg Skansi* (N=506; p<0.0001) or the *Point Sur* (N=53; p<0.0001). The two MOCNESS cruises were also significantly different from each other in their respective total counts but less so (p<0.01). Using t-tests to compare abundances caught by day (744) and by night (1397), Paralepidids as a group were caught at significantly greater abundances in night trawls (p<0.002). Standardized abundances caught by volume filtered within respective, quantifiable samples ranged from 0.15 $/10^6*m^3$ to 14903.13 $/10^6*m^3$ and depended greatly on the landing gear used. For *Pisces* samples, which utilized the HSRT net and filtered the greatest volume of water per sample, the median standardized density for any given barracudina species caught was 0.72 $/10^6*m^3$ and the mode 0.7

/10^6*m^3. Samples from quantifiable, individual nets of the MOCNESS aboard the *Meg Skansi* caught a median of 40.03 x 10^{-6}/m^3 and mode of 39.93 /10^6*m^3.

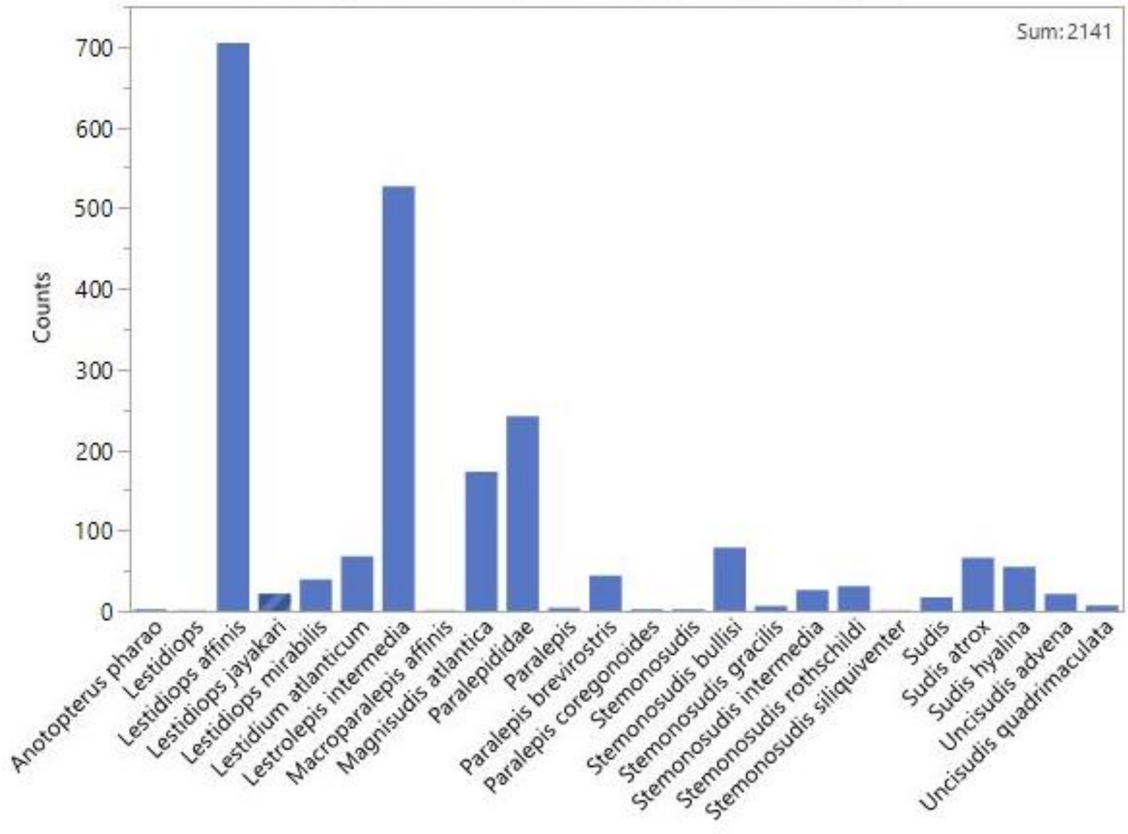


Figure 5 - Total catch of Paralepididae over all cruises by lowest taxonomic unit. *Lestidiops affinis* was far and away the most commonly collected species. “Paralepididae” were specimens too damaged to identify. *Lestrolepis intermedia* are mostly composed summer HSRT samples.

The *Point Sur* MOCNESS nets sampled slightly lower with documented abundances having a median of 29.12 /10^6*m^3 and a mode of 26.6 /10^6*m^3, however, when Loop Current and common water samples were accounted for, this difference was determined to be statistically significant (Welch’s ANOVA $p<0.0137$). In addition, markedly greater species richness was documented by the *Meg Skansi* compared with the *Point Sur* (see Table 3 below).

Of the 19 species caught, *Lestidiops affinis* was the most frequently encountered barracudina with 705 specimens collected over all cruises. The most infrequently encountered species was *Stemonosudis siliquiventer* which was represented from these efforts by a single specimen. *Anotopterus pharao* and *Paralepis coregonoides* are only represented by 2 specimens each and *Macroparalepis affinis* by 3. *Stemonosudis siliquiventer, Anotopterus pharao, Paralepis brevirostris,* and *Paralepis coregonoides* represent first records of occurrence in the gulf (McEachran 2009).

Table 1 - Total numbers, standardized densities, size ranges, and depth ranges for species found during the Meg Skansi cruises. Standardized densities are derived only from samples where the volume filtered by discrete nets was considered "quantifiable" while total numbers caught, as well as size and depth ranges, are derived from all available samples. The largest size *Magnisudis* (380 mm) represents an extreme outlier. The sole *Stemonosudis siliquiventer* specimen was captured in a non-standardized net.

Species	**n**	**Mean Standard Density (/10^6*m^3)**	**Standard Length Range (mm)**	**Depth Range (meters)**	**Discrete Net Mean Standard Densities (/ 10^6*m^3)**				
					Deep				**Shallow**
					1	**2**	**3**	**4**	**5**
Lestidiops affinis	208	60.7	14 – 97	0 – 1500	16.1	37.9	22.1	31.4	74.8
L. jayakari	8	48.5	14 – 35	0 – 600	0	0	13.1	0	55.6
L. mirabilis	2	41.5	18 & 33	0 – 200	0	0	0	0	41.5
Lestidium atlanticum	2	47	33 & 35	0 – 200	0	0	0	0	47
Lestrolepis intermedia	11	67.6	20 – 98	0 – 1500	29.4	0	0	24.9	83.8
Macroparalepis affinis	3	48.8	35 – 45	0 – 200	0	0	0	0	48.8
Magnisudis atlantica	68	23	15 – 380	800 – 1500	27.9	0	22.8	22.3	0
Paralepis brevirostris	20	28.3	12 – 41	600 – 1000	0	0	17.9	10	0
P. coregonoides	2	19	25 & 38	600 –1000	0	0	19	0	0

Table 1 – Continued

Stemonosudis bullisi	26	52.7	16 – 88	0 – 200	0	0	0	17	59.5
S. gracilis	2	38.7	29 & 88	0 – 211	0	0	0	0	38.7
S. intermedia	4	36.9	54 – 80	0 – 600	0	0	0	28.7	41
S. rothschildi	5	36.4	25 – 89	0 – 1000	0	0	24.3	0	40.4
S. siliquiventer	1	Non-standard	64	0 – 500	Non-standard				
Sudis atrox	44	39.4	9 – 40	0 – 1500	15.9	0	15.9	15.2	50
S. hyalina	35	49.5	9 – 43	0 – 1200	0	45.6	21.7	29	52.3
Uncisudis advena	11	62.6	16 – 84	0 – 600	0	0	0	45.7	75.8
U. quadrimaculata	2	17.4	32 & 56	200 – 600	0	0	0	17.4	0

Table 2 - Total numbers, standardized densities, size ranges, and depth ranges for species found during the Pisces cruises. Standardized densities are derived only from samples where the volume filtered by discrete tows was considered "quantifiable" while total numbers caught, as well as size and depth ranges, are Tderived from all available samples. The 2 *Anotopterus pharoa* specimens were captured in a non-standardized net and were damaged. The depth ranges here represent the maximal trawling extents of the respective samples and not necessarily the strata where these species are found.

Species	**n**	**Mean Standard Density ($/10^6*m^3$)**	**Standard Length Range (mm)**	**Depth Range (m)**	**HSRT Sample Depth Mean Standard Densities ($/10^6*m^3$)**	
Anotopterus pharoa	2	Non-Standard	N/A	N/A	Non-Standard	
Lestidiops affinis	479	1.9	11 – 234	0 – 1500	**>700 meters** 1.3	**<700 meters** 2.7
L. jayakari	14	0.5	84 – 157	0 – 1437	0.5	0.6
L. mirabilis	37	9.5	44 – 185	0 – 1417	0.5	20.3

Table 2 – continued

Lestidium atlanticum	68	7.0	41 – 187	0 – 1447	0.7	17.2
Lestrolepis intermedia	510	10.5	39 – 172	0 – 1516	3.3	16.9
Magnisudis atlantica	129	0.7	11 – 145	0 – 1623	0.6	0.9
Paralepis brevirostris	21	0.5	43 – 104	0 – 1419	0.4	0.5
Stemonosudis bullisi	51	2.8	29 – 204	0 – 1439	0.6	6.7
S. gracilis	4	0.5	87 – 207	0 – 1428	0.3	0.7
S. intermedia	21	0.4	56 – 234	0 – 1495	0.3	0.7
S. rothschildi	25	0.6	39 – 110	0 – 1495	0.4	0.9
Sudis atrox	16	0.7	43 – 140	0 – 1495	0.5	0.7
S. hyalina	19	0.6	36 – 193	0 – 1428	0.4	0.9
Uncisudis advena	2	0.3	50	0 – 1405	0.3	0
U. quadrimaculata	4	0.7	72 – 104	0 – 770	0	0.7

Table 3 - Total numbers, standardized densities, size ranges, and depth ranges for species found during the Point Sur cruises. Standardized densities are derived only from samples where the volume filtered by discrete nets was considered “quantifiable” while total numbers caught, as well as size and depth ranges, are derived from all available samples. A single *Stemonosudis rothschildi* was caught in a non-standardized tow. Several mean standard densities differ from sub-sample sum of discrete nets because specimens were collected from the “tare” bin or net 0.

Species	**n**	**Mean Standard Density (/10^6*m^3)**	**Standard Length Range (mm)**	**Depth Range (meters)**	**Discrete Net Mean Standard Densities (/ 10^6*m^3)**				
					Deep				**Shallow**
					1	**2**	**3**	**4**	**5**
Lestidiops affinis	18	48	31 – 75	0 – 1500	0	0	32	30.4	64.7
Lestidium atlanticum	1	29.5	36	0 – 200	0	0	0	0	29.5
Lestrolepis intermedia	6	29.2	22 – 87	0 – 1500	0	0	0	32.7	34.3
Magnisudis atlantica	5	17.9	15 – 380	600 – 1500	0	0	29.4	0	0
Paralepis brevirostris	3	27.2	27 – 38	600 – 1500	0	0	35.7	0	0
Stemonosudis bullisi	3	50.9	43 – 67	0 – 200	0	0	0	0	26.6
S. intermedia	1	29.3	100	0 – 200	0	0	0	0	29.3
S. rothschildi	1	Non-Standard	119	600 – 1000	Non-Standard				
Sudis atrox	6	21	27 – 81	0 – 1500	19	0	0	0	27.9
S. hyalina	1	38.4	32	0 – 200	0	0	0	0	38.4
Uncisudis advena	1	19	34	0 – 200	0	0	0	0	19
U. quadrimaculata	1	26.6	41	0 – 200	0	0	0	0	26.6

Lestrolepis intermedia was the second most abundant member of the Lestidiinae sub-family after *Lestidiops affinis* at 527 specimens total. However, this total is highly skewed by sampling gear and season as this species was overwhelmingly more frequent in *Pisces* summer samples than any MOCNESS samples. Similar results followed for the entire Paralepididae family treated as a whole (see figure). Of the Paralepidinae sub-family, the most common species was *Magnisudis atlantica* (173), and of the Sudinae, *Sudis atrox* (66). Individual species are treated respectively below.

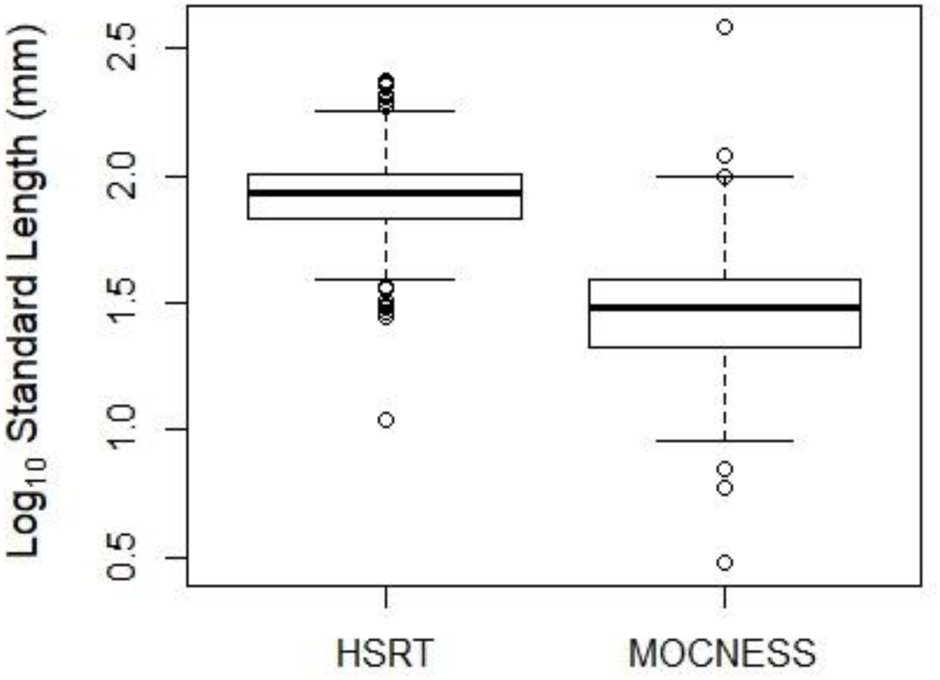


Figure 6- Comparing Log10 transformed data of frequency of standard lengths for all Paralepididae species caught between the Pisces (HSRT) and Meg Skansi/Point Sur (MOCNESS) net gear. The HSRT gear documented significantly greater frequencies of standard lengths (t-test: t = 41.011, df = 617.1, p-value < 2.2e-16) than MOCNESS samples. Far larger and far more specimens were captured by that gear. However, comparing standardized abundances seen in Tables 1 and 2 shows that the relative abundances were far lesser in the HSRT than the MOCNESS due to the enormous water volume filtered by that gear compared to the more modest volume by the MOCNESS. This seems to indicate that while the largest size classes are avoiding research grade trawling nets (MOCNESS) overall abundances are not necessarily under characterized.

Species

The following accounts for each species are based on specimens only collected by the NOAA NRDA and DEEPEND investigations.

Anotopterus pharoa

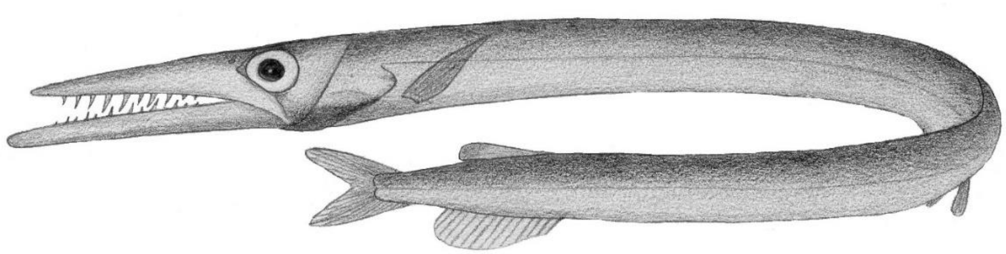


Figure 7 - The Daggertooth (*Anotopterus pharoa*). Max recorded SL: 510 mm (Rofen, 1966). No dorsal fin present. Lower jaw protrudes distinctly beyond upper. Has a highly reflective appearance in life. Illustration by Ray Simpson.

Description: The "daggertooth" is a large, highly elongate and highly compressed fish which had historically been classified in a separate family. However, morphological work by Baldwin & Johnson (1996) and recent molecular work (Davis & Fietlitz, 2010; Davis, 2010) determined it to be more closely allied with the Paralepidinae than previously thought and it is treated here as a barracudina. *Anotopterus. pharoa* almost completely lacks squamation (except a single row of scales embedded along the lateral line) and its skin possesses subdermal layers of guanine that are highly refractory of light and impart an iridescently silver coloration to this fish. Preserved specimens appear iridescent brown to black with a darkened section of pigment running dorsally along the back. *A. pharoa* is quite distinctive among most fishes for completely lacking a dorsal fin, while it still possesses the posterior-dorsal adipose fin typical of barracudina. A degree of lateral, dermal keeling is common along the posterior portion just prior to the caudal peduncle. The lower jaw is highly elongate and protrudes well beyond the upper jaw and ends in a sharp point. The teeth along the premaxillary are extremely minute or entirely absent while the teeth along the maxilla and palatine are large and triangular shaped “daggers” pointing toward the anterior of the mouth. The teeth along the mandible are an odd mixture of depressible and fixed, short and tall, forward and rear facing fangs.

Similar Species in the Gulf of Mexico: While its highly elongated appearance may lead to confusion of *A. pharoa* with some *Stemonosudis, Macroparalepis,* or even *Paralepis* species, the lack of the dorsal fin, the uniquely reflective appearance of the skin, the presence of lateral keeling near the caudal, the unique dentition, and, often, the large size of this species easily differentiates it from all other barracudina.

Only 2 specimens were sampled by these efforts in the GoMx. They were both captured in non-standardized, HSRT tows ranging to 1500 meters and the specimens were partially damaged, so not much natural history on this species in the GoMx is presented here. However, this is the first documented case of *A. pharoa* in the GoMx and the implications of this are treated further in the Discussion section.

Lestidiops affinis

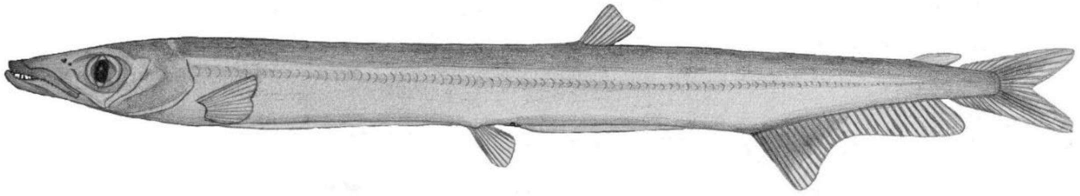
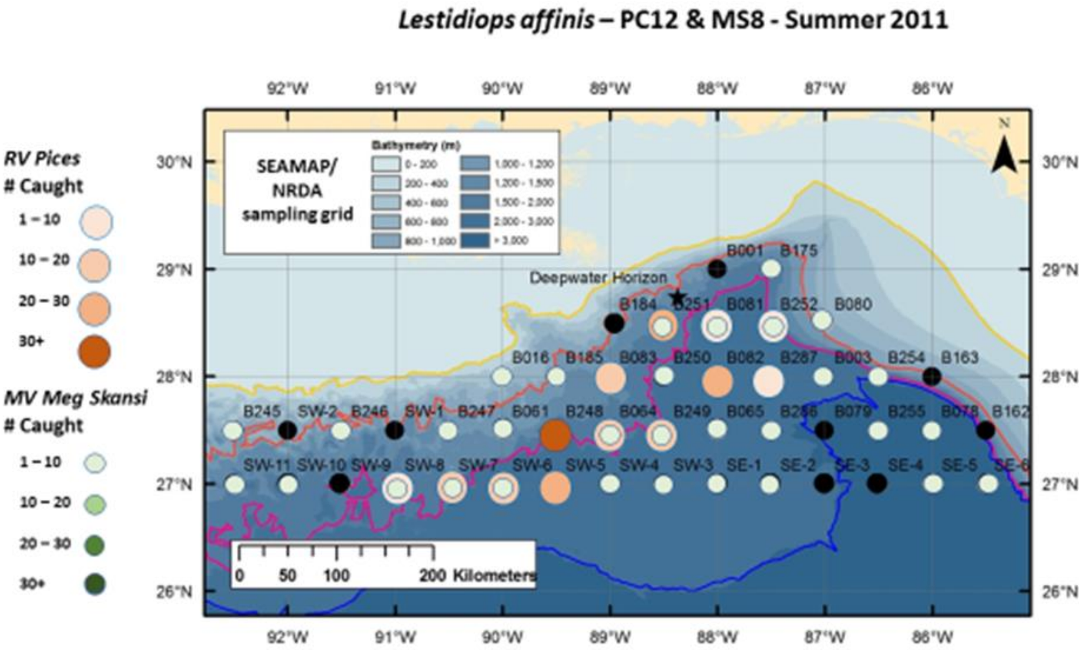


Figure 8 - The common barracudina (*Lestidiops affinis*). Max. recorded SL: 149 mm*. Translucent and unpigmented except for a row of copper colored chromatophores, 5-15 chromatopohores wide, along the dorsum, as well as copper colored pigment on the lateral area just anterior to the caudal peduncle and above the occiput. Pelvic fins well anterior to dorsal fin origin. Illustration by Ray Simpson.

Description: The "common barracudina" is a medium sized barracudina of the sub-family Lestidiinae that almost entirely lacks squamation (a single row of scales is embedded along the lateral line) and appears highly translucent in life at all stages of development. *L. affinis* has a very short snout (about 7 – 8% SL) for a barracudina with numerous saw-like teeth regularly spaced along the pre-maxilla. There are 8 – 12 peritoneal patches clearly visible in most individuals >60 mm SL. Above 15 mm SL, 8 – 14 stellate melanophores are fairly evenly distributed mid-ventrally at the base of the adipose tissue between the anus and AFO. Adult pigmentation generally begins to become apparent in the 30 – 60 mm SL size range. These pigmentations include lateral rows of large, dorsal chromatophores, about 5-15 pigments wide, covering the entire dorsal length, a subdermal copper coloration covering the brain and occiput, and a coppery/brassy coloration to the posterior-dorsal portion of the body and caudal peduncle. No luminous organs are present.

Similar Species in the Gulf of Mexico: *L. affinis* is often and easily conflated with its congener, *Lestidiops jayakari*. The two species are usually identical in meristic counts but can be distinguished by adult pigmentation and/or the relative positions of the DFO relative to the PVO. In *L. affinis*, the distance between the DFO and PVO/anus is greater than in that of *L. jayakari* with the pelvic fin and anus anterior to the DFO in *L. affinis*. The snout to DFO length is usually 60% of SL or greater in *L. affinis* and the anus is some millimeters anterior to the DFO. In *L. jayakari*, the snout to DFO length is usually 60% of SL or less and the anus is almost directly below the DFO. *Lestidiops affinis* can also be confused with several other members of the Lestidiinae sub-family, especially *Lestrolepis intermedia*, *Macroparalepis affinis,* and *Stemonosudis bullisi*. At adult sizes, those species can easily be distinguished from *Lestidiops* spp. by differences in pigmentation. At smaller sizes (<60 mm SL), *Lestidiops* spp. can be differentiated from other Lestidiinae by having fewer AFR and/or DFR elements and being generally less elongate. *Lestidiops affinis* can appear very similar to *Macroparalepis affinis* in pigmentation but differ in the number of DFR elements (*L. affinis* has fewer, at most 10) and the distance between the snout and anus, which ranges from 59 – 60% of SL in *L. affinis* and from 69 – 71% of SL in *M. affinis*. The distance from the snout to AFO can also be useful and generally ranges from 77 – 76% of SL in *L. affinis* and 80 – 81% of SL in *M. affinis*.

Geographic, Seasonal, Diel, and Vertical Distribution: *Lestidiops affinis* was found to be common year-round and highly distributed throughout the sampling area with a strong disposition for the epipelagic/upper mesopelagic. No statistical difference was noted between total abundances observed at stations near and far from the shelf for either gear type. However, significantly greater abundances of *L. affinis* were documented by MOCNESS at stations nearer the shelf compared with those farther from it ($p<0.0308$) during the winter sampling months. No such trends were observed during the summer or spring. No differences in abundance were observed in HSRT data with respect to the shelf. MOCNESS data for this species showed no difference in abundances from east to west overall or within seasons. Overall, abundances compared among seasons were not significantly different within the MOCNESS samples but were within the HSRT samples, with summer abundances being significantly greater than those of either winter ($p<0.0001$) or spring ($p<0.0244$). MOCNESS samples captured significantly greater abundances during night trawls than day trawls ($p<0.0001$) while there was no such trend documented by the HSRT gear. MOCNESS depth data from both the *Meg Skansi* and *Point Sur* cruises show that the most significant depth region in terms of abundance for this species is the first 200 meters ($p<0.0001$ – $P<0.0206$; Wilcoxon comparison of abundance by strata 5 vs 3, 1, and 4), however, no statistical difference was found between 5 and 2 (0.2479). A few individuals were found as deep as 1500 meters and at varying depths and abundances between (see Figure 13). Abundance by depth in HSRT samples was also significantly skewed toward “shallow” trawls ($p<0.0002$; H8).



Lestidiops affinis **– PC12 & MS8 - Summer 2011**

Figure 9 - Geographic distribution of the common barracudina in the sampling region during the summer of 2011. The Pisces sampled a total biomass of 171.6 g at an average specimen SL of 75 mm. The Meg Skansi sampled a total biomass of 29.1 grams at an average specimen SL of 47 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

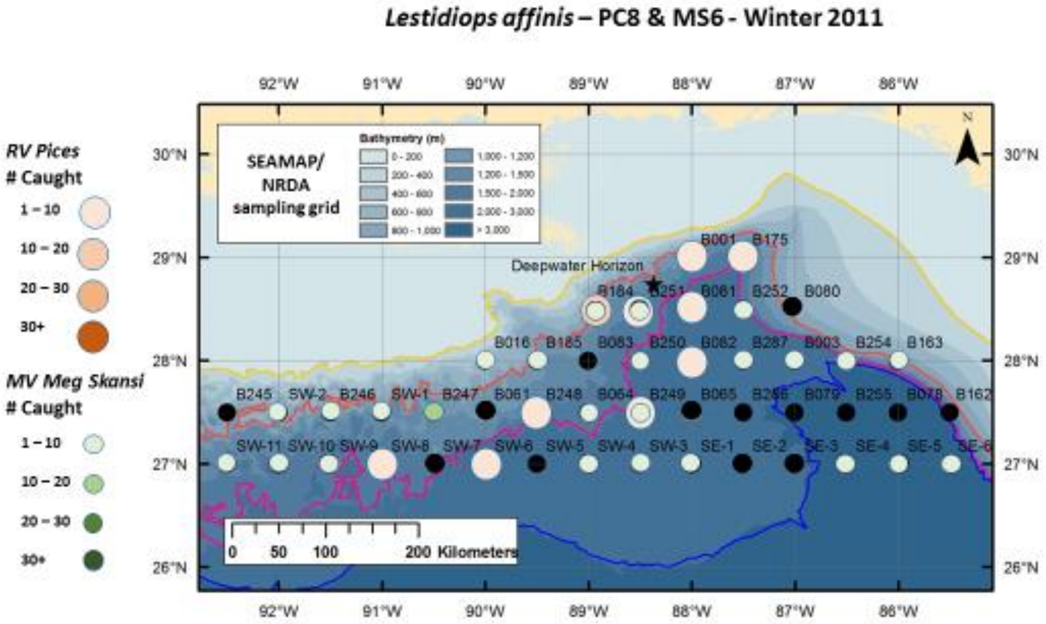


Figure 10 - Geographic distribution of the common barracudina in the sampling region during the winter of 2011. The Pisces sampled a total biomass of 24.8 g at an average specimen SL of 75 mm. The Meg Skansi sampled a total biomass of 29.1 g at an average average specimen SL of 47 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

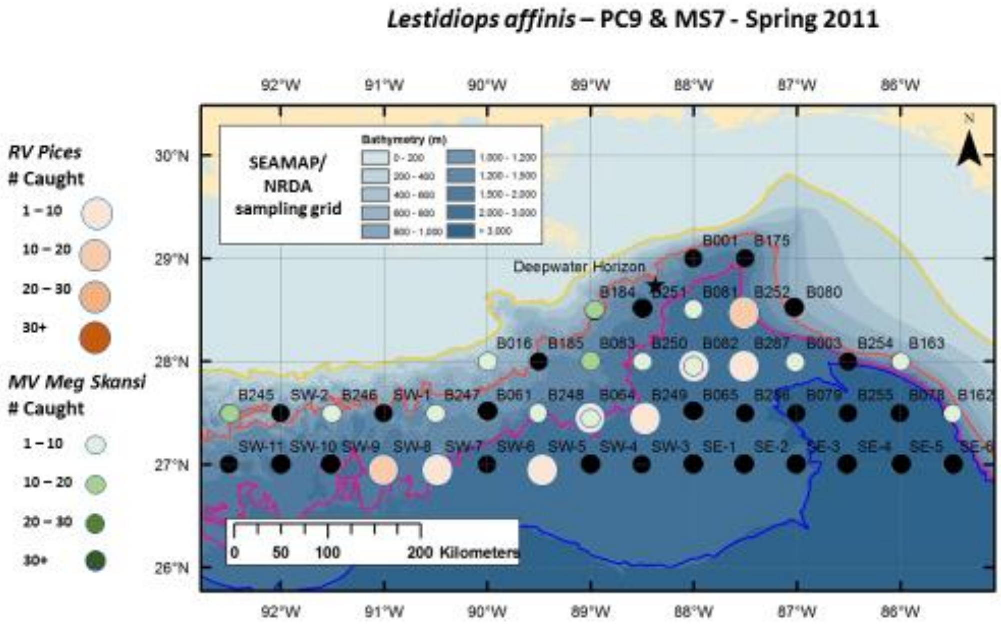


Figure 11 - Geographic distribution of the common barracudina in the sampling region during the spring of 2011. The Pisces sampled a total biomass of 52.1 g at an average specimen SL of 77 mm. The Meg Skansi sampled a total biomass of 7.7 g at an average specimen SL of 37 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

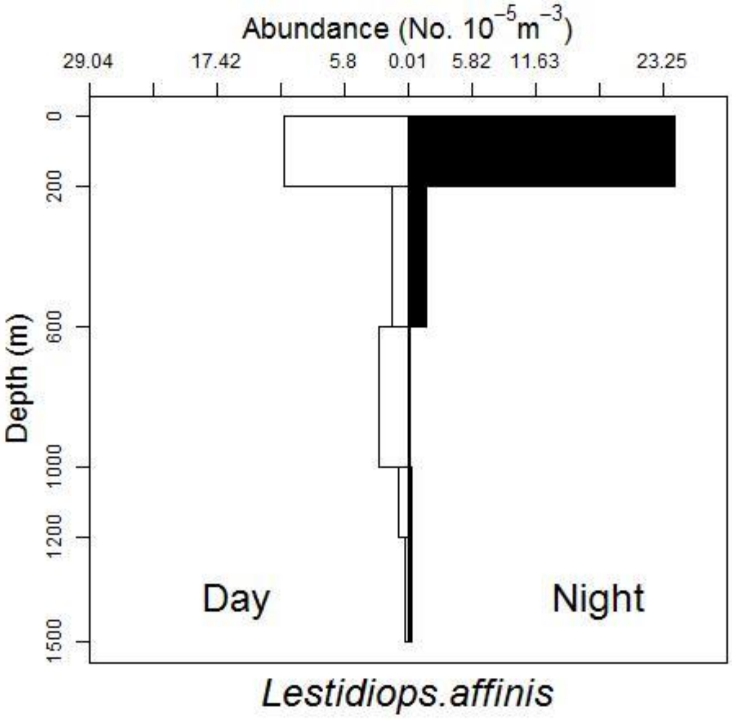


Figure 12 - Vertical depth distribution of the common barracudina over all Meg Skansi samples. The greatest abundance of this species was documented in the first 200 meters (net 5). Significantly greater abundances were captured in this depth strata at night. Specimens of this species were documented at every depth strata but became rarer with depth. A slight tendency for vertical migration may exist given these data but this trend could also be explained by vertical ontogeny and/or net evasion (see Figure 14).

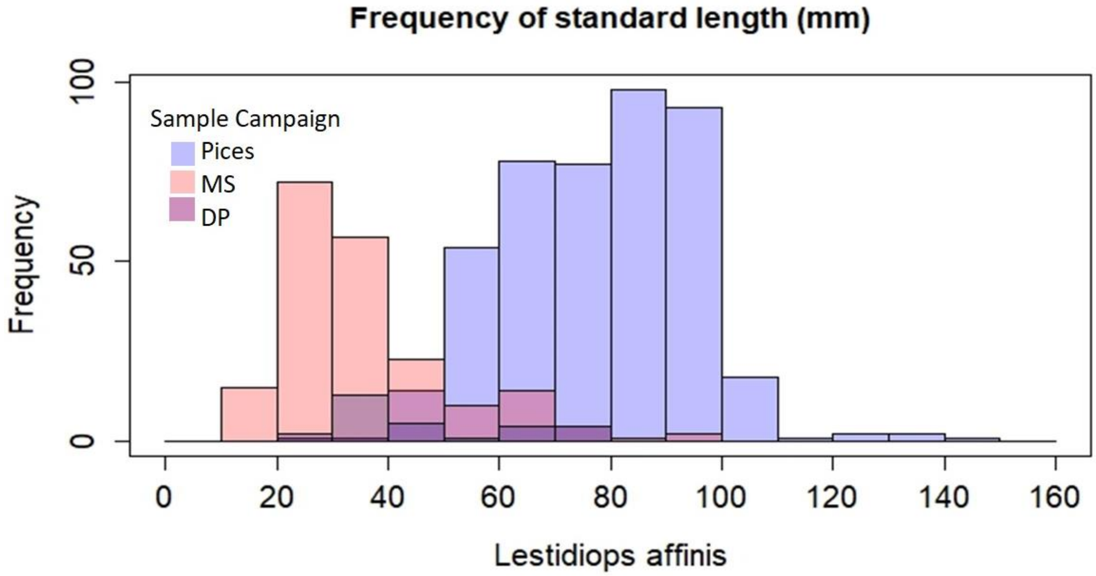


Figure 13 - Frequency of *Lestidiops affinis* standard lengths by cruise. The Pisces (in blue) caught significantly greater numbers (Welch's ANOVA; p<0.0001) than either MOCNESS (Meg Skansi = Salmon; Point Sur = Purple) geared vessel and nearly all the data on the largest size classes are represented by *Pisces* samples.

Diet: Based on gut surveys of 168 specimens varying in size from 60 to 149 mm SL, the diet of *L. affinis* was found to almost entirely consist of small, mesopelagic fishes with a majority of the identifiable prey being Myctophids and Phosichthyids. While the mean stomach fullness was greatest for specimens collected at day, the difference between full stomachs sampled at day and at night was not statistically significant, however, significantly greater digestion of prey was noted among specimens sampled at night compared with day (p<0.0021) and the greatest %N of unidentifiable/Teleost prey were found in specimens sampled at night (see Figure 16). Comparisons of gut surveyed by sample station found that stations B248 and B251 were significantly more represented in these data than other stations. No difference was found in mean stomach fullness among the seasonal sampling periods.

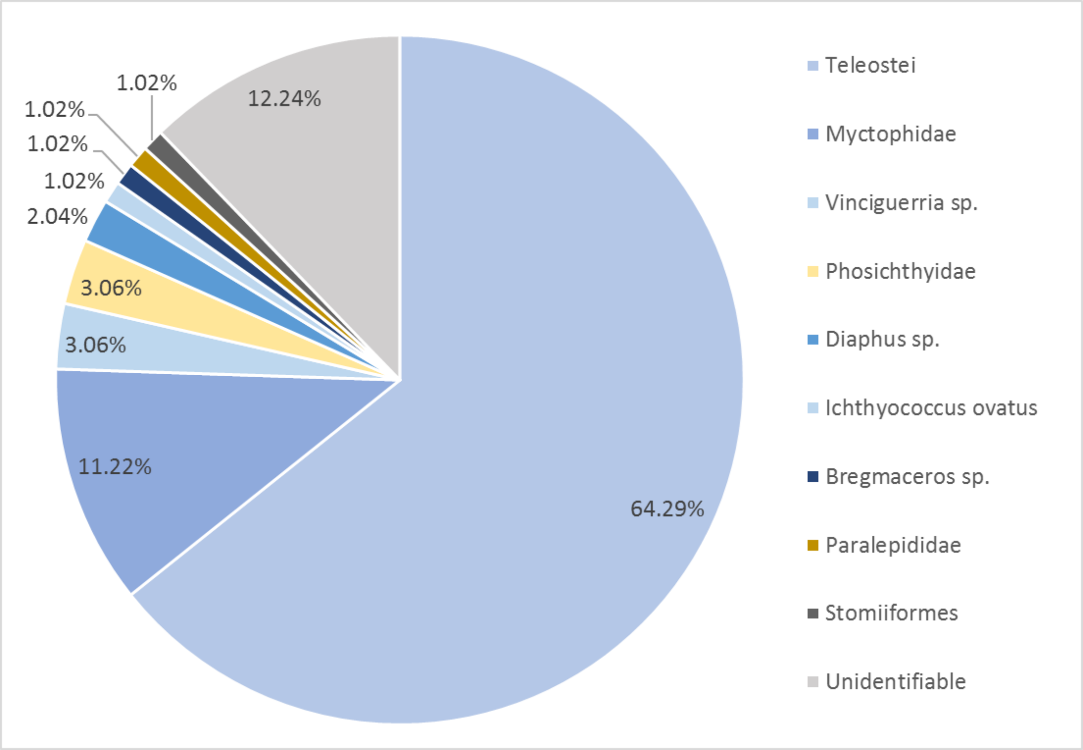


Figure 14 - Dietary Composition of *Lestidiops affinis*. The diet of adults is overwhelmingly composed of mesopelagic fishes, especially Myctophids. No evidence of any other prey Phyla was found in stomachs surveyed. Prey identified to genus and species indicate mesopelagic or vertical migrator feeding selectivity is likely.

Table 4 - Dietary Composition of *Lestidiops affinis*: The diet of adults was overwhelmingly composed of mesopelagic fishes, especially Myctophids. No evidence of any other prey Phyla was found in stomachs surveyed. Prey identified to genus and species indicate mesopelagic or vertical migrator feeding selectivity. With the types of LTU present, it can be inferred that adult *L. affinis* are mesopelagic.

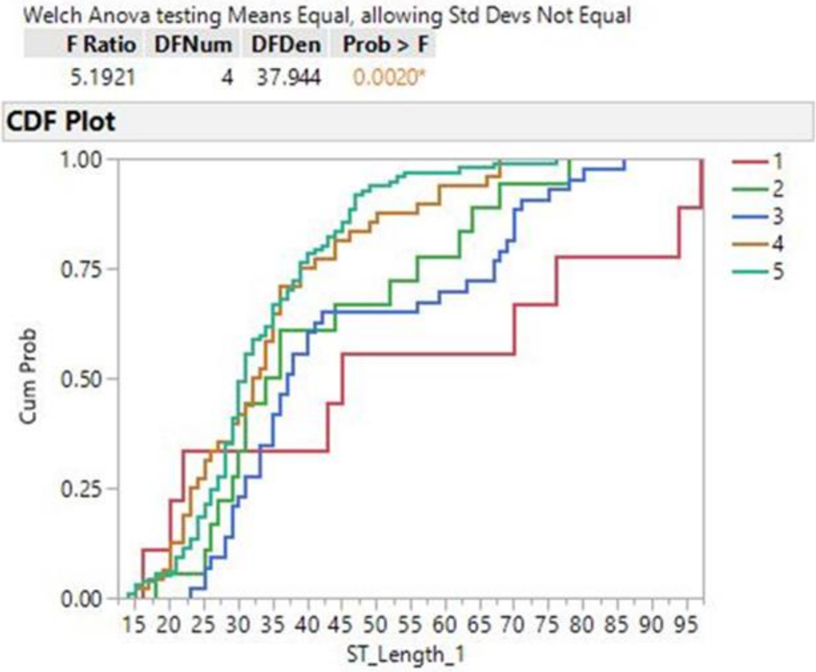
Prey LTU	**%N**	**%F**	**%WB**	**IRI**
Teleostei	64.29%	55.76%	21.22%	0.48
Myctophidae	11.22%	11.69%	9.14%	0.02
Vinciguerria sp.	3.06%	2.70%	4.17%	0.00
Phosichthyidae	3.06%	2.70%	3.22%	0.00
Diaphus sp.	2.04%	1.80%	3.09%	0.00
Ichthyococcus ovatus	1.02%	1.80%	1.07%	0.00
Bregmaceros sp.	1.02%	0.90%	2.02%	0.00
Paralepididae	1.02%	0.90%	2.02%	0.00
Stomiiformes	1.02%	0.90%	0.13%	0.00
Unidentifiable	12.24%	0.00%	53.92%	0.00

Table 5 - Dietary composition of *Lestidiops affinis* by solar cycle. Prey identified to Lowest Taxonomic Unit (LTU) at the genus and species level. Mesopelagic fishes were mostly found in a relatively undigested state in daytime collected specimens.

	Day				**Night**			
Prey LTU	**%N**	**%F**	**%WB**	**IRI**	**%N**	**%F**	**%WB**	**IRI**
Teleostei	51%	122%	13.19%	0.229	77.6%	184.2%	84.59%	2.987
Myctophidae	22.5%	59.1%	10.30%	0.084	0.00%	0.00%	0.00%	0.000
Unidentified	8.16%	0.00%	60.62%	0.049	16.3%	0.00%	1.08%	0.000
Vinciguerria	6.12%	13.7%	4.69%	0.009	0.00%	0.00%	0.00%	0.000
Phosichthyide	4.08%	9.09%	2.27%	0.003	2.04%	5.26%	10.75%	0.007
Diaphus	2.04%	4.55%	3.18%	0.002	2.04%	5.26%	2.39%	0.002
Bregmaceros	2.04%	4.55%	2.27%	0.001	0.00%	0.00%	0.00%	0.000
Paralepididae	2.04%	4.55%	2.27%	0.001	0.00%	0.00%	0.00%	0.000
Ichthyococcus ovatus	2.04%	9.09%	1.21%	0.001	0.00%	0.00%	0.00%	0.000
Stomiiformes	0.00%	0.00%	0.00%	0.000	2.04%	5.26%	1.19%	0.002

Ontogeny and Reproduction: The greatest frequencies of SL were found in the HSRT data ($p<0.0001$; see figure), however, only three specimens collected by the HSRT data were below 40mm SL, while the majority of the MOCNESS specimens were below 40 mm SL. No statistical difference was found in the frequency of SL by season, however, the small SL specimens were most frequent in summer ($p<0.0381$), with both winter and summer sampling periods seeing significantly higher frequencies of small size classes ($p<0.0001$) compared with spring. Assessing the frequency of SL by depth, MOCNESS data showed much greater encounters with small specimens in shallow strata, however, the heterogeneity of variance was significant (Levene's test; $p<0.0002$) and Welch's ANOVA at $\alpha=0.25$ found no significance among depths for the small size class ($p<0.2111$). The large size class (>70 mm SL) was almost exclusively found in net 3 of the MOCNESS with one individual found in nets 2 and 5, respectively. Plotting cumulative density functions for frequency of SL by depth level, Figure 16 shows how a greater proportion of larger individuals were captured by the MOCNESS in deeper strata, just less frequently. HSRT data, represented the largest size classes and collected significantly greater frequencies of larger SL individuals in "deep" trawls compared to shallow ($p<0.0011$), and significantly greater frequencies of larger SL individuals during day time trawls compared to night ($p<0.0014$).

Based on the 168 gut surveys of the juvenile and adult specimens described above, the average SL for *Lestidiops affinis* found with pigmented eggs was 94 mm. The smallest individual documented with mature gonadal features was 75 mm SL. Large pigmented eggs were documented in specimens collected from all seasons (See figure 18).



Welch Anova testing Means Equal, allowing Std Devs Not Equal

F Ratio	DFNum	DFDen	Prob > F
5.1921	4	37.944	0.0020*

CDF Plot

Figure 15- Frequency of all standard lengths by depth for *L. affinis* collected by the Meg Skansi, plotted as Cumulative Density Functions. While heterogeneity of variance was great, Welch's ANOVA found deeper depth strata to produced significantly larger SL individuals, though less individuals were found with increasing depth overall.

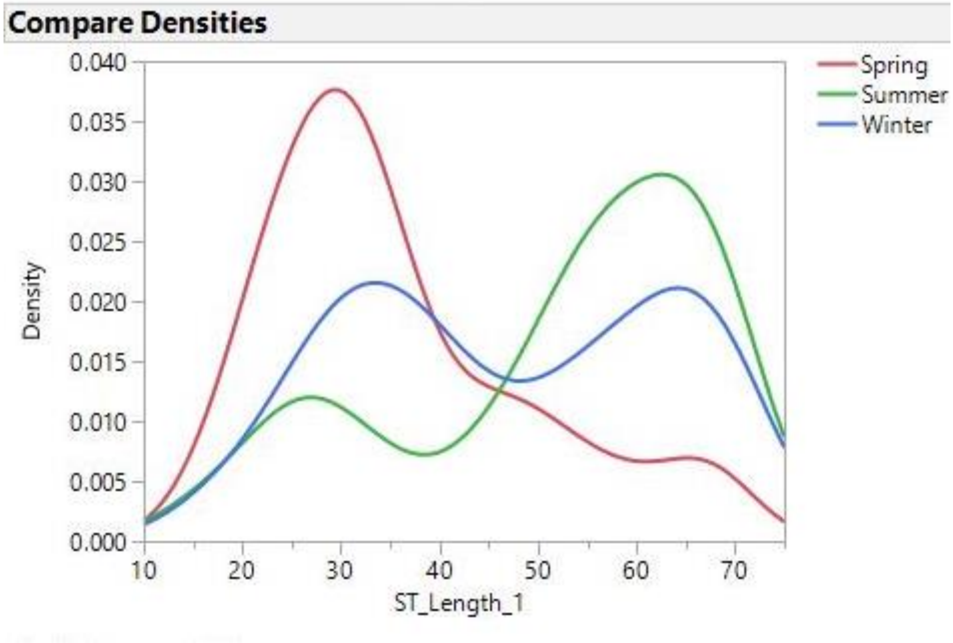


Figure 16 - Proportional density curves for frequency of standard lengths within the smaller size class (<70mm SL) of *L. affinis* by season. The smallest individuals are in greatest numbers during spring, and only somewhat during winter. The summer sampling period saw the highest frequency of sub-adult sizes.

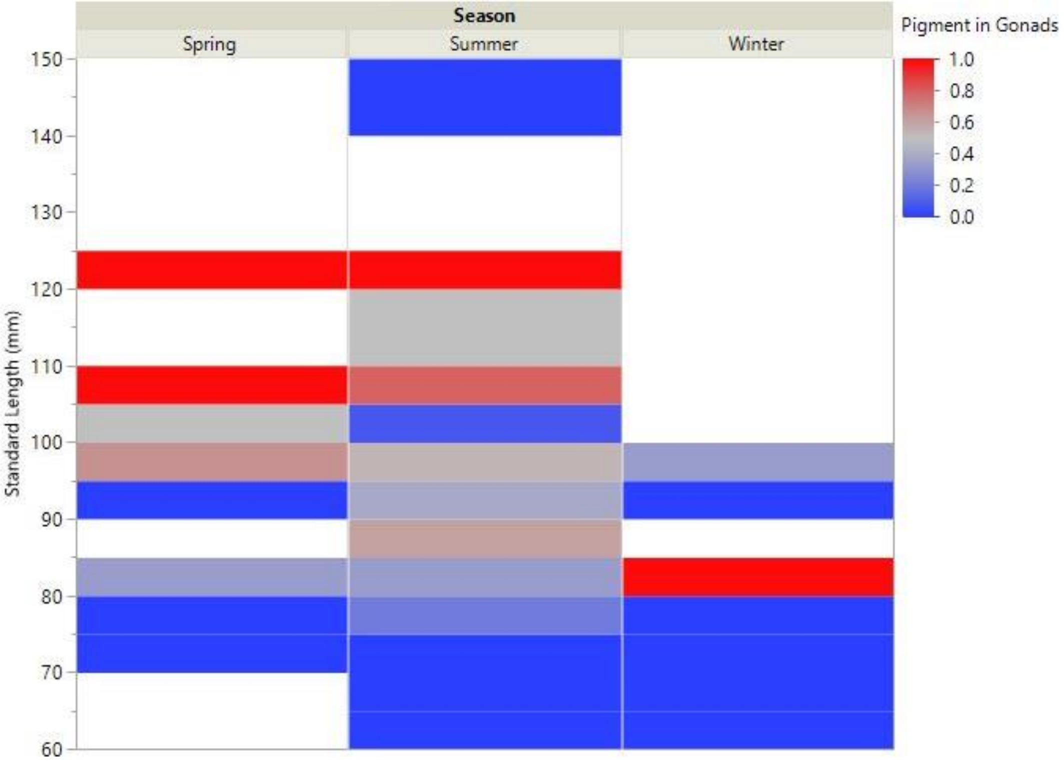


Figure 17 - Relative density chart for the presence of large, pigmented eggs, graphed by SL, from the 168 *L. affinis* surveyed for gut contents. The highest density of pigmented eggs was witnessed in spring and summer while a few individuals were documented with this feature in the winter samples. The winter specimens also represented the smallest size individuals with large, pigmented eggs.

Lestidiops jayakari

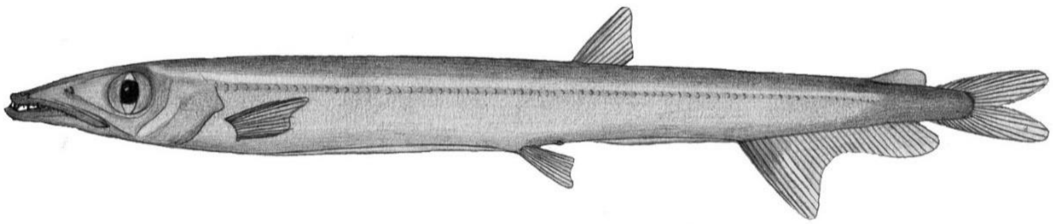


Figure 18 - The Pacific barracudina (*Lestidiops jayakari*). Max recorded SL: 187 mm (McEachran and Fechhelm, 1998). Translucent and unpigmented except for a row of copper colored chromatophores, 45-100 chromatophores wide, along the dorsum, as well as copper colored pigment on the lateral area just anterior to the caudal peduncle and above the occiput. Dorsal fin origin is situated almost directly above the anus. Illustration by Ray Simpson.

Description: The “Pacific barracudina” is a medium sized barracudina of the sub-family Lestidiinae that almost entirely lacks squamation (a single row of scales are embedded along the lateral line) and appears highly translucent in life at all stages of development. The snout is relatively short and ranges from 9 – 10% of SL. Numerous saw-like teeth are regularly spaced along the pre-maxilla. Above 15mm SL, 8 – 14 stellate melanophores are apparent located mid-ventrally along the adipose tissue between the vent and AFO. Adult pigmentation generally begins to become apparent in the 30 – 60 mm SL size range. These pigmentations include lateral rows of densely packed, small dorsal chromatophores, about 45 – 100 pigments wide, covering the entire dorsal length, and a subdermal copper coloration covering the brain and occiput. The coppery/brassy coloration to the posterior-dorsal portion of the body and caudal peduncle found in *L. affinis* is usually absent in *L. jayakari* but sometimes may be mildly present in very large (>100mm SL) specimens. No luminous organs are present.

Similar Species in the Gulf of Mexico: See above section on similar species to *Lestidiops affinis*. As with *L. affinis, L. jayakari* can be confused with several other Lestidiinae but is most easily conflated with its cogeners. *L. jayakari* is usually identical in meristic counts to *L. affinis* but can be distinguished by pigmentation and/or the relative positions of the DFO and PVO. In *L. jayakari*, the snout to DFO length is usually 60% of SL or less and the anus is approximately below the DFO throughout development. In adult specimens (>60 mm SL) pigmentation can readily distinguish *L. jayakari* from *L. affinis* as *L. jayakari* has noticeably smaller and more abundant dorsal pigments than *L. affinis,* and generally lacks brassy coloration along the caudal peduncle, although sometimes this trait may be occasionally present in large (>100 mm SL) individuals.

Geographic, Seasonal, Diel, and Vertical Distribution: *Lestidiops jayakari* were rare and overall abundances in 2011 were low (N=22), as such the present statistical analyses did not prove useful due to low power (<0.1) and significant heterogeneity of variance at all levels of analysis. Looking at the raw data, patterns of geographic distribution in this species were reminiscent to that of *L. affinis*, with a high level of spread throughout the northern GoMx (see Figures 21 - 22). Abundances were similar between summer and spring months, with the greatest numerical abundances occurring in summer, while no *L. jayakari* were collected during winter sampling periods. The majority of *L. jayakari* abundances were observed at night, with no specimens collected at day by the MOCNESS and only 2% of HSRT abundance being collected during day-time trawls. All individuals captured by MOCNESS gear were collected during night time sampling and were found in either depth bins 3 or 5 (see Figure 23).

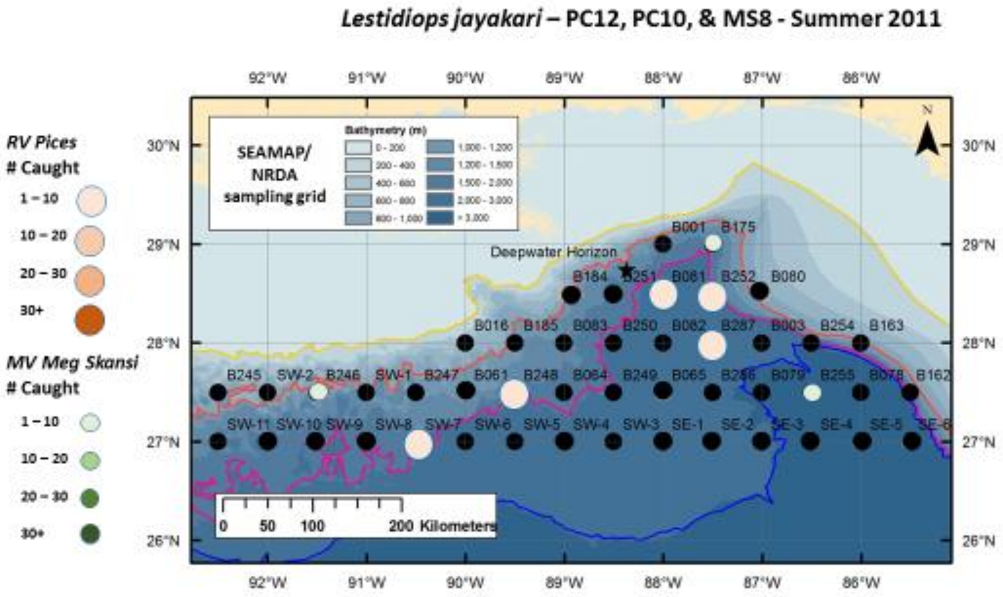


Figure 19 - Geographic distribution of the pacific barracudina in the sampling region during the summer of 2011. The Pisces sampled a total biomass of 45.9 g at an average specimen SL of 120.8 mm. The Meg Skansi sampled a total biomass of 0.08 g at an average specimen SL of 27.2 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

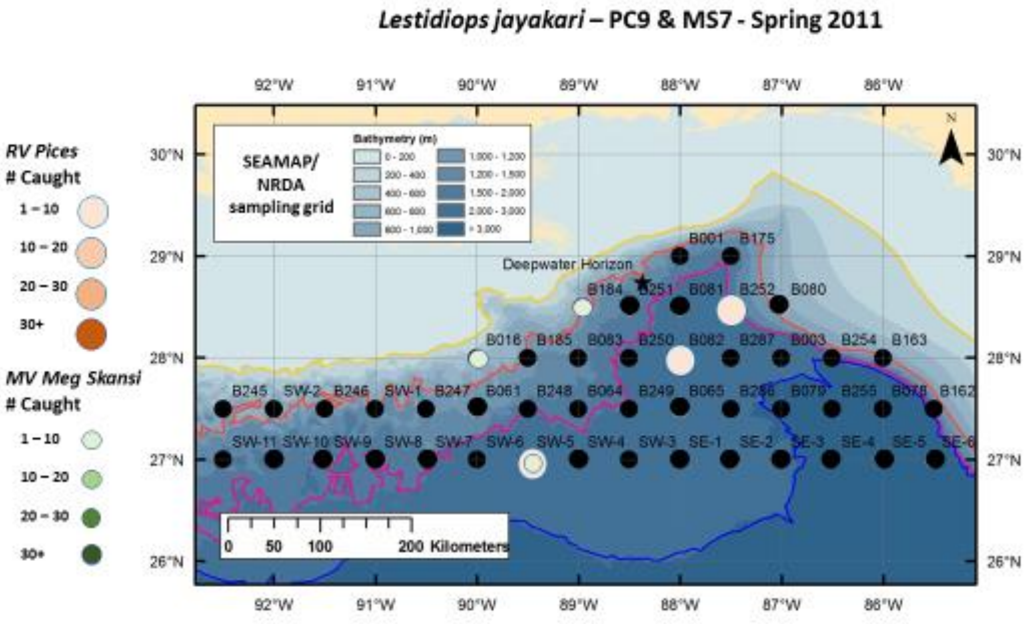


Figure 20 - Geographic distribution of the Pacific barracudina in the sampling region during the spring of 2011. The Pisces sampled a total biomass of 9.6 g at an average specimen SL of 120 mm. The Meg Skansi sampled a total biomass of 0.09 g at an average specimen SL of 23.3 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

Diet: Based on gut surveys of 17 specimens varying in size from 80 to 134 mm SL, the diet of *L. jayakari* consists of mesopelagic fishes. There were only 5 specimens documented to have gut contents, 1 individual had eaten a fish identifiable as a Phosichthyidae.

Ontogeny and Reproduction: Since the majority of specimens were caught during summer, comparison of size classes by season was problematic. However, specimens <70 mm SL were found at all times of year and caught exclusively by the MOCNESS at night. Large, pigmented eggs were documented in all seasons which specimens were sampled from (only summer and spring). The average SL for pigmented eggs was 117 mm and the smallest documented was 91 mm SL.

Lestidiops mirabilis

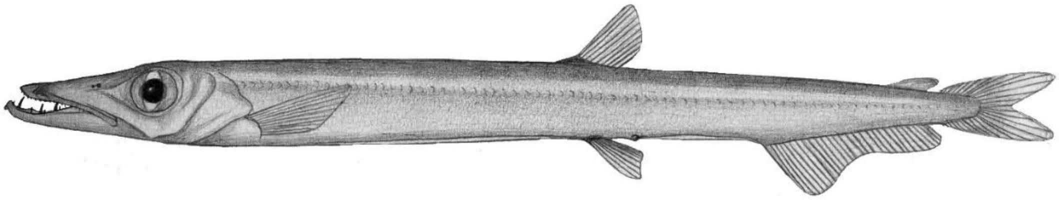


Figure 21 - The dusky barracudina (*Lestidiops mirabilis*). Max recorded SL: 170 mm*. Translucent at smaller (<60 mm SL) sizes, becoming darkly pigmented as an adult, appears iridescent black in life. The dorsal fin is approximately over the pelvic fin origin. Illustration by Ray Simpson.

Description: The “dusky barracudina” (a.k.a. “strange pike smelt” in fishbase.org) is a medium sized barracudina of the sub-family Lestidiinae that almost entirely lacks squamation (a single row of scales is embedded along the lateral line) and is highly translucent when juvenile but darkly pigmented when mature. The snout is elongate for a *Lestidiops* species and ranges from 10 – 13% of SL. Numerous saw-like teeth are regularly spaced along the pre-maxilla. At 15 – 40 mm SL, two vertical pigment bands are apparent, located laterally above the AFR elements. Also, at these sizes, 5 - 6 thick peritoneal patches become clearly apparent. Between 60 and 120 mm SL, the bands of tail pigments recede as adult pigmentation develops. Numerous, dendritic melanophores begin to cluster dorsally, ventrally, and at the base of fin ray elements, eventually covering the entire body. The guanine embedded in the dermis (common to Paralepididae species) coupled with the dark pigmentation of mature *L. mirabilis* specimens gives them a metallic iridescence in life but, overall, mature individuals appear black. DFO located approximately above or directly in front of PVO. In adults, the snout is somewhat elongate for a *Lestidiops* (12 – 14% of SL). No luminous organs are present.

Similar Species in the Gulf of Mexico: *L. mirabilis* is similar in many respects to the other *Lestidiops* species but is readily differentiated by the relative positions of DFO and PVO as well as pigmentation and number and size of peritoneal patches. The DFO being nearly directly over the PVO in *L. mirabilis* can lead one to confuse this species with *Lestidium atlanticum* but these species differ in pigmentation throughout development as well as the number of peritoneal patches and the presence/absence of a luminous organ. At smaller sizes (<60 mm SL) *L. mirabilis* could be confused with *Magnisudis atlantica* due to the similar orientations of their caudal pigments and peritoneal patches. However, the number of said pigments and patches, as well as the number of AFR, differ and are diagnostic for the two species.

Geographic, Seasonal, Diel, and Vertical Distribution: *Lestidiops mirabilis* was rare and overall abundances were low (N=39), as such, statistical analyses were not useful due to low power (<0.1) and a high degree of heterogeneity of variance at all levels. Geographic distribution of this species from the raw data was apparently relegated to the sample transect of the *Pisces* (see Figures 25 - 26). Four specimens were captured at stations within 25 km of the 1000-meter isobath while the remainder (35) were collected farther from it. The greatest number of this species was captured in the summer months of 2011 and none were collected during winter sampling. Considering MOCNESS data, this species was exclusively represented in depth bin 5 at night, indicating an epipelagic distribution at least for smaller the size classes. Almost twice as many *L. mirabilis* were caught in “shallow” (24) tows of the HSRT as “deep” (15), and most of these landings (28) occurred at night.

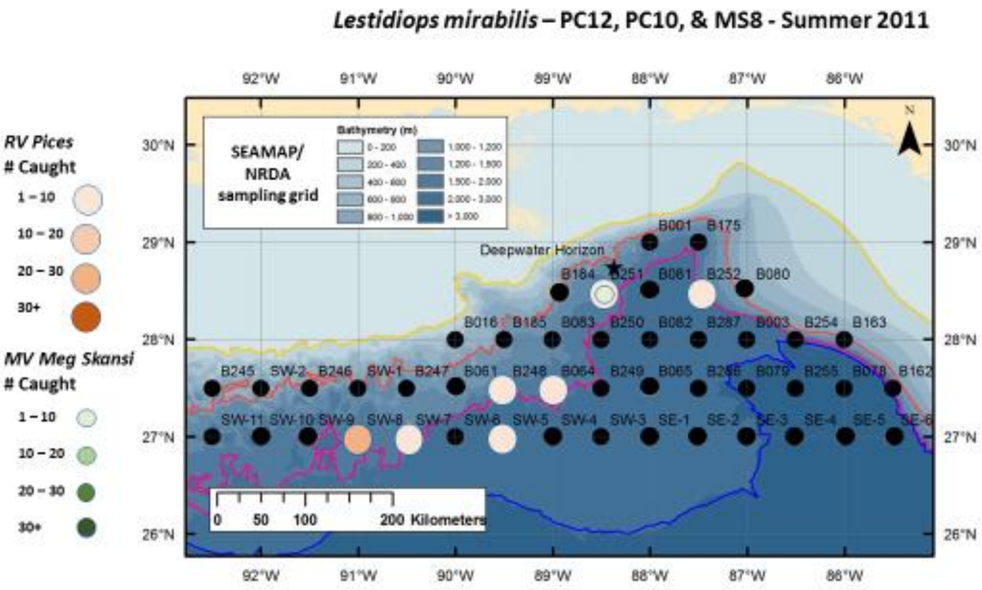


Figure 22 - Geographic distribution of the dusky barracudina in the sampling region during the summer of 2011. The Pisces sampled a total biomass of 50.1 g at an average specimen SL of 128.5 mm. The Meg Skansi sampled a total biomass of 0.05 g at an average specimen SL of 33 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

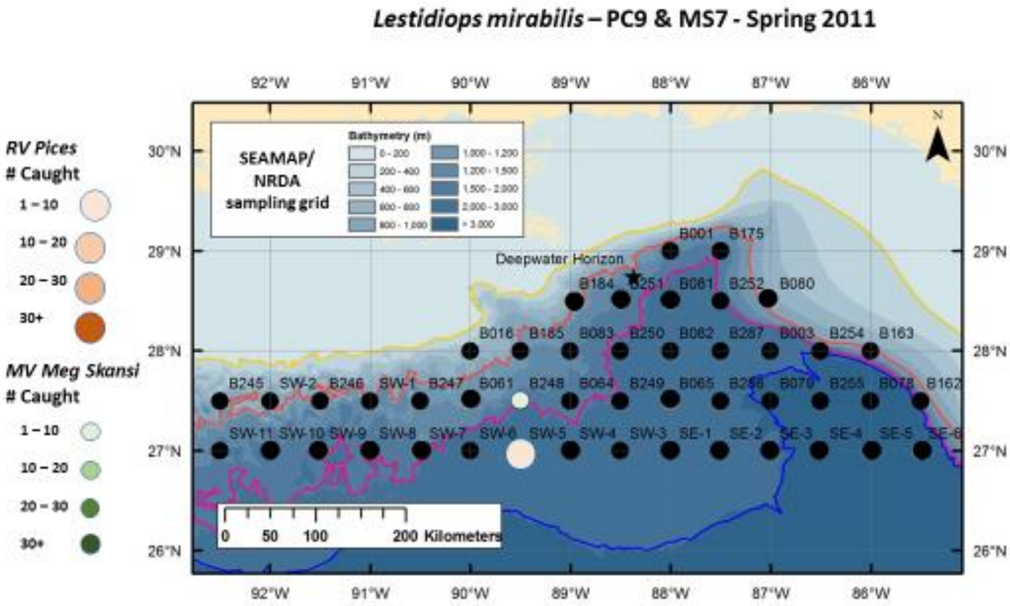


Figure 23 - Geographic distribution of the dusky barracudina in the sampling region during the spring of 2011. The Pisces sampled a total biomass of 8.1 g at an average specimen SL of 78 mm. The Meg Skansi sampled a total biomass of 0.02 g at an average specimen SL of 18 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

Diet: Based on gut surveys of 9 specimens varying in size from 59 to 170 mm SL, the diet of *L. mirabilis* is possibly varied and consists of fishes, euphausiid shrimps, and squid. However, only one individual was documented with all 3 of these prey items in its stomach, all of which were at an advanced degree of digestion. All other specimens with stomach contents contained unidentifiable fish digesta.

Ontogeny and Reproduction: All specimens >40 mm SL were captured with the HSRT and most of these were collected during the summer. Only 3 specimens <40 mm SL were collected by the MOCNESS. Of the 9 specimens used in the gut surveys, 3 had apparently mature eggs and were 89, 124, and 170 mm SL, respectively. All three were collected during the summer sampling periods.*Lestidium atlanticum*

Lestidium atlanticum

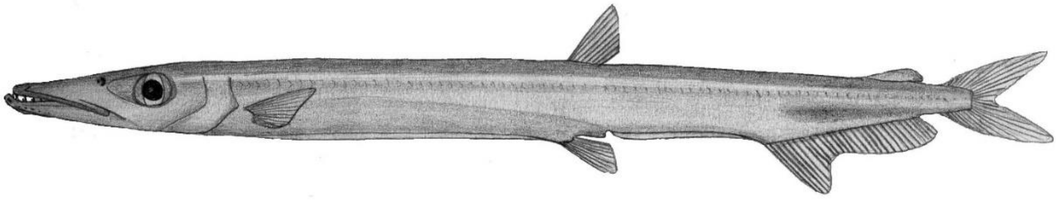


Figure 24 - The Atlantic barracudina (*Lestidium atlanticum*). Max. recorded SL: 250 mm SL (fishbase.org). Unique among barracudina in that it possesses a single, ventral bioluminescent duct below the gut lining. Mostly translucent. Dorsal fin origin directly over pelvic fin origin. Illustration by Ray Simpson.

Description: The "Atlantic barracudina" is a medium sized barracudina of the sub-family Lestidiinae that almost entirely lacks squamation (a single row of scales is embedded along the lateral line) and appears highly translucent in life at all stages of development. *L. atlanticum* is unique among barracudina in that it possesses a single, internal duct of a bioluminescent organ that runs ventrally along the gut, and which has been determined by Ghedotti, *et al.* (2014) to be derived from hepato-pancreatic tissues. It is said that this feature imparts a faint yellow glow to this species in life (Rofen, 1966). At SL between 15 and 60 mm, 8 peritoneal patches become visible. Between 60 and 100 mm SL, these peritoneal patches begin to appear fused into a single, darkly occluded gut lining. The DFO is positioned directly above the PVO during all stages of development. Larger specimens of *L. atlanticum* (>60mm SL) usually possess a distinct set of pigmentations: a diffuse, brown dorsal band of pigment that runs the entire length of the body, a separate band of brown pigment following and surrounding the lateral line, and a narrow brown streak located immediately posterior to each eye running vertically along the curve of the orbit. A single luminescent organ appears as a dark line running along the mid-ventral of a bright, silvery band just below the peritoneum. This band becomes especially silvery in specimens 60 mm SL or greater.A few specimens identified as *L. atlanticum* from these samples represent problematic variations.

Similar Species in the Gulf of Mexico: *Lestidium atlanticum* could be confused with many other species of Lestidiinae. It can be differentiated from most by the relative position of the DFO and PVO, which are immediately above and below each other. While this is a similar character state to that of *Lestidiops mirabilis*, these two species can be easily differentiated by their pigmentation, AFR count, and number of peritoneal patches. Of all barracudina, *Lestidium atlanticum* is the only species known to have a single luminous organ situated ventrally along the gut, however, it may be confused with *Lestrolepis intermedia* for having a ventral light organ. *L. atlanticum* can be distinguished from *Lestrolepis intermedia* by the relative placement of fins, by its lack of photophores before the eyes, and by the difference in AFR element counts.

Geographic, Seasonal, and Vertical Distribution: *Lestidium atlanticum* was uncommon overall (68), and heterogeneity of variance was high; Welch's ANOVAs produced no statistically significant results. Most numbers (60) were caught at stations farther than 25 km away from the 1000-meter isobath. As with *Lestidiops mirabilis*, these data mirror the geographic distribution of the *Pisces* sampling transect (see Figures 28 - 30), likely an artefact of the low numbers collected by the *Meg Skansi*. It also appears that their numbers and extent are greatest in the summer months. Of the MOCNESS depth data, only 3 individuals of *L. atlanticum* were found in nets 4 (200 – 600 m) and 5 (0 – 200 m) at night.

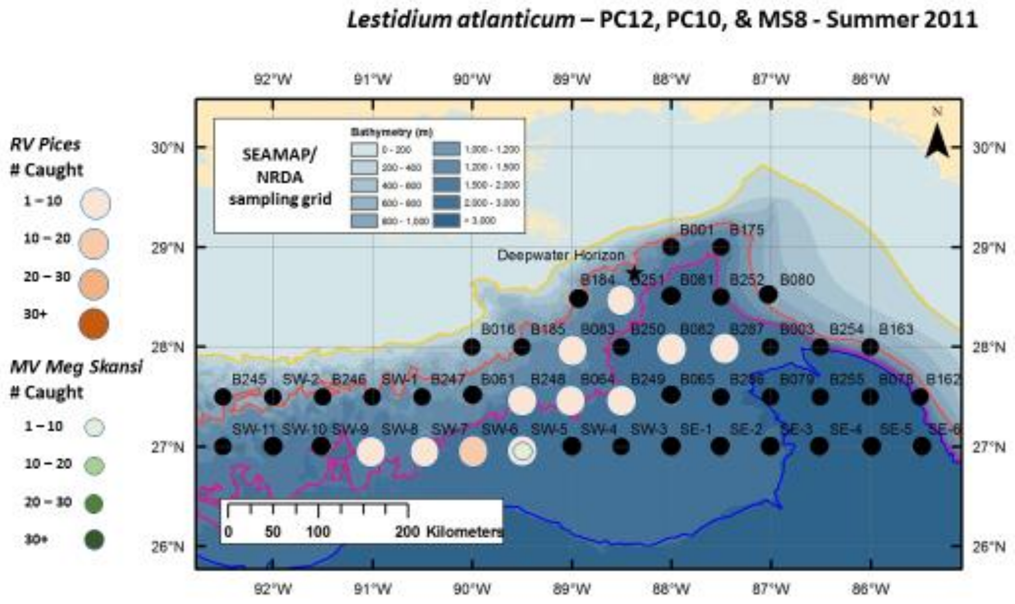


Figure 25 - Geographic distribution of the Atlantic barracudina in the sampling region during the summer of 2011. The Pisces sampled a total biomass of 65.2 g at an average specimen SL of 95 mm. The Meg Skansi sampled a total biomass of 0.05 g at an average specimen SL of 33 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

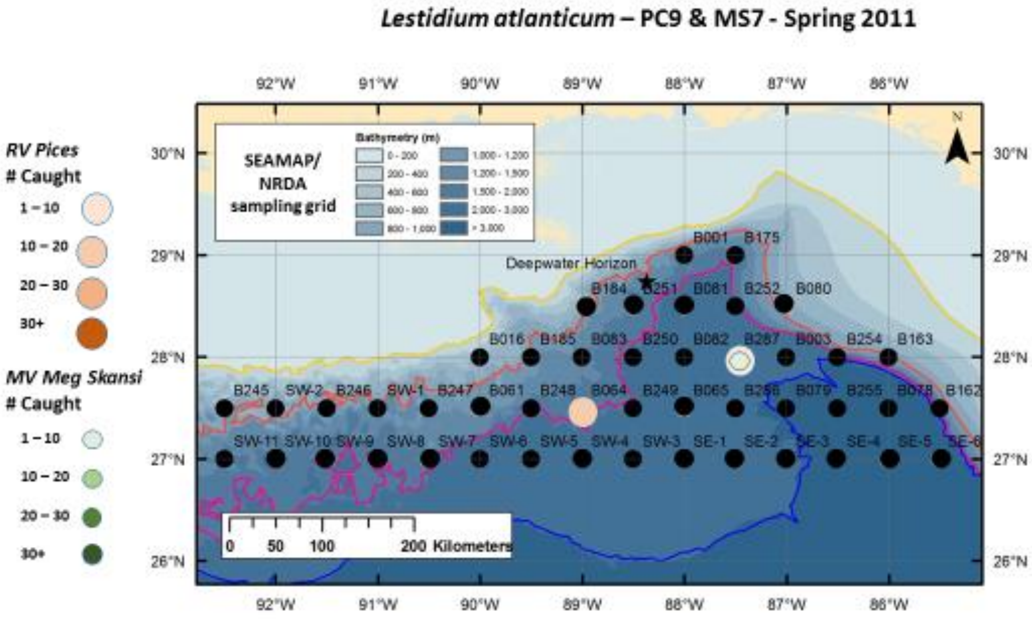


Figure 26 - Geographic distribution of the Atlantic barracudina in the sampling region during the spring of 2011. The Pisces sampled a total biomass of 16.7 g at an average specimen SL of 84.5 mm. The Meg Skansi sampled a total biomass of 0.05 g at an average specimen SL of 35 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

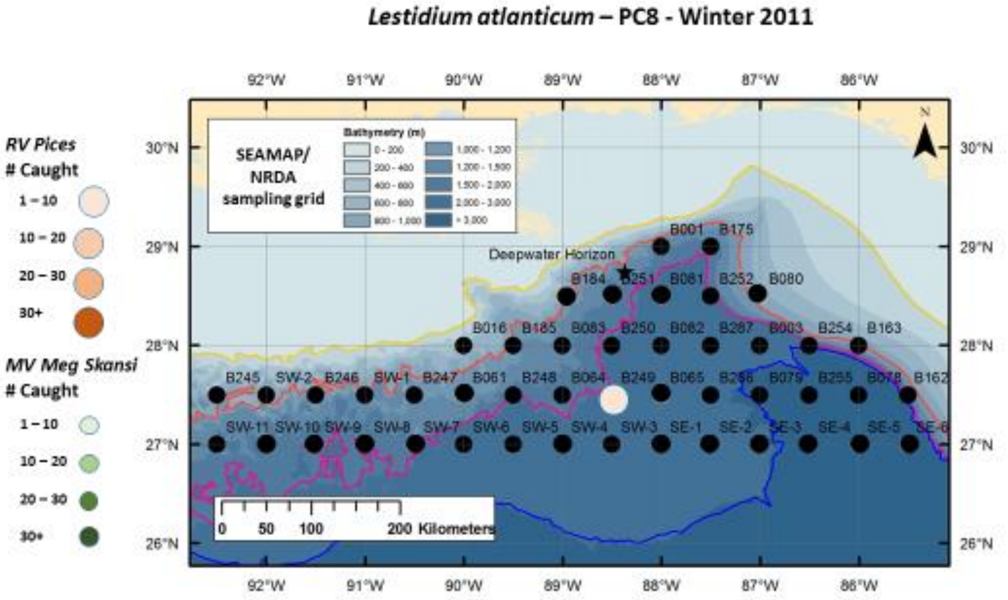


Figure 27 - Geographic distribution of the Atlantic barracudina in the sampling region during the winter of 2011. The Pisces sampled a total biomass of 3.2 g at an average specimen SL of 130 mm. The Meg Skansi did not collect any specimens during that sampling period. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

Diet: Based on gut surveys of 29 individuals, ranging in size from 53 to 189 mm SL, adult *L. atlanticum* have a diet entirely composed of mesopelagic fishes. Of the specimens surveyed, 20 had stomach contents. Of those, specimens with notably “full” stomachs were significantly more commonly collected at day than at night ($p<0.0225$). No statistical difference was noted in the level of digestion of prey taxa between day and night collected specimens.

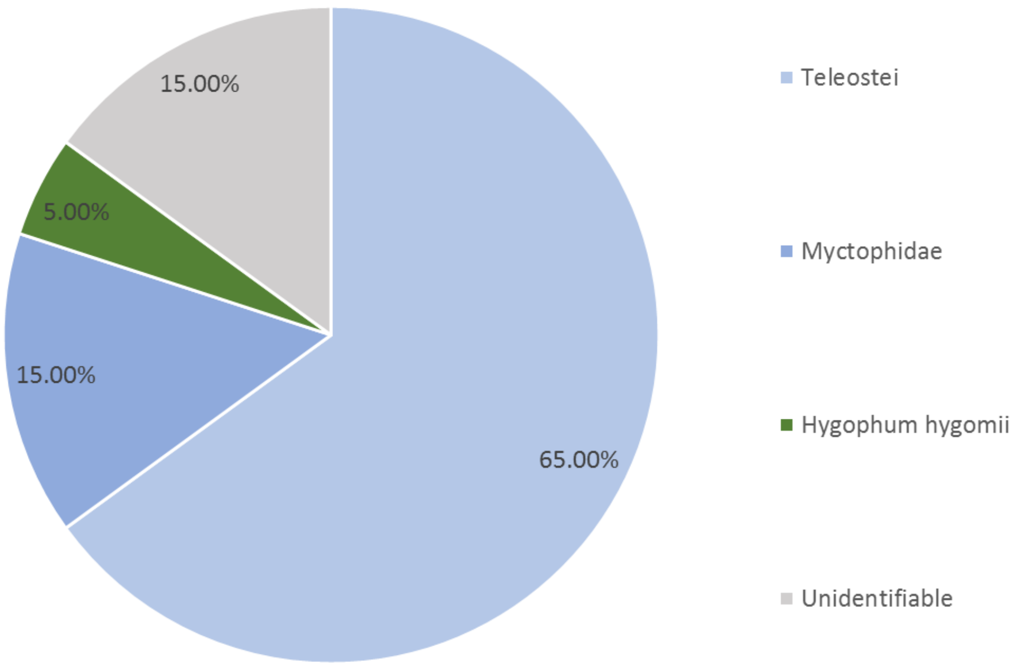


Figure 28 - Dietary composition of *Lestidium atlanticum.* Entirely composed of fishes.

Table 6 - Dietary composition of *Lestidium atlanticum* had a diet entirely composed of mesopelagic fishes.

Prey LTU	**%N**	**%F**	**%WB**	**IRI**
Teleostei	65.00%	45.00%	82.82%	0.67
Myctophidae	15.00%	65.00%	15.85%	0.20
Hygophum ygomii	5.00%	5.00%	1.28%	0.00
Unidentifiable	15.00%	0.00%	0.05%	0.00

Table 7 - Dietary composition of *Lestidium atlanticum* by solar cycle. Stomachs were significantly fuller in daytime collected L. atlanticum specimens but the lowest LTU was from a night-collected specimen.

	Day				**Night**			
Prey LTU	**%N**	**%F**	**%WB**	**IRI**	**%N**	**%F**	**%WB**	**IRI**
Myctophidae	16.67%	91.67%	91.74%	0.99	12.50%	25.00%	1.71%	0.04
Teleostei	83.33%	66.67%	8.26%	0.61	37.50%	12.50%	96.71%	0.17
Hygophum hygomii	0.00%	0.00%	0.00%	0.00	12.50%	12.50%	1.52%	0.02
Unidentifiable	0.00%	0.00%	0.00%	0.00	37.50%	0.00%	0.06%	0.00

Ontogeny and Reproduction: Of the largest size class (>70 mm SL), 71% were collected at night, 64% were collected during summer, and all were collected from deep trawls. Of the smaller size class (<70 mm SL), 77% were collected at night, 90% were collected in summer, and 67% were collected from “shallow” trawls. Of the 29 specimens surveyed for gut contents, 12 individuals were noted with large, pigmented eggs. These were exclusively documented in spring and summer collected specimens. The average SL for these 12 specimens was 122 mm; the smallest was 76 mm SL and collected in spring.

Figure 29 – Relative density chart for the presence of large, pigmented eggs, graphed by SL and season, from the 29 *L. atlanticum* surveyed for gut contents. The highest density of pigmented eggs was witnessed in summer while 2 individuals were documented with this feature in the spring samples.

Lestrolepis intermedia

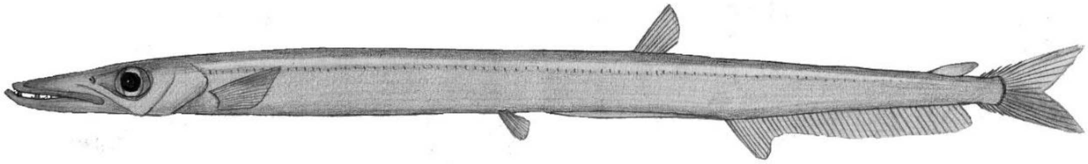


Figure 30 - The javelin barracudina (*Lestrolepis intermedia*). Max. recorded SL: 380 mm (fishbase.org). Unique among barracudina for having a pair of bioluminescent ducts running ventral to the gut lining. Highly translucent and overall quite elongate with a high anal fin ray count. Illustration by Ray Simpson.

Description: The “javelin barracudina” is a medium-large sized barracudina of the sub-family Lestidiinae that almost entirely lacks squamation (a single row of scales is embedded along the lateral line) and appears highly translucent in life at all stages of development. *Lestrolepis intermedia* is unique among barracudina in that it possesses a pair of internal ducts of bioluminescent organs which run ventrally along the gut, and that have been determined by Ghedotti *et al.* (2014) to be derived from hepato-pancreatic tissues. It is said that this feature imparts a faint yellow glow to this species in life (Rofen, 1966). In addition, Ghedotti *et al.* determined that the unique pigment spots just anterior to either eye in this species are bioluminescent organs as well, likely used to match light intensity in the mesopelagic. These photophores only begin to develop and become apparent in specimens between 40 – 70 mm SL. *Lestrolepis intermedia* is elongate especially posterior of the venter where the body becomes highly compressed laterally. This elongated nature is further reflected in the high AFR count (40 – 42) and the long area between the vent and AFO, where the midventral adipose fin is located. The elongated tapering of its body combined with its long snout (~20% of SL) impart an overall spear-like, or “javelin”-like appearance to this fish. Specimens between 10 and 40 mm SL have 8 – 10 peritoneal patches clearly visible and occasionally in living specimens, organ tissues are visible through the skin and appear pinkish or reddish. Between 60 and 100 mm SL, these patches begin to appear fused into a single, darkly occluded gut lining and adult pigmentation begins to develop. This pigmentation includes a dorsal band of chromatophores, about 20 pigments wide, that covers the dorsal section of the entire body above the lateral line, and a subdermal brassy pigmentation covering the brain and occiput. Numerous other chromatophores sparsely dot the posterior-lateral portion of the body below the lateral line, between the anus and AFO, and a dense row of chromatophores usually line the mid-ventral base of the adipose fin. The sides of the caudal peduncle are intensely pigmented. A single row of obliquely vertical, subdermal pigments is spaced mid-laterally along each myomere. These are located deep within the tissue, ventral to the spine and lateral line, and span from the vent to the caudal. Two luminous organs appear as dark lines running along the mid-ventral of a bright, silvery band just below the peritoneum. This band becomes especially silvery in specimens 60 mm SL or greater.

Similar Species in the Gulf of Mexico: At smaller sizes (<60 mm SL) *L. intermedia* is very similar in appearance to many other members of Lestidiinae. However, the high number of AFR elements distinguish this species from those of *Lestidiops* and *Macroparalepis*, and the latter of these two has a higher DFR count than *L. intermedia*. While the general appearance of the ventral luminous organs is very similar to that of the single organ in *Lestidium atlanticum*, the relative placements of the DFO and PVO are significantly different as the PVO is appreciably farther forward of the DFO in *L. intermedia* while the PVO is directly beneath the DFO in *Lestidium atlanticum*. *Lestrolepis intermedia* is also much more elongate in appearance than *Lestidium atlanticum*. In the GoMx, *L. intermedia* is most easily confused with *Stemonosudis bullisi*, which has about the same meristic counts as *L. intermedia* and appears similarly elongated. At smaller sizes (<60 mm SL), these two species can be differentiated by the presence/absence of pigments on the lateral line, which are absent in *L. intermedia* but are present in *S. bullisi* as a row of paired melanophores oriented above and below each lateral line scale like a colon punctuation mark. At larger sizes (>60 mm SL) adult pigmentation begins to develop and the two species are differentiated by the presence/absence of the light organs. Of all barracudina, *L. intermedia* is the only known species to have two ventral luminous organs and a photophore before each eye.

Geographic, Seasonal, Diel, and Vertical Distribution: *Lestrolepis intermedia* was found to be common and widely distributed throughout the study area during the summer sampling period, with an overall affinity for the lower epipelagic. No statistical difference was noted between abundances at stations near or far to the 1000-meter isobath. Abundances were skewed slightly to the western side of the study area likely due to the greatest abundances being collected by the *Pisces*. Standardized abundances were highest during the summer ($p<0.0367$) months and lowest during the winter in HSRT samples (see figures). Summer HSRT samples found significantly greater abundances at day compared to night ($p<0.0132$), and significantly greater abundances in “shallow” trawls compared to “deep” ($p<0.0202$). While abundances of *L. intermedia* documented by MOCNESS gear were low ($n = 11$), all specimens except one were documented in either depth bin 5 (0 – 200 m) or 4 (200 – 600 m), indicating a mostly epipelagic and upper mesopelagic distribution for smaller size classes. However, one outlier individual was found in depth bin 1 (1200 – 1500 m), the deepest sampling strata, and measured 46 mm SL.

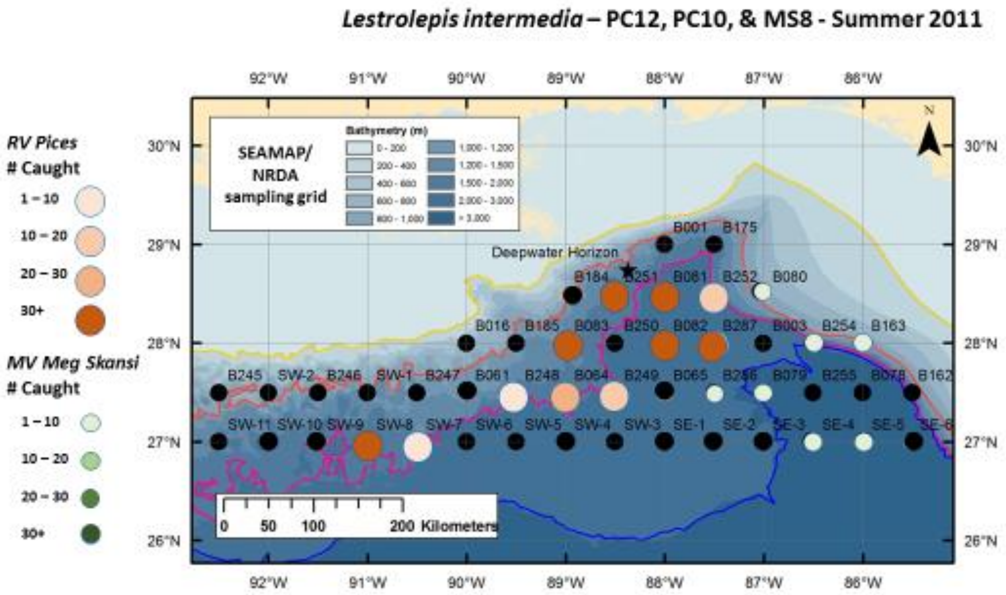


Figure 31- Geographic distribution of the javelin barracudina in the sampling region during the summer of 2011. The Pisces sampled a total biomass of 429.1 grams at an average specimen SL of 106 mm. The Meg Skansi sampled a total biomass of 1.03 grams at an average specimen SL of 39.9 mm. On this map, 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

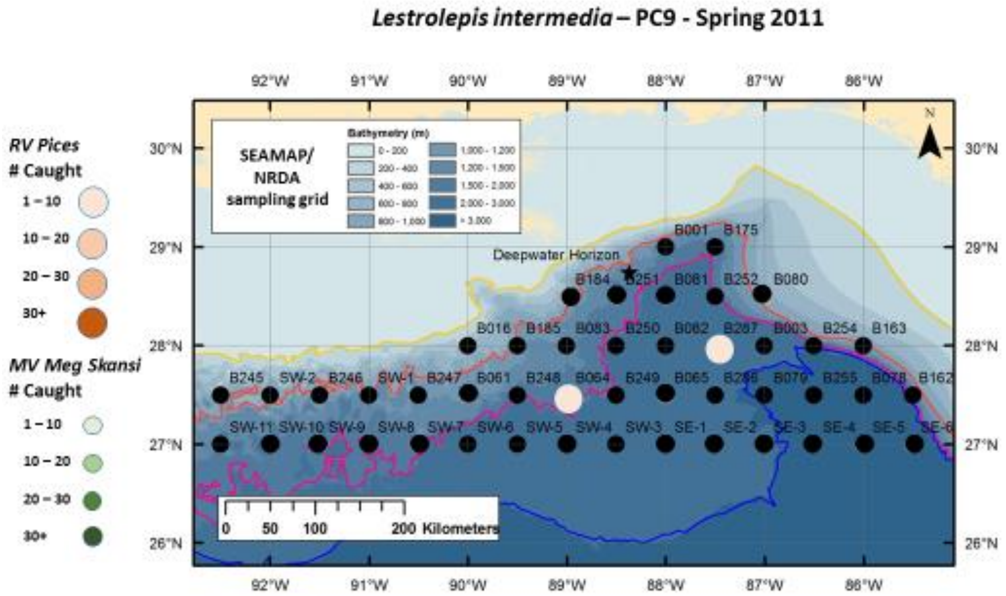
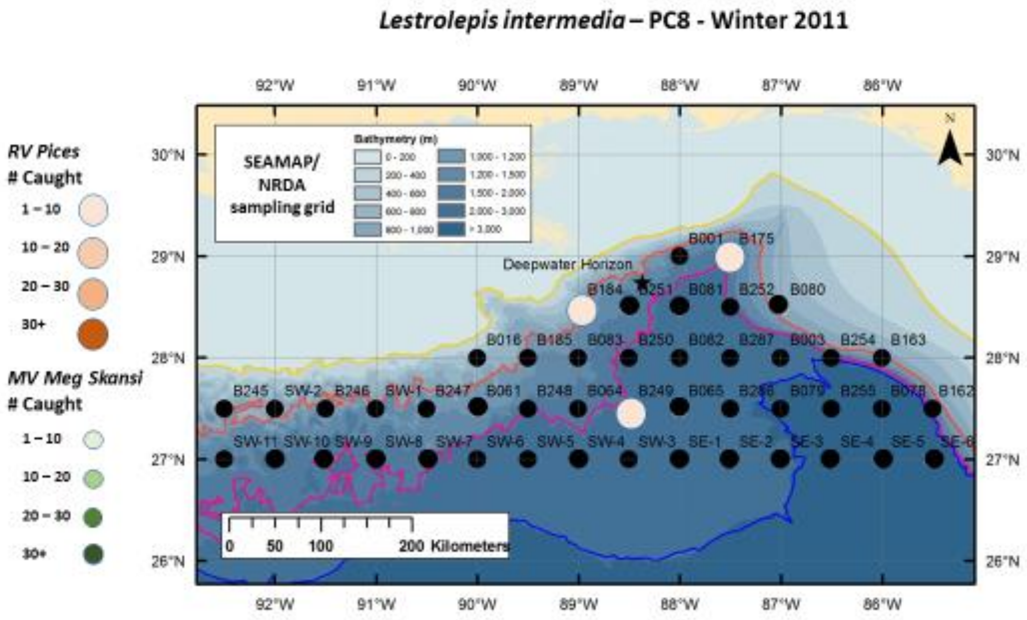


Figure 32 - Geographic distribution of the javelin barracudina in the sampling region during the spring of 2011. Only 2 specimens were collected by the Pisces at this sampling period, both from non-standard tows. Their respective weights and SL were 0.23 grams, 74 mm SL and 0.42 grams, 82 mm SL. On this map, 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.



Lestrolepis intermedia – PC8 - Winter 2011

Figure 33 - Geographic distribution of the javelin barracudina in the sampling region during the winter of 2011. The Pisces sampled a total of 10 individuals, with a total biomass of 3.2 grams and average SL of 130 mm. No specimens were collected by the Meg *Skansi* during that sampling period. On this map, 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

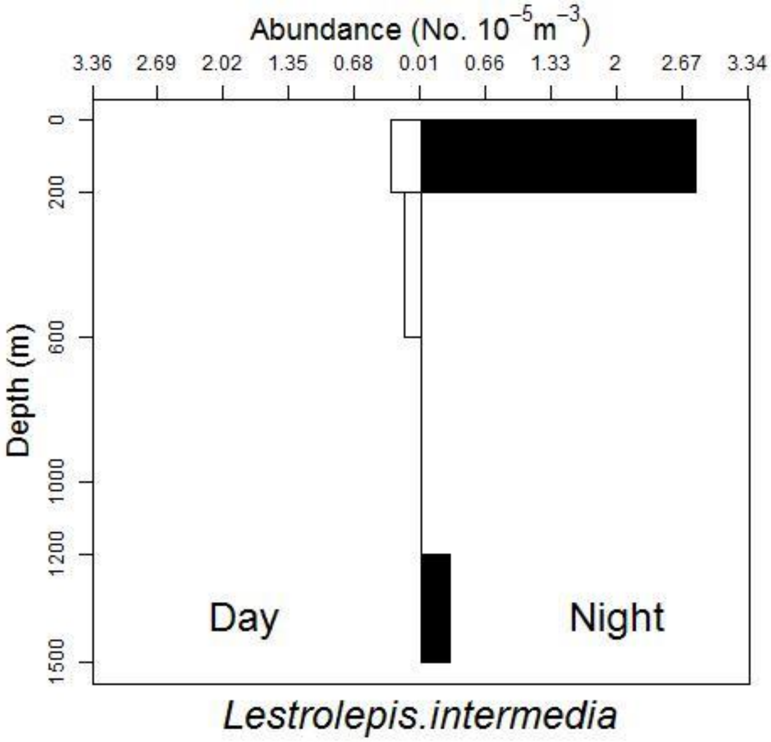


Figure 34 - Depth by Solar Cycle Diel, vertical depth distribution of the javelin barracudina over all *Meg Skansi* samples. Only 11 specimens of this species were produced by the Meg Skansi collection efforts. Most were found in net 5 (0 – 200 meters) at night but a few were documented in net 4 during day samples and one individual was collected from the deepest net (net 1) during a night sampling trawl.

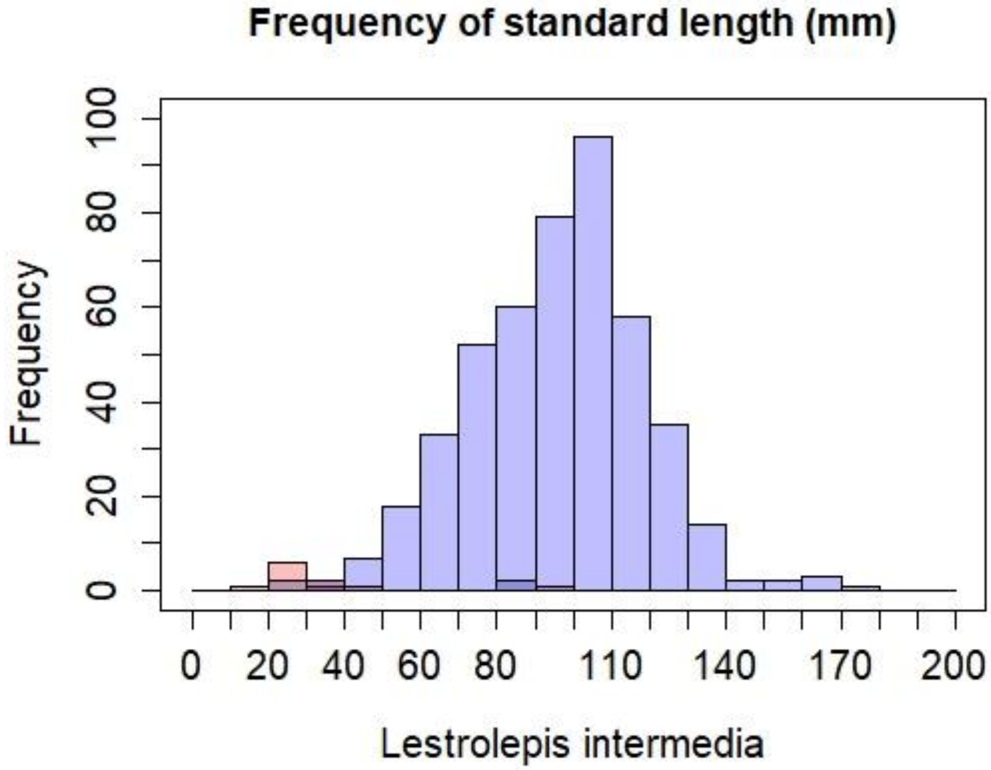


Figure 35 - Frequency of standard lengths in *L. intermedia* by cruise. The *Pisces* (in blue) caught significantly greater numbers (Welch's ANOVA; p<0.0001) than the two MOCNESS cruises combined (Meg Skansi = Salmon; Point Sur = Purple) and nearly all the data for this species are represented by *Pisces* samples.

Diet: Based on gut surveys of 188 individuals, ranging in size from 62 to 161 mm SL, *L. intermedia* has a diet largely composed of mesopelagic fishes, though one individual was found with cephalopod tentacle parts in its gut (unfortunately, no beak was found with them). Of the fish prey taxa identified to family level or lower, 77% were Myctophids. No statistically significant difference was noted between the stomach "fullness" of night and day collected specimens.

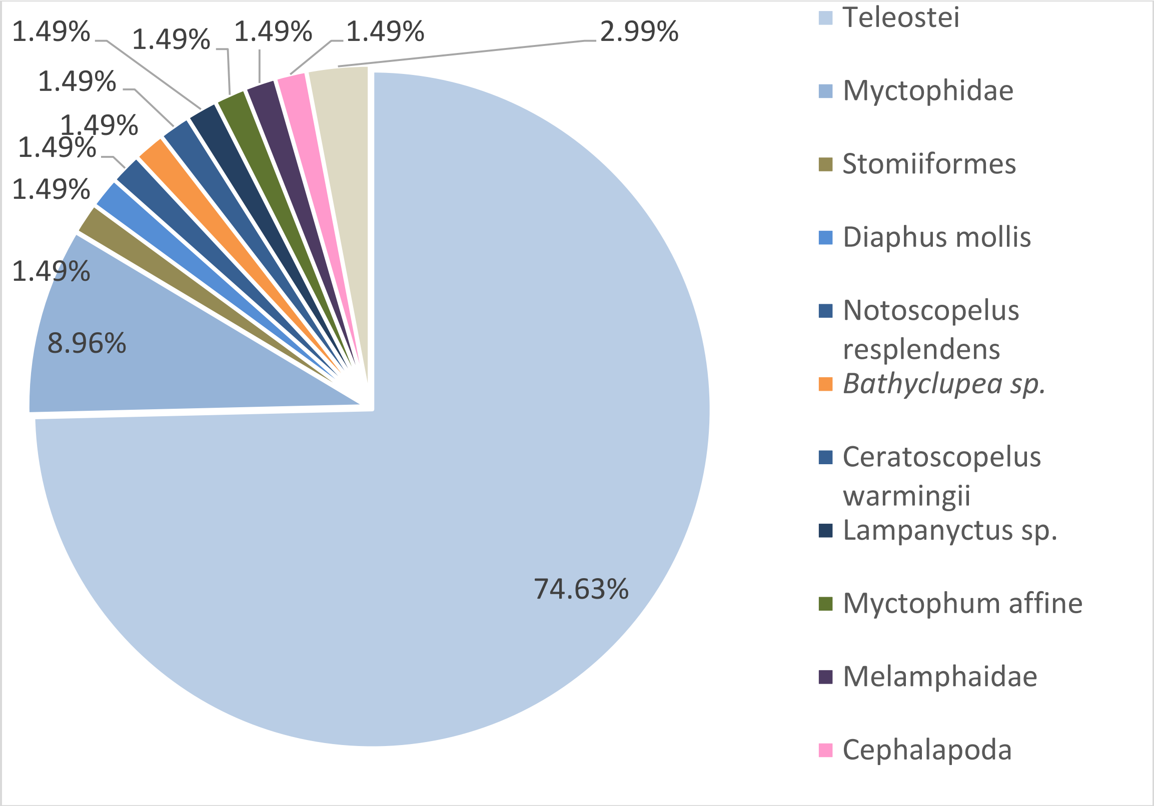


Figure 36 - Dietary Composition. The diet of adult *L. intermedia* was found to be almost entirely composed of mesopelagic fishes except for some evidence of cephalopod consumption by a single individual. 77% of the identifiable fish prey were Myctophids.

Table 8 - Dietary Composition of *Lestrolepis intermedia*. The diet of adults was found to be almost entirely composed of mesopelagic fishes except for some evidence of cephalopod consumption by a single individual. 77% of the identifiable fish prey were Myctophids.

Prey LTU	**%N**	**%F**	**%WB**	**IRI**
Teleostei	74.63%	71.64%	59.03%	0.96
Myctophidae	8.96%	10.45%	8.69%	0.02
Stomiiformes	1.49%	1.49%	28.98%	0.00
Diaphus mollis	1.49%	2.99%	1.16%	0.00
Notoscopelus resplendens	1.49%	1.49%	0.87%	0.00
Bathyclupea sp.	1.49%	1.49%	0.48%	0.00
Ceratoscopelus warmingii	1.49%	1.49%	0.28%	0.00
Lampanyctus sp.	1.49%	1.49%	0.19%	0.00
Myctophum affine	1.49%	1.49%	0.19%	0.00
Melamphaidae	1.49%	1.49%	0.10%	0.00
Cephalapoda	1.49%	1.49%	0.01%	0.00
Unidentifiable	2.99%	0.00%	0.02%	0.00

Table 9 - Dietary composition of *Lestrolepis intermedia* by Solar Cycle. The majority of precisely identified LTU prey items were from night samples. However, no significant difference was noted between stomach fullness at day or night and the percentage of full stomachs found at night (68%) was very near the percentage of total, night collected specimens surveyed (79%).

	Day				**Night**			
Prey LTU	**%N**	**%F**	**%WB**	**IRI**	**%N**	**%F**	**%WB**	**IRI**
Teleostei	90.48%	109.52%	56.80%	1.61	67.39%	54.35%	59.29%	0.69
Myctophidae	4.76%	4.76%	38.70%	0.02	10.87%	13.04%	5.09%	0.02
Bathyclupea sp.	4.76%	4.76%	4.50%	0.00	0.00%	0.00%	0.00%	0.00
Cephalapoda	0.00%	0.00%	0.00%	0.00	2.17%	2.17%	0.01%	0.00
Ceratoscopelus warmingii	0.00%	0.00%	0.00%	0.00	2.17%	2.17%	0.31%	0.00
Diaphus mollis	0.00%	0.00%	0.00%	0.00	2.17%	4.35%	1.30%	0.00
Lampanyctus sp.	0.00%	0.00%	0.00%	0.00	2.17%	2.17%	0.22%	0.00
Melamphaidae	0.00%	0.00%	0.00%	0.00	2.17%	2.17%	0.11%	0.00
Myctophum affine	0.00%	0.00%	0.00%	0.00	2.17%	2.17%	0.22%	0.00
Notoscopelus resplendens	0.00%	0.00%	0.00%	0.00	2.17%	2.17%	0.97%	0.00
Stomiiformes	0.00%	0.00%	0.00%	0.00	2.17%	2.17%	32.46%	0.01
Unidentifiable	0.00%	0.00%	0.00%	0.00	4.35%	0.00%	0.02%	0.00

Ontogeny and Reproduction: Statistical analyses of differences in the frequency of SL were problematic due to most specimens having been collected solely by shallow tows of the HSRT in the summer. No statistical difference in frequency of either size classes was noted between day and night trawls. Based on the 188 individual gut surveys, the average SL for large, pigmented eggs to occur in *L. intermedia* was 111 mm SL, with the smallest specimen to exhibit mature eggs measuring 82 mm SL. The great majority (98%) of specimens with mature eggs were collected in the summer sampling months but two specimens that possessed large, pigmented eggs were sampled in winter. No specimens collected during spring were surveyed for gut contents.

Macroparalepis affinis

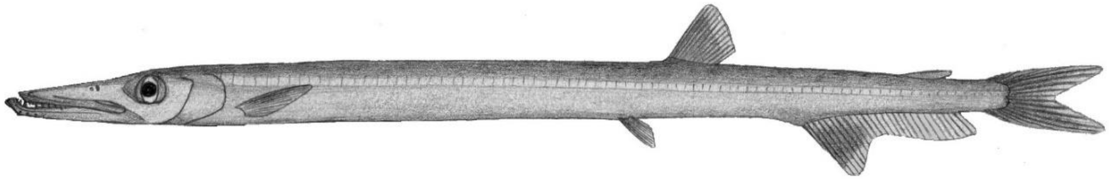


Figure 37- The slender barracudina (*Macroparalepis affinis*). Max. recorded SL: 550 mm SL (Fishbase.org). A fairly elongate barracudina that has a snout to dorsal fin origin length that is a high percentage of SL. A mottled silvery pigmentation lines the dorsum of adults and a series of 6 – 8 occipital ridges line the head above either eye. Illustration by Ray Simpson.

Description: The "slender barracudina" is a medium sized barracudina of the sub-family Lestidiinae that almost entirely lacks squamation (a single row of scales is embedded along the lateral line). *M. affinis* is unique among Lestidiinae species for having 6 to 8 bony ridges on the occiput just posterior to the orbits. This barracudina is elongate and laterally compressed relatively evenly throughout its length. At SL less than 60 mm, 10 peritoneal patches are apparent, becoming more obscured by tissue with age. Typical to the *Macroparalepis* genus, *M. affinis* possesses a silvery, mottling pattern of pigmentation covering the entire dorsal length.

Similar Species in the Gulf of Mexico: At smaller sizes, *M. affinis* can be confused with many other species of Lestidiinae. At all sizes, *Macroparalepis* are perhaps most like *Lestidiops affinis* and *L. jayakari*. *M. affinis* can be distinguished from *Lestidiops* species by merisitic counts and by the number and prominence of the occipital ridges. Additionally, the placement of the anus and the DFO are further posterior in *M. affinis* than in other Lestidiinae species. The distance between the snout and vent ranges from 69 – 71% of SL in *M. affinis* and the distance from the snout to AFO is 80 – 81% of SL. Compared with *Lestidiops*, *Lestrolepis*, and *Lestidium*, which vary in their lateral widths, *Macroparalepis* species are about the same thickness throughout the length of their bodies. This evenly slender and compressed appearance is like that of a few species of *Stemonosudis,* but those species also have a lower DFR count and some are much more elongate or have remarkably different pigmentation. The only other barracudina in the GoMx with a DFR count of 13 is *Sudis hyalina*, which is quite different from *Macroparalepis* in all other respects.

Macroparalepis affinis was extremely rare in the study area; because only three specimens were sampled from these efforts no natural history information is presented here regarding this species in the GoMx.

Magnisudis atlantica

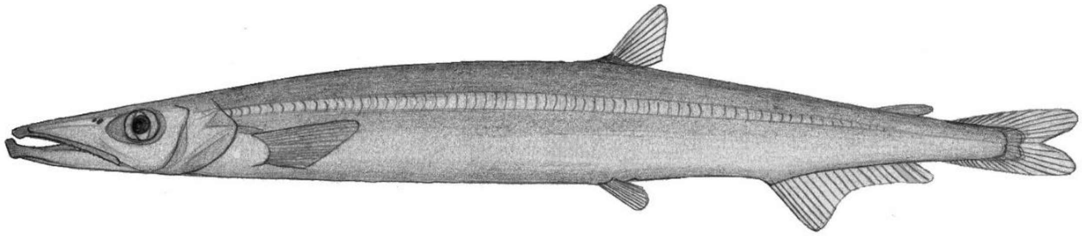


Figure 38 - The duck-billed barracudina (*Magnisudis atlantica*). Max. recorded size 560 mm SL (fishbase.org). A large, scaly barracudina which appears iridescently silver in life. This barracudina is rounded, does not exhibit ventral keeling, and generally dorso-ventrally taller than other Paralepididnae. Illustration by Ray Simpson.

Description: The “duck-billed barracudina” is a large barracudina of the sub-family Paralepidinae that is covered in a delicate layer of skin and cycloid scales which will often tear completely off with capture. In life, the overall appearance of this fish is a brilliantly iridescent silver (see Figure 1). *Magnisudis atlantica* have a mix of extremely minute depressible canines and fixed teeth along the premaxilla, which appear quite bristle-like at a glance, and that reduce in number and stature with age to the point of almost complete loss in some very mature specimens. The profile of *M. atlantica* is like that of other Paralepidinae which is moderately elongate but comparatively dorso-ventrally tall at mid-body. *Magnisudis atlantica* does not exhibit ventral keeling as do most other barracudina. Often larger *M. atlantica* specimens appear to have a “hump” or “kink” in their dorsal profile at about mid-body. The snout is moderately long (11 – 16% of SL) and broad, and the slope of the upper jaw between the eye and the snout is lesser than the slope posterior to the head, imparting a “duckbill-like” appearance. At SL <30 mm, 2 – 4 large peritoneal patches are apparent and a vertical band of pigment rising from the anal fin, either immediately anterior to or on the caudal peduncle, meets with and conjoins to a dorsal row of dark pigmentation that stretches to the occipital. In specimens <15 mm SL, the dorsal pigment row may not be apparent, and the vertical bar of pigment on the caudal peduncle may be a mere grouping of 2 – 4 chromatophores set about the notochord. No luminous organs are present.

Similar Species in the Gulf of Mexico: *M. atlantica* can easily be confused with the other species of Paralepidinae in the GoMx. At SL <100 mm, *M. atlantica* is readily distinguished from both species of *Paralepis* in having significantly fewer peritoneal patches and, at SL <40 mm, in the placement and shape of pigments along the caudal peduncle. At these smaller sizes, the general appearance of *M. atlantica* could be confused with *Lestidiops mirabilis* but the two species can easily be distinguished by the number of peritoneal patches and the shape and number of caudal peduncle pigments. At larger sizes, when the peritoneal patches are not easily visible, it can be much harder to differentiate the 3 species of Paralepidinae found in the GoMx. However, the snout length (12 – 16% of SL) and head length (27 – 30% of SL) in *M. atlantica* are markedly longer than either *Paralepis* species. In addition, *M. atlantica* lacks strong keeling, and the lateral width of the ventral portion of the mid-body is generally much more robust and rounded in *M. atlantica* than in either species of *Paralepis*, which do tend to exhibit ventral keeling at about mid-body. The body height of adult *Paralepis* species is also appreciably less than that of *M. atlantica*, which can be massive compared to the more elongate *Paralepis*. *Paralepis brevirostris* has a distinctly shorter snout than either species.

Geographic, Seasonal, Diel, and Vertical Distribution: *Magnisudis atlantica* was found to be common and evenly distributed throughout the study area with an apparent disposition for the mesopelagic. No statistical differences were noted in relationship to the 1000-meter isobaths nor to either longitudinal side of the study area. In both MOCNESS and HSRT sampling, abundances were highest during summer and lowest during spring, however, abundances were equally high in winter *Pisces* samples as with summer *Pisces* samples and there was no statistical difference between observed summer and winter levels (p<0.3211). Significantly greater abundances were captured at night by the HSRT gear while there was no statistical difference documented between day and night trawls of the MOCNESS. Significantly greater abundances were documented in the "shallow" trawls of the HSRT compared with "deep" (p<0.0077). While no statistical difference was observed in abundance among the MOCNESS depth data, almost all samples came from depth bin 3 (38), and only single individuals were documented in depth bins 1 (1200 – 1500 m) and 4 (200 – 600 m), respectively.

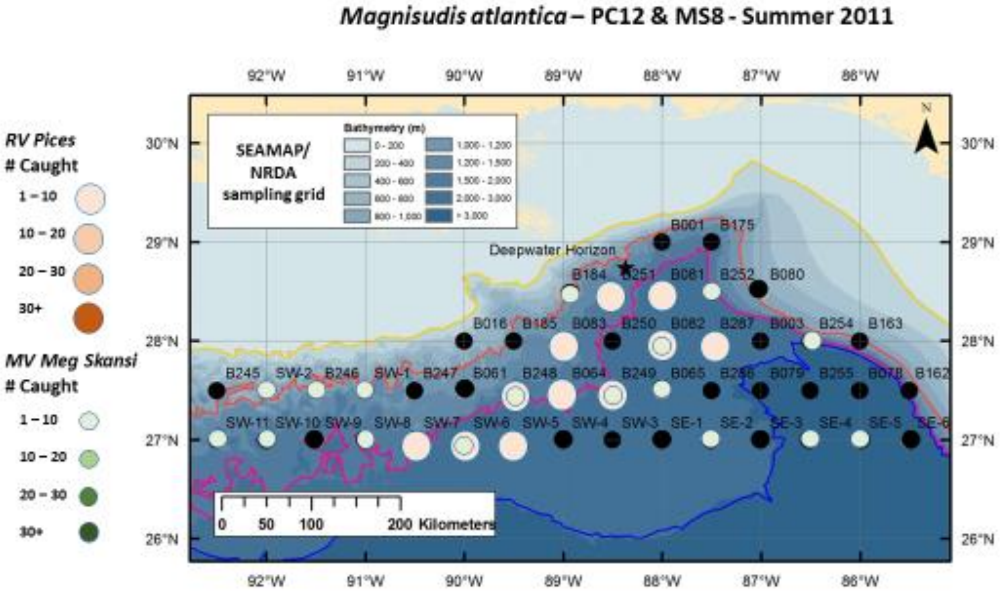


Figure 39 - Geographic distribution of the duck-billed barrracudina during the summer 2011 sampling period. The Pisces sampled a total biomass of 42.7 g and average SL of 61.5 mm. The Meg Skansi sampled a total biomass of 216.2 g with an average SL of 46.5 mm. The observed values in the Meg Skansi samples was highly skewed by the presence of an extremely large outlier (380 mm SL specimen) captured at this time. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

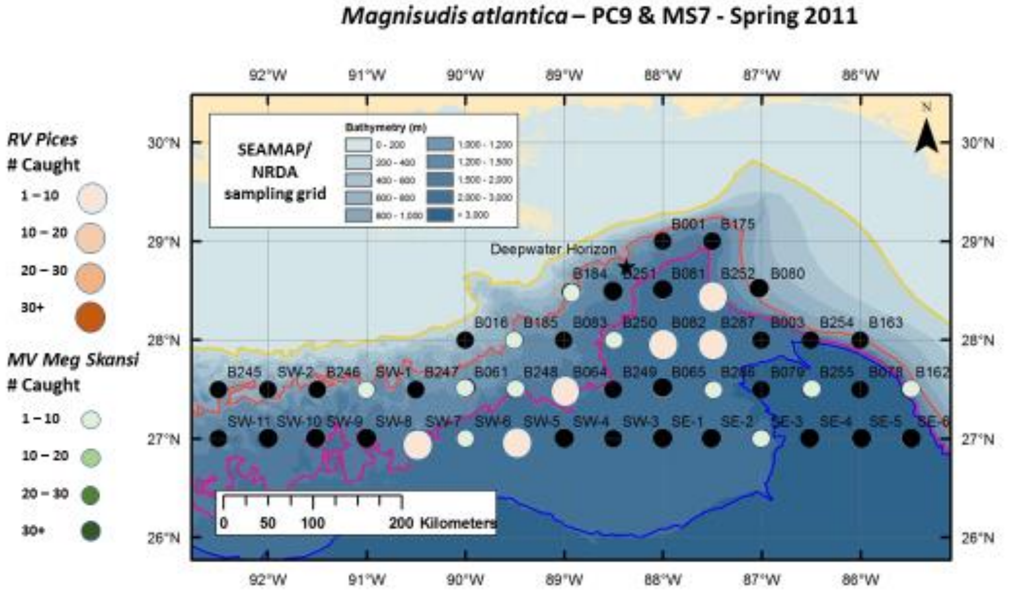


Figure 40 - Geographic distribution of the duck-billed barrracudina during the spring 2011 sampling period. The Pisces sampled a total biomass of 50.8 g and average SL of 79.7 mm. The Meg Skansi sampled a total biomass of 0.6 g with an average SL of 20.2 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

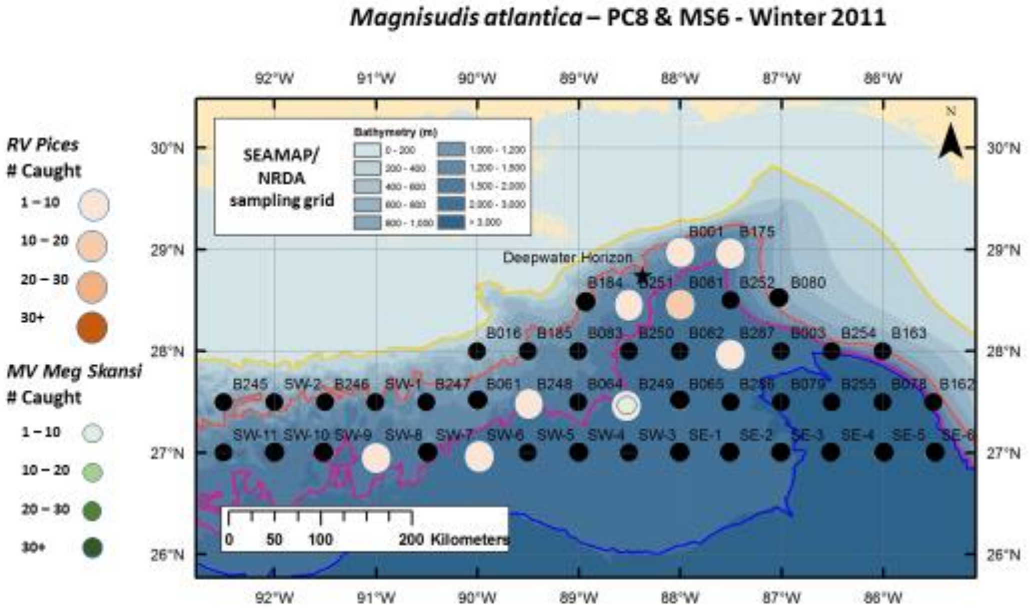


Figure 41 - Geographic distribution of the duck-billed barrracudina during the winter 2011 sampling period. The Pisces sampled a total biomass of 47.1 g and average SL of 72 mm. The Meg Skansi sampled a total biomass of 2.5 g with an average SL of 80 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

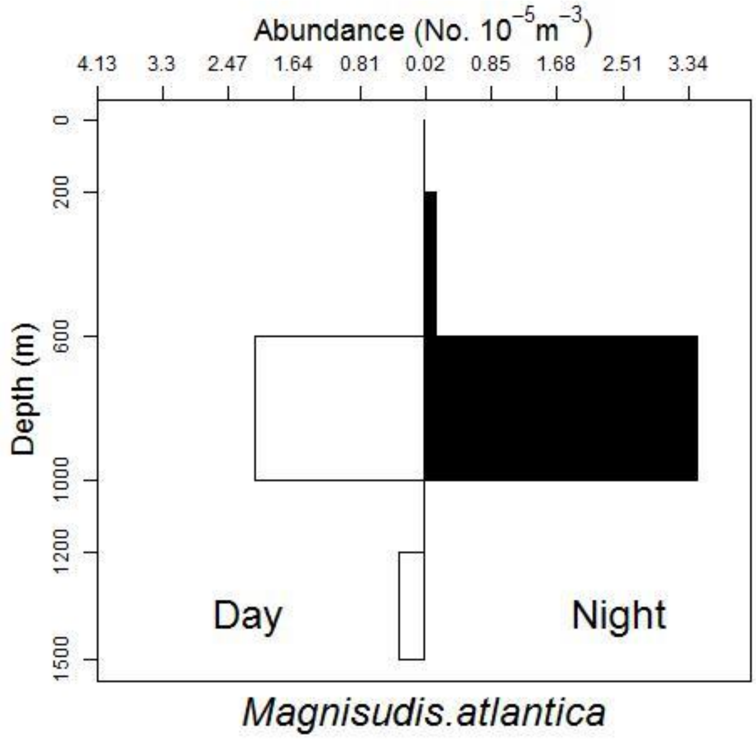


Figure 42 - Depth by Solar Cycle Diel, depth distribution of standardized abundances for the duck-billed barracudina in MOCNESS data found that nearly all the specimens collected occupied the depth strata sampled by net 3 (600 – 1000 meters). Only one individual was sampled from net 1 (1200 – 1500 meters) and net 4 (200 – 600 meters), respectively. No significant difference between day and night abundances were found in these data.

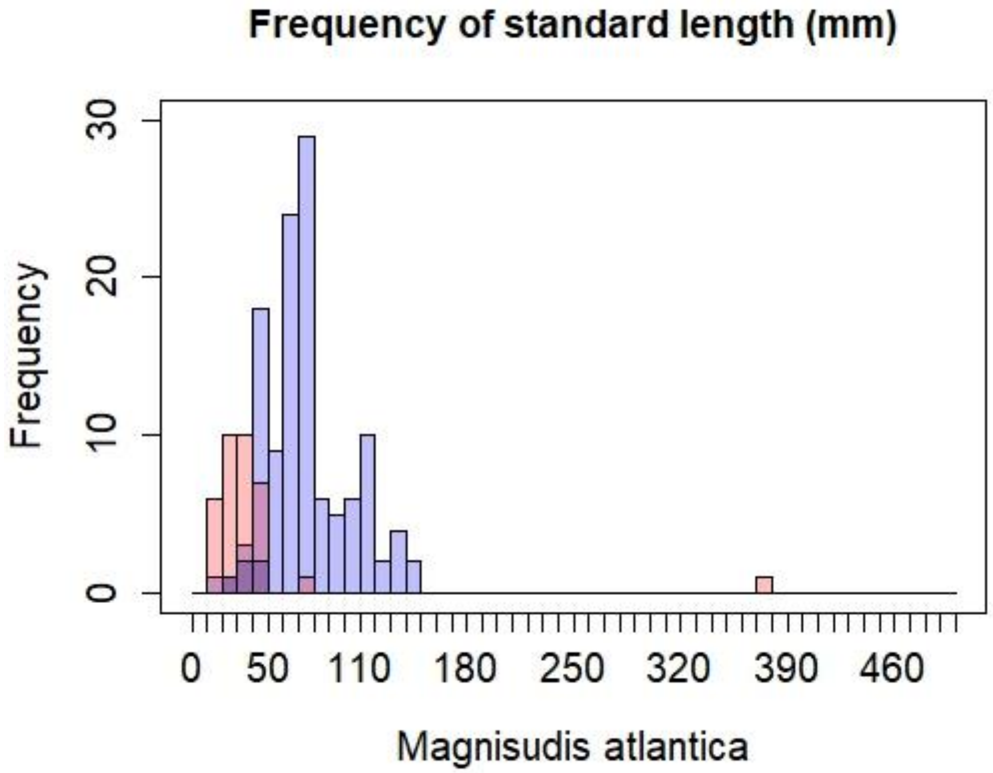


Figure 43 - Frequency of standard lengths by cruise. Note the presence of the outlier in the Meg Skansi data. Omitting the one Meg Skansi outlier, the Pisces (in blue) caught significantly more larger individuals (Welch's ANOVA; $p<0.0001$) than either MOCNESS (Meg *Skansi* = Salmon; *Point Sur* = Purple) geared vessel and nearly all the data on the largest size classes are represented by *Pisces* samples.

Diet: Based on the gut surveys of 63 specimens, ranging in size from 33 – 141 mm SL, the diet of *M. atlantica* is composed of euphausiid shrimps, fish, and cephalopods. No identifications were produced for prey taxa below the family level. Crustacean parts used to identify the Euphausiidae family were hexagonal faceted eyes and cone-shaped tissues. From these data, it appears that euphausiids are a major component in the diet of adult *M. atlantica* as evidenced by %F and %WB, but %N indicates that this species is likely not as selective of prey type as adults of other barracudina investigated here. No statistical difference was noted in stomach "fullness" between day and night collected samples nor by season.

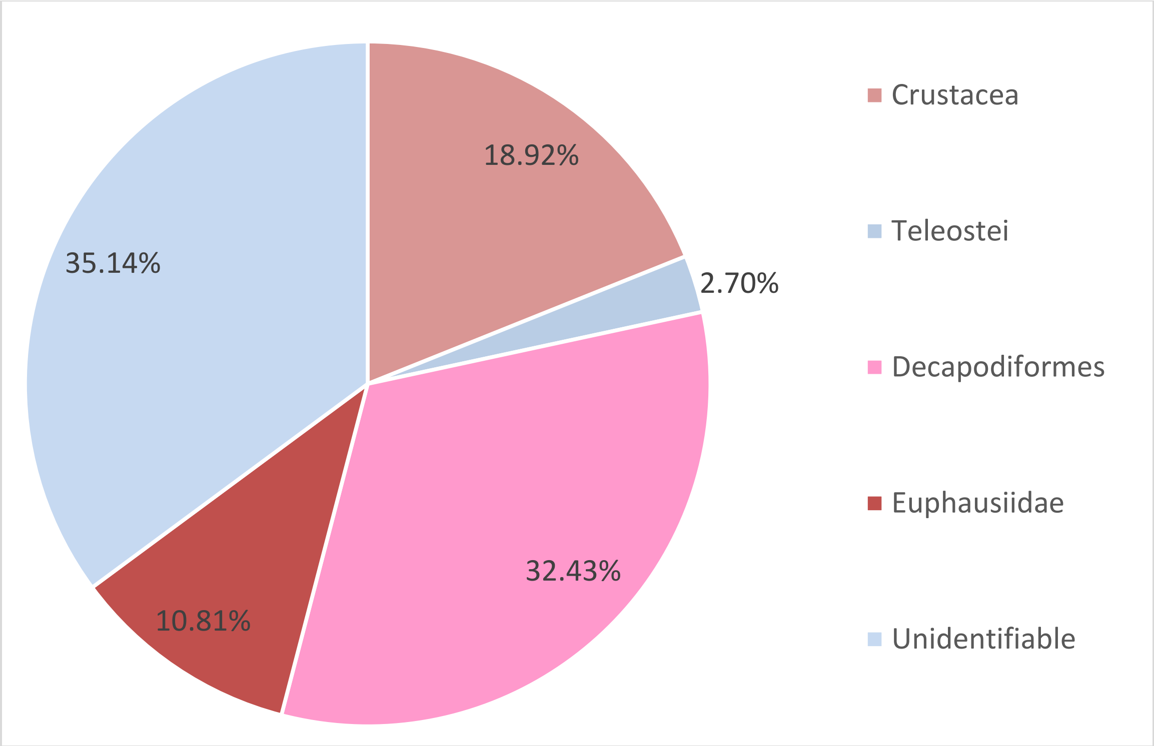


Figure 44 - Euphausiid shrimps appear to have the greatest relative importance to the diets of adult *M. atlantica*. However, a greater share of the diets in the specimens of this species examined were composed of squids compared to other barracudina species assessed here. Evidence of fish prey tissue were also present in several specimens surveyed.

Table 10 - Dietary Composition of *Magnisudis atlantica*. Euphausiid shrimps appear to have the greatest relative importance to the diets of adult *M. atlantica*. However, a greater share of the diets in the specimens of this species examined were composed of squids compared to other barracudina species assessed here. Evidence of fish prey tissue were also present in several specimens surveyed.

Prey LTU	**%N**	**%F**	**%W**	**IRI**
Euphausiidae	32.43%	124.32%	9.24%	0.52
Crustacea	18.92%	5.41%	88.42%	0.06
Teleostei	10.81%	5.41%	1.31%	0.01
Decapodiformes	2.70%	2.70%	0.02%	0.00
Unidentifiable	35.14%	0.00%	1.02%	0.00

Table 11 - Dietary composition of *Magnisudis atlantica* by solar cycle. From these data, it is difficult to discern a difference in feeding activity by day and night. Stomach fullness did not determine a statistically significant difference either. Therefore, it is likely that this species does not have a strong chronology to feeding, albeit, the data are somewhat lacking.

	Day				**Night**			
Prey LTU	**%N**	**%F**	**%WB**	**IRI**	**%N**	**%F**	**%WB**	**IRI**
Crustacea	18.18%	0.00%	95.98%	0.00	19.23%	7.69%	18.12%	0.03
Decapodiformes	0.00%	0.00%	0.00%	0.00	3.85%	3.85%	0.18%	0.00
Euphausiidae	45.45%	163.64%	3.94%	0.81	26.92%	107.69%	58.44%	0.92
Teleostei	0.00%	0.00%	0.00%	0.00	15.38%	7.69%	13.50%	0.02
Unidentifiable	36.36%	0.00%	0.08%	0.00	34.62%	0.00%	9.77%	0.00

Ontogeny and Reproduction: The smaller size class was significantly more frequent during the spring sampling months ($p<0.0001$) and least frequent during the winter ($p<0.0001$; see figure). No significant difference in frequency of SL was determined by season for the large size class but the largest individuals were captured in summer while the greatest mean SL was observed during the winter sampling period. Of the small size class (<70 mm SL) all seasons had significantly different frequencies of SL ($p<0.0001$; see Figure 50) and it appears that this species likely has a distinctly seasonal spawning behavior. No differences in frequency of SL were observed between day and night samples within the small size class but the large size class was significantly more frequent at day ($p<0.0325$). No significant trends in abundance were determined between depth codes of either the HSRT or MOCNESS samples. However, larger specimens were significantly more common in "deep" HSRT trawls ($p<0.007$) and depth bin 4 ($p<0.001$) of the MOCNESS trawls.

Of the specimens surveyed for gut contents, 4 exhibited large, pigmented eggs with half being collected during the spring and half in summer. The average SL of these 4 specimens was 97 mm SL, with the smallest individual being 52 mm SL.

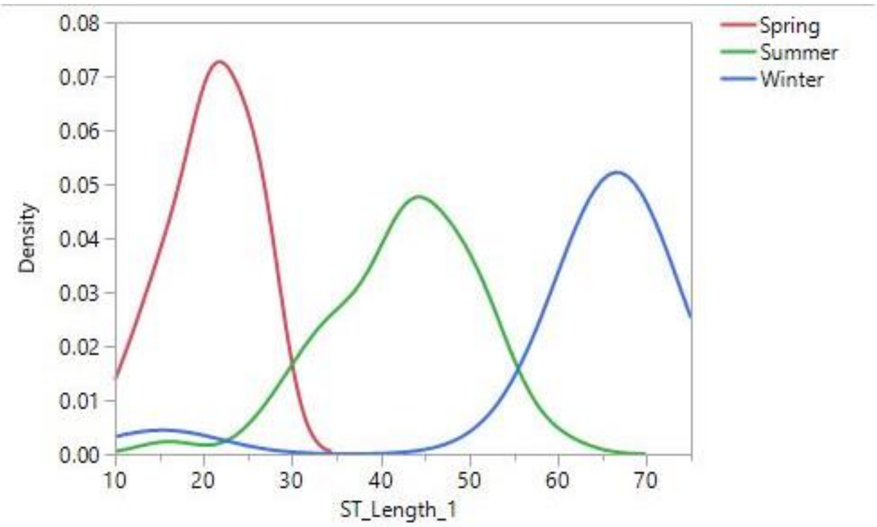


Figure 45 - Proportional density curves for frequency of standard lengths within the small size classes (<70mm SL) of *M. atlantica* by season. The smallest individuals are in greatest numbers during spring. A clear seasonal delineation of cohorts is apparent from these data.

Paralepis brevirostris

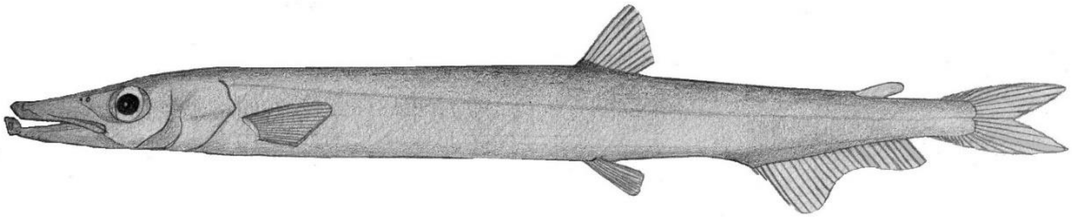


Figure 46 - The shortnose barracudina (*Paralepis brevirostris*). Max recorded length 242 mm SL (fishbase.org). A member of the “scaly” barracudina, this species has a much shorter snout compared with its relatives. Illustration by Ray Simpson.

Description: The “shortnose barracudina” is a large barracudina of the sub-family Paralepidinae that is covered in a delicate layer of skin and cycloid scales which will often tear completely off with trawl capture. No adult specimens of this species were captured in these sampling efforts, so descriptions are limited here. There are 7 – 8 block-like peritoneal patches lining the gut. Head length is between 24 – 26% of SL, snout length is between 8 – 10% SL. Ventral body has a noticeable degree of keeling which terminates in a fleshy line below the gut running from the base of the opercula to the anus.

Similar Species in the Gulf of Mexico: *Paralepis brevirostris* is easily confused with other species of Paralepidinae. It can be differentiated from *Magnisudis atlantica* by the number of peritoneal patches at sizes where the gut lining pigments are still visible. At larger sizes, the proportionally smaller size of the snout and head, as well as the presence of distinguished ventral keeling, differentiate it from *M. atlantica*. This species is nearly identical to its cogener *P. coregonoides* in most ways except for the proportional length of the snout which is always less than 10% of SL in *P. brevirostris,* whereas in *P. coregonoides* snout length is usually 10% of SL or greater.

Geographic, Seasonal, Diel, and Vertical Distribution: *Paralepis brevirostris* was found to be infrequent but evenly distributed throughout the study area with an affinity for the mesopelagic. No significant trends toward the continental shelf nor to the east or west of the region were documented. Although heterogeneity of variance was significant (Levene's test; $p<0.0001$) Welch's ANOVA at $\alpha=0.25$ for MOCNESS abundances by season found summer to have significantly higher abundances than the other sampling periods ($p<0.0324$). No such differences were noted among the HSRT data. No trends were determined in abundances by day or night. In HSRT data, this species was exclusively caught in "deep" trawls. For MOCNESS data, this species was nearly exclusively caught in net 3 (600 – 1000 m) except for a single individual collected in net 4 (1000 – 1200 m).

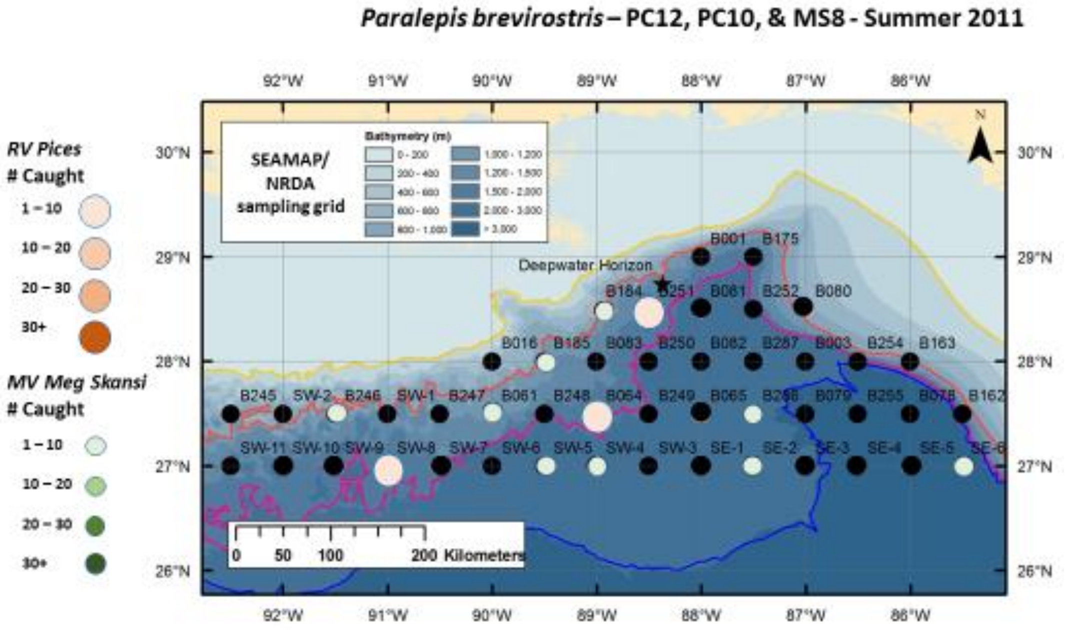

Paralepis brevirostris – PC12, PC10, & MS8 - Summer 2011

Figure 47 - Geographic distribution of the shortnose barracudina in the sampling region during the summer of 2011. The Pisces sampled a total biomass of 2.2 g at an average specimen SL of 59 mm. The Meg Skansi sampled a total biomass of 1 g at an average specimen SL of 23.4 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

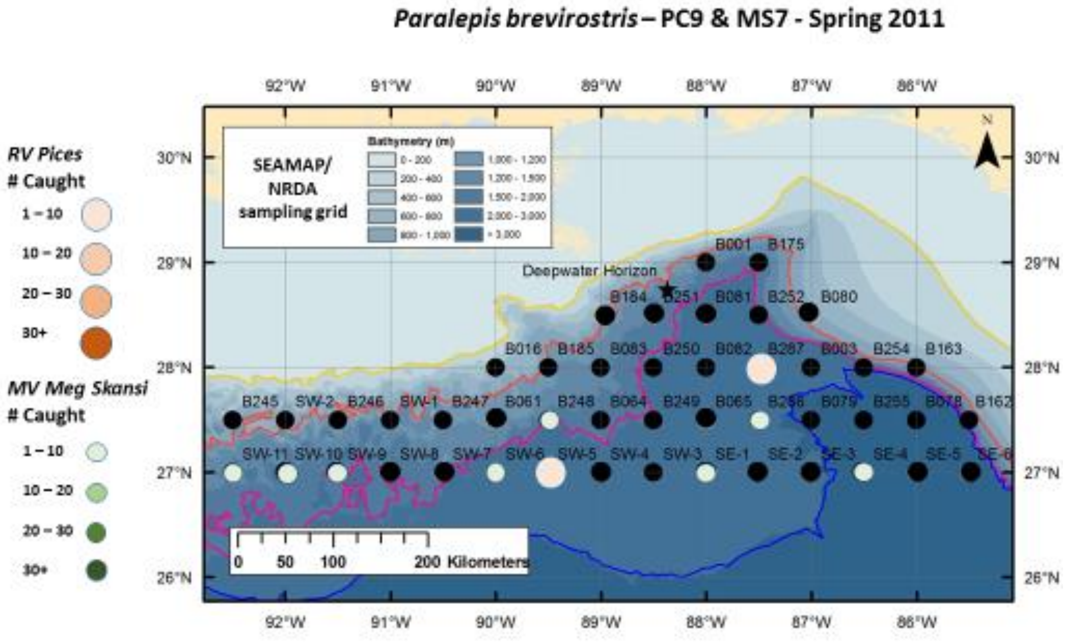


Figure 48 - Geographic distribution of the shortnose barracudina in the sampling region during the spring of 2011. The Pisces sampled a total biomass of 5 g at an average specimen SL of 90.5 mm. The Meg Skansi sampled a total biomass of 0.4 grams at an average specimen SL of 16.1 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

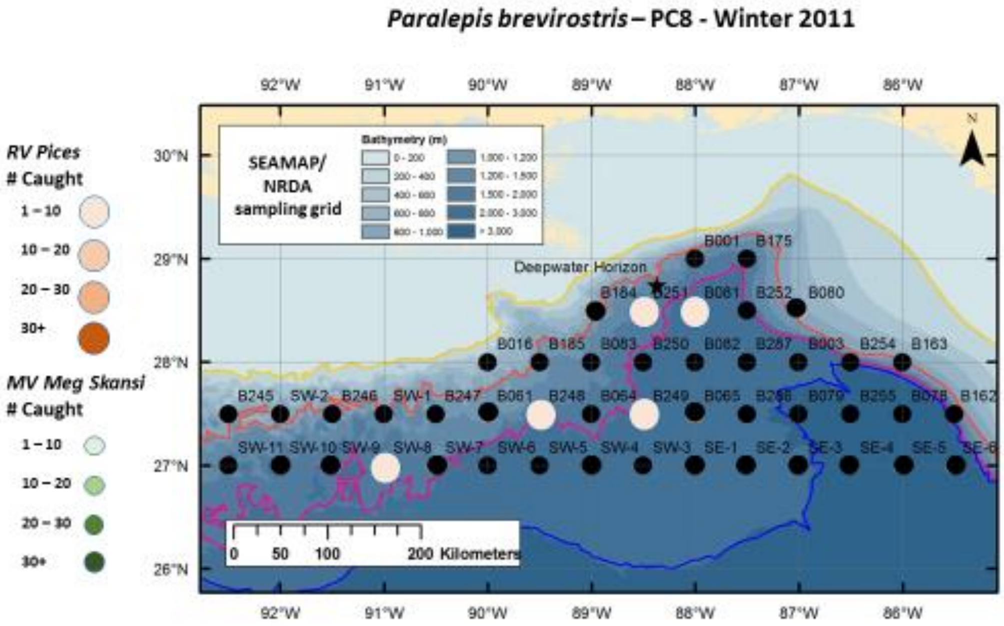


Figure 49 - Geographic distribution of the common barracudina in the sampling region during the winter of 2011. The Pisces sampled a total biomass of 3.2 g at an average specimen SL of 130 mm. The Meg Skansi did not produce any P. brevirostris at this sampling period. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

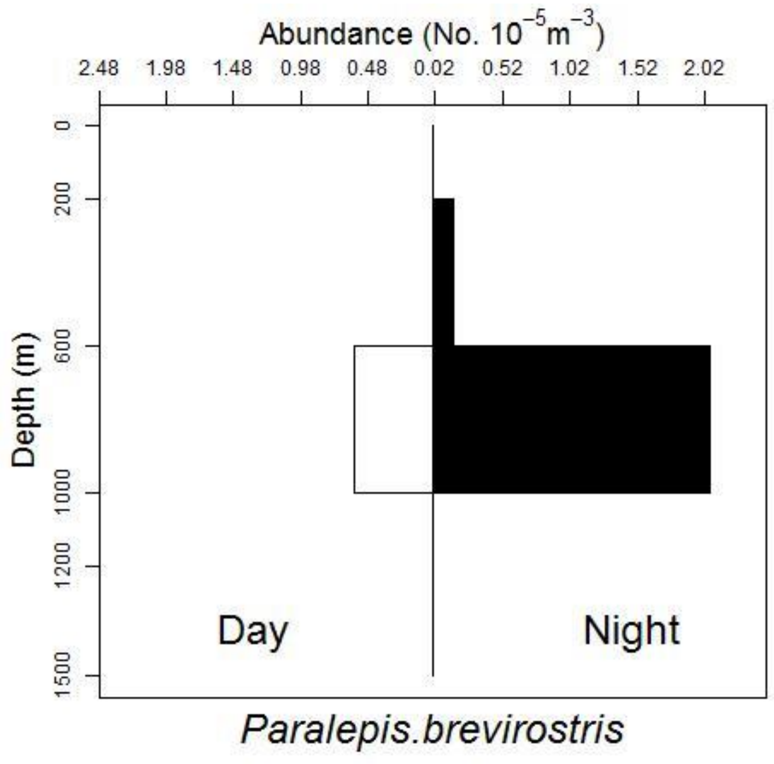


Figure 50 - Depth by Solar Cycle Diel, depth distribution of standardized abundances for the shortnosed barracudina in MOCNESS data. All the specimens collected were found in the depth strata sampled by net 3 (600 – 1000 meters) except for one individual sampled by net 4 at night.

Diet: Based on gut surveys of 14 individuals, ranging in size from 61 to 105 mm SL, *P. brevirostris* was found to have a diet composed of mesopelagic shrimps and fish. The 10 *P. brevirostris* that were found to have stomach contents were all collected from night time trawls and the majority were from the winter sampling period except one collected during spring and one during summer, respectively. Most stomach contents surveyed were unidentifiable to taxonomic unit (e.g. chyme near the intestines that did not stain as chitin and was not identifiable as fish tissue).

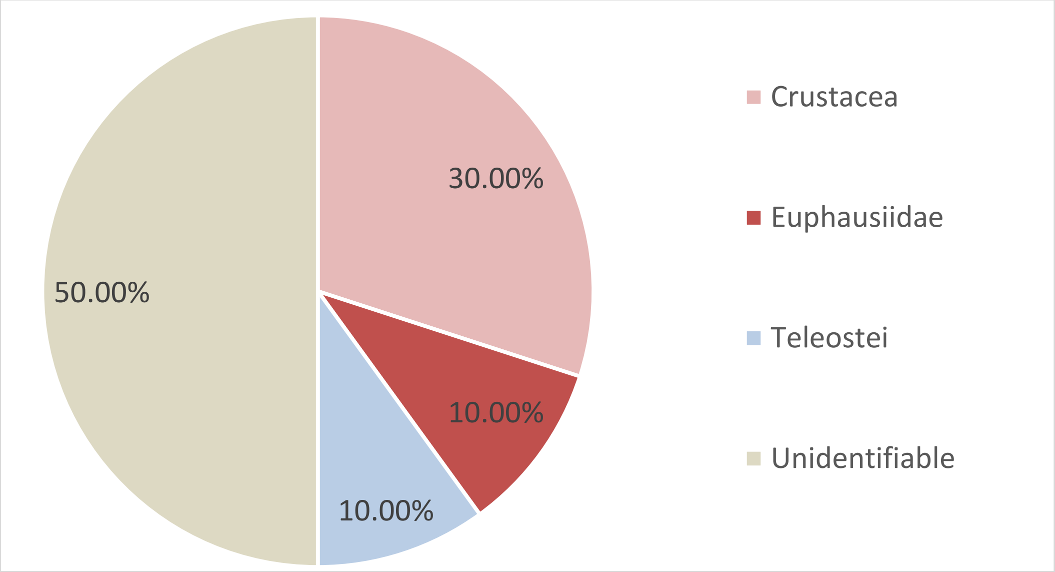


Figure 51 - Dietary Habits. Like *M. atlantica*, *P. brevirostris* was found to have a diet largely composed of Euphausiid shrimps by %F and %WB but also a fair amount of fish.

Table 12 - Dietary Composition of *Paralepis brevirostris*. Like *M. atlantica*, *P. brevirostris* was found to have a diet largely composed of Euphausiid shrimps by %F and %WB but also a fair amount of fish.

Prey LTU	**%N**	**%F**	**%WB**	**IRI**
Euphausiidae	10.00%	40.00%	23.26%	0.13
Crustacea	30.00%	10.00%	34.88%	0.06
Teleostei	10.00%	10.00%	9.30%	0.02
Unidentifiable	50.00%	0.00%	32.56%	0.00

Ontogeny and Reproduction: Most specimens collected were of the “small” (<70 mm SL) size class, however, these were significantly more abundant during spring months than other times of year ($p<0.0087$). No other significant trends were observed.

Of the specimens surveyed for gut contents, none were reported to have had apparently large or pigmented eggs.

Paralepis coregonoides

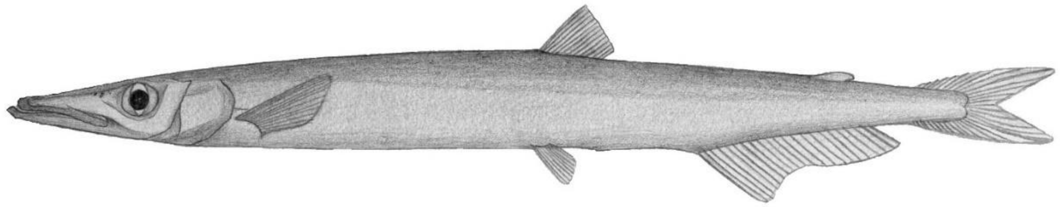


Figure 52 - The sharpchin barracudina (*Paralepis coregonoides*). Max recorded length 500 mm SL (fishbase.org). A large member of the “scaly” barracudina group. Illustration by Ray Simpson.

Description: The “sharpchin barracudina” is a large barracudina and a member of the Paralepidinae. It is covered in a delicate layer of skin and cycloid scales which will often tear completely off with trawl capture. No adult specimens of this species were captured in these sampling efforts, so descriptions are limited here. There 7 – 8 block-like peritoneal patches lining the gut. Head length is between 24 – 26% of SL, snout length is between 10 – 13% SL. Ventral body has noticeable degree of keeling which terminates in a fleshy line below the gut running from the base of the opercula to the anus.

Similar Species: *Paralepis coregonoides* is easily confused with other species of Paralepidinae. It can be differentiated from *Magnisudis atlantica* by the number of peritoneal patches at sizes where the gut lining is still visible. At larger sizes, the proportionally smaller size of the snout and head, as well as the presence of distinguished ventral keeling, differentiate it from *M. atlantica*. This species is nearly identical to its cogener *P. brevirostris* in most ways except the proportional length of the snout which is always 10% of SL or greater, whereas in *P. brevirostris,* the snout length is always less than 10% of SL.

The shrapchin barracudina was extremely rare in the sampling region. Because only 2 specimens were collected over the entire 2011 sampling period, not much natural history inferences were possible regarding this species in the GoMx.

Stemonosudis bullisi

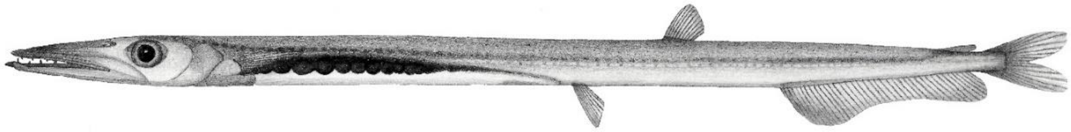


Figure 53 - Bullis' barracudina. Max recorded size 211 mm SL*. A Gulf of Mexico endemic previously known from only 2 specimens. These records constitute the greatest sizes and numbers ever recorded for this species. Illustration by Ray Simpson.

Description: The "Bullis' barracudina" is a medium-sized barracudina of the sub-family Lestidiinae that almost completely lacks squamation (except for a single row of scales embedded along the lateral line) and is quite translucent in life. Like other species of *Stemonosudis*, *S. bullisi* is elongate and laterally compressed, with a high AFR element count. Also, like other species of *Stemonosudis*, the lower jaw of *S. bullisi* projects beyond the upper as the tip is prolonged, however, this occurs much later in development (>70 mm SL) compared with its cogeners. At smaller sizes (<60 mm SL), *S. bullisi* has a series of stellate melanophores as a paired row along the mid-lateral, oriented above and below each lateral line scale like a colon punctuation mark; this character fades with age, however, and is completely absent by 100 mm SL. At smaller sizes, 8 – 10 distinct peritoneal patches are visible. A narrow mid dorsal band on the dorsum spans the body from the occiput to the caudal and is composed of 5 – 6 irregular rows of stellate melanophores. At fully mature sizes (>100 mm SL), the anterior half of the snout, on both the lower and upper jaws, is darkly pigmented. At these larger sizes, the peritoneal patches expand and become fused into a single, elongated, black gut lining with 8 “loops” or “half-moons” along the ventral edge, which straighten out at either end and become highly attenuated toward the anus. The gut below the peritoneum appears iridescently silver at these sizes. Luminous organ absent.

Similar Species in the Gulf of Mexico: *Stemonosudis bullisi*, while maintaining a general similarity, is usually quite easy to distinguish from its cogeners based on body proportions and/or pigmentation. Of *Stemonosudis, S. bullisi* is one of the least “eel-like” and the only species to completely lack the distinct dorsal “saddle” pigments. Additionally, *S. bullisi* is much less elongate than other *Stemonosudids* such as *S. gracilis* or *S. intermedia*. At smaller sizes (<60 mm SL) *S. bullisi* can be confused with several non-*Stemonosudis* Lestidiinae species which can be narrowed down to *Lestrolepis intermedia* by way of peritoneal patch number and AFR element count. *Lestrolepis intermedia* is nearly identical to *S. bullisi* in meristic counts and these two species are very easy to confuse at small sizes.

Geographic, Seasonal, and Vertical Distribution: *Stemonosudis bullisi* is the only barracudina thought to be endemic to the GoMx basin because it has never been found anywhere else (McEachran & Fechhelm, 1998). In these data, *S. bullsi* was uncommon but found to be fairly distributed throughout the sample area in the summer and spring months with an affinity for the epipelagic/upper mesopelagic. Abundances were not found to associate toward or away from the continental shelf. No *S. bullisi* were captured during winter sampling months but no differences in abundance were noted between summer and spring for either gear type. No statistical difference was found between day and night samples for either gear type. *S. bullisi* was documented exclusively in nets 5 (0 – 200 m) and 4 (200 – 600 m) of the MOCNESS, of which net 5 had significantly greater abundances ($p<0.0149$), indicating a general disposition for the epipelagic.

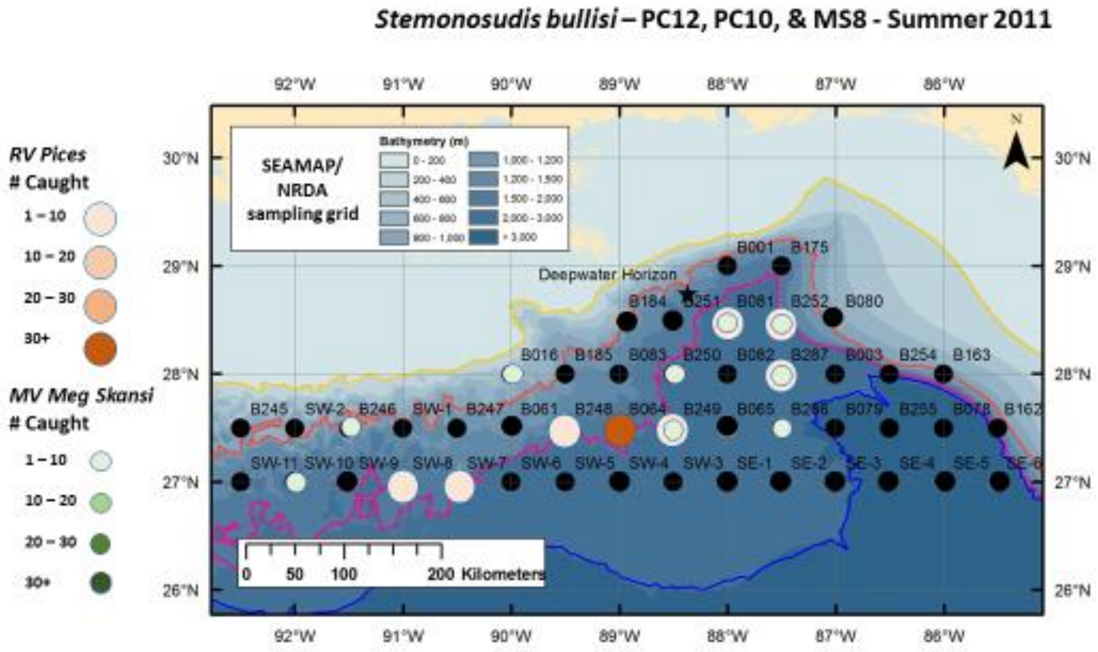


Figure 54 - Geographic distribution of the Bullis' barracudina in the sampling region during the summer of 2011. The Pisces sampled a total biomass of 15 g at an average specimen SL of 79 mm. The Meg Skansi sampled a total biomass of 1.2 g at an average specimen SL of 32.7 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

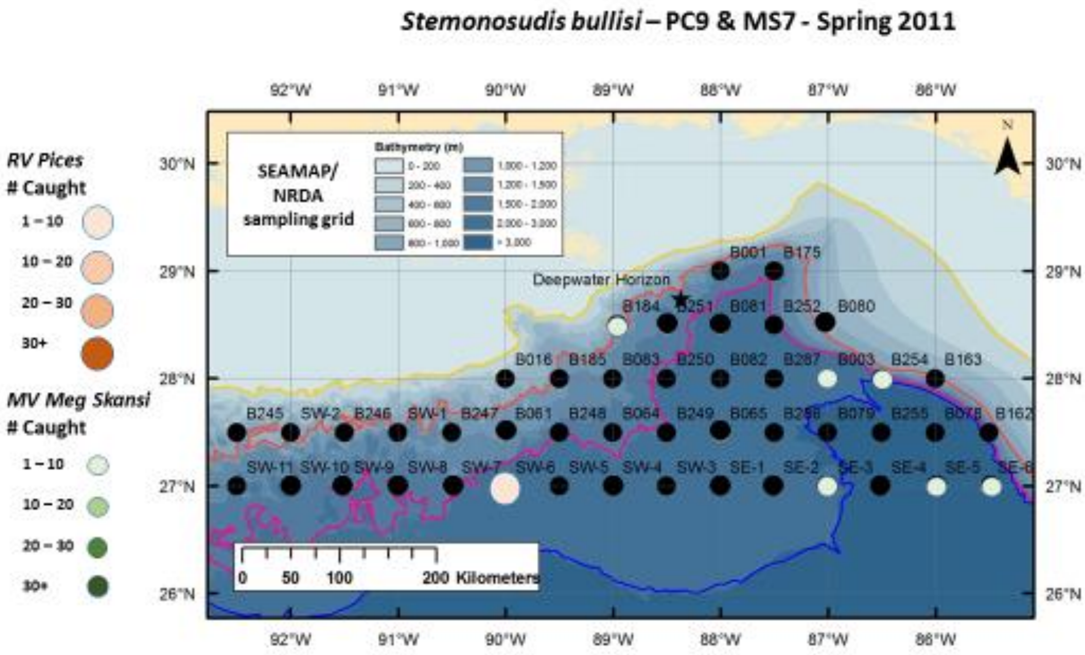


Figure 55 - Geographic distribution of the Bullis' barracudina in the sampling region during the spring of 2011. The Pisces sampled a total biomass of 0.7 g at an average specimen SL of 110 mm. The Meg Skansi sampled a total biomass of 0.3 g at an average specimen SL of 31.2 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue. On this map, 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

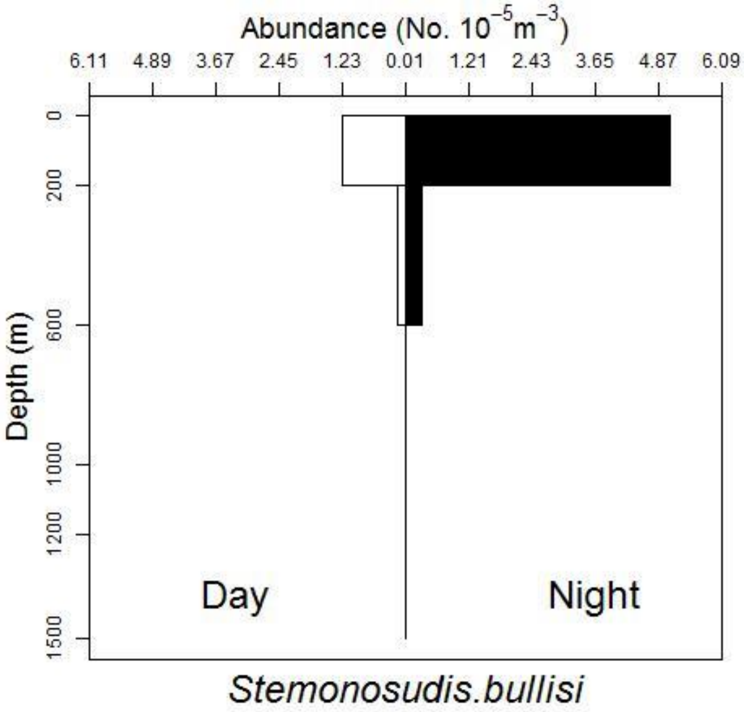


Figure 56 - Depth by Solar Cycle Diel, depth distribution of standardized abundances for the Bullis' barracudina in MOCNESS data. All the specimens collected were found in the depth strata sampled by net 5 (0 – 200 meters) except for one individual sampled by net 4 at both day and night.

Diet: Only two adult *S. bullisi* specimens were surveyed for gut contents and the stomachs of those respective specimens were both found to be empty of contents.

Ontogeny and Reproduction: The *Meg Skans*i caught the numerical majority of *S. bullisi* and all of these specimens fell into the "small" size class category. No difference was found in the frequency of either size class by day and night samples. The small size class was most abundant during the spring sampling period ($p<0.0195$; see figure). The largest specimens captured by the MOCNESS were trawled by net 4 (see figure).

Both specimens dissected for gut surveys contained large, pigmented eggs, and were collected during the summer sampling period. They measured 170 and 211 mm SL, respectively.

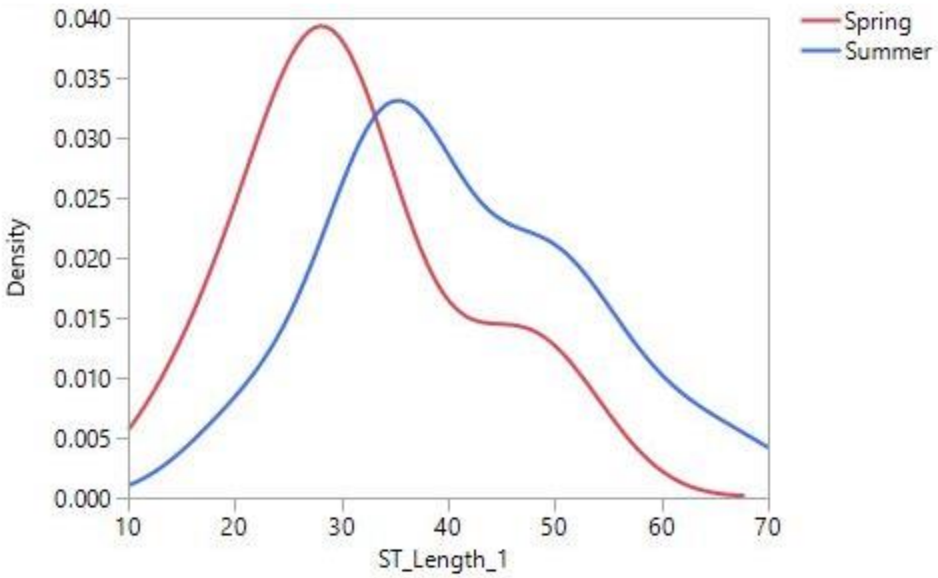


Figure 57 - Proportional density curves for frequency of standard lengths within the small size class (<70mm SL) of S. bullisi by season. The smallest individuals were in greatest numbers during spring.

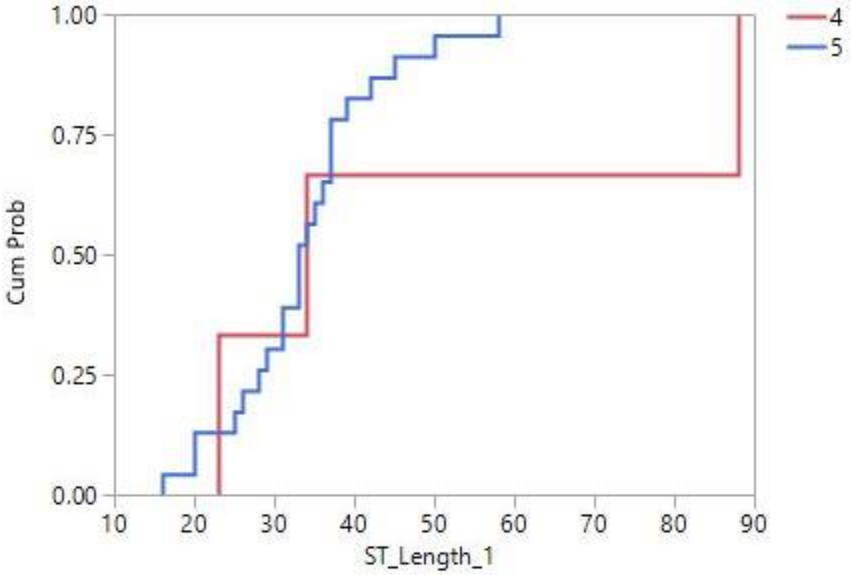


Figure 58 - Frequency of all standard lengths by depth for *S. bullisi* collected by the Meg Skansi, plotted as Cumulative Density Functions by net number.

Stemonosudis gracilis

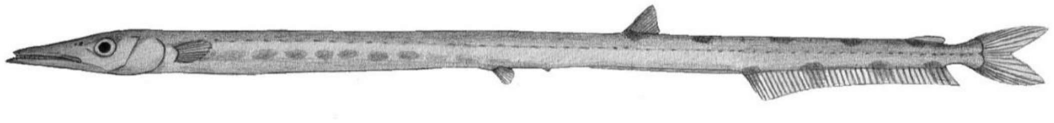


Figure 59 - The graceful barracudina (*Stemonosudis gracilis*). Max recorded size 990 mm SL (fishbase.org). An elongate and eel-like barracudina of the Lestidiinae sub-family. Illustration by Ray Simpson.

Description: The "graceful barracudina" is an extremely elongate, eel-like member of the Lestidiinae sub-family that almost completely lacks squamation (except for a single row of scales embedded along the lateral line) and is quite translucent in life. The body width is extremely compressed throughout its length and throughout development. At sizes <15 mm SL, there are usually 13 or less peritoneal patches apparent. Pigment along the tail and lower jaw may be visible at these sizes. The mature peritoneal patch count is either 14 or 15 and the patches remain distinctly separate into maturity. The defining pigment pattern of *S. gracilis* is 4 – 5 alternating "saddle" patches, along the dorsal posterior body starting with the dorsal fin base. The anterior-most ventral saddle patch appears as a faint continuation of the peritoneal patch series and four more prominent ventral patches are associated with the anal fin. As with all other species of *Stemonosudis*, *S. gracilis* possesses a lower jaw which distinctly protrudes beyond the upper. *Stemonosudis gracilis* is superlative among its cogeners for having the longest head which can be anywhere from 16 – 18% of SL in mature specimens. Luminous organ absent.

Similar Species in the Gulf of Mexico: *Stemonosudis gracilis*, being extremely elongate and eel-like is most like its cogener, *S. intermedia*. The two species have some key meristic differences, however, in that they differ in the number of peritoneal patches and the number of dorsal/ventral alternating saddle patches. Additionally, *S. gracilis* usually has a measurably longer head than *S. intermedia* at maturity that comes out to about 18% of SL.

Geographic, Seasonal, Diel, and Vertical Distribution: *Stemonosudis gracilis* was very infrequent and over the entire 2011 sampling period only 6 specimens were collected, 4 by the *Pisces* (summer) and 2 by the *Meg Skansi* (one summer, one winter). Five of the 6 specimens collected were collected during day time trawls, only one was sampled by a night trawl. All MOCNESS specimens came from net 5 and the *Pisces* specimens were split evenly between "deep" and "shallow". The geographic and vertical distributions found for this species are presented as they are below.

Diet: One large (207 mm SL) specimen was dissected to survey its gut contents. A small, partially digested *Lestidiops sp.* was found weighing about 0.26 grams. The specimen had been collected during a day time trawl in summer and its stomach appeared full, the prey item only partially digested, indicating it may have been consumed during the day.

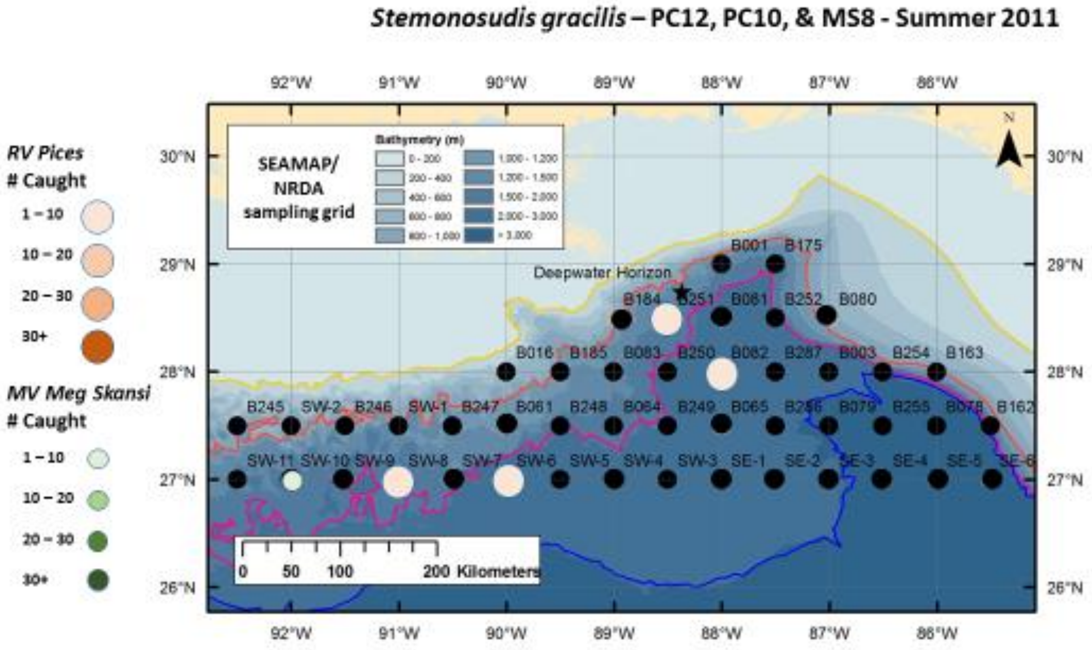


Figure 60 - Geographic distribution of the graceful barracudina in the sampling region during the summer of 2011. The Pisces sampled a total biomass of 4.7 g at an average specimen SL of 136 mm. The Meg Skansi sampled a total biomass of 0.2 g at an average specimen SL of 88 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

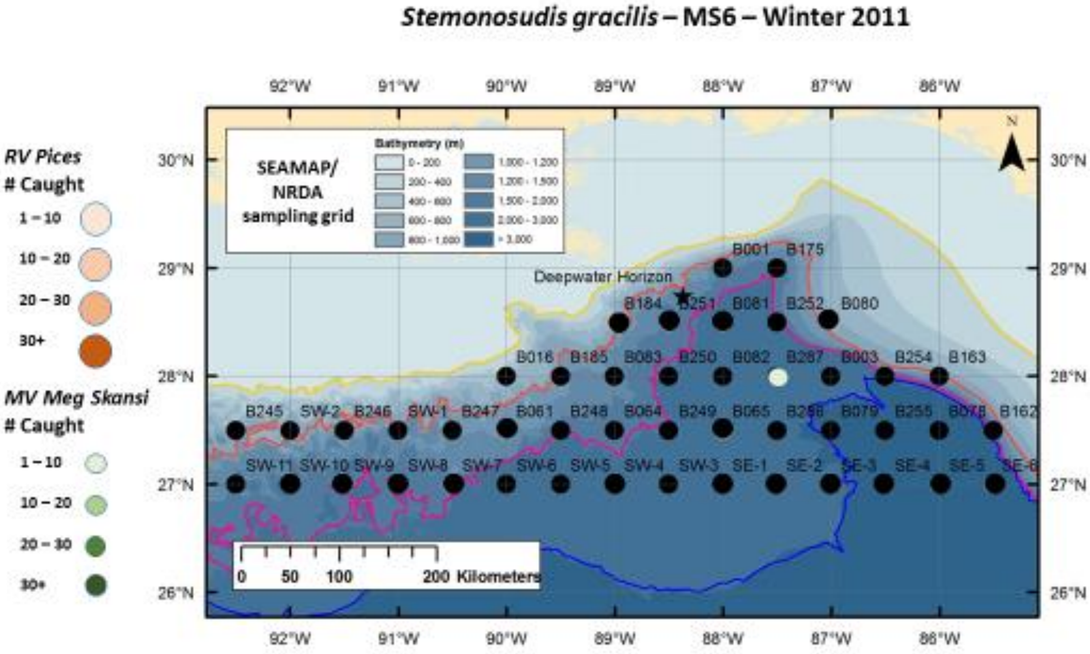


Figure 61 - Geographic distribution of the graceful barracudina in the sampling region during the spring of 2011. The Pisces did not collect any specimens at this time. The Meg Skansi sampled a total biomass of 0.1 g at an average specimen SL of 29 mm. On this map, 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

Stemonosudis intermedia

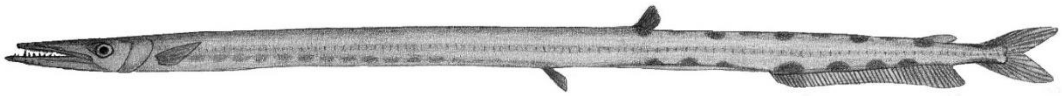


Figure 62 - The eel barracudina (*Stemonosudis intermedia*). Max recorded size 229 mm SL*. An extremely elongate and eel-like member of the Lestidiinae sub-family. Illustration by Ray Simpson.

Description: The “eel barracudina” is an extremely elongate, eel-like member of the Lestidiinae sub-family that almost completely lacks squamation (except for a single row of scales embedded along the lateral line) and is quite translucent in life. The body width is extremely narrow throughout its length and throughout development. By about 15 mm SL, there are usually at least 16 peritoneal patches apparent. Pigment along the tail and lower jaw may be visible at these sizes. The mature peritoneal patch count is 16 to 18 and the patches remain distinctly separate into maturity. The defining pigment pattern for *S. intermedia* is 6 – 8 alternating "saddle" patches along the dorsal and ventral of the posterior portion of the body. The anterior-most saddle patch being located directly along the base of the dorsal fin. As with all other species of *Stemonosudis, S. intermedia* possesses a lower jaw which distinctly protrudes beyond the upper. *Stemonosudis intermedia* is superlative among its cogeners for having the greatest proportional distance from the pectoral fins to the pelvic fins. No luminous organ present.

Similar Species in the Gulf of Mexico: *Stemonosudis intermedia*, being extremely elongate and eel-like, is most like its cogener, *Stemonosudis gracilis*. The two species have some key meristic differences, however, in that they differ in the number of peritoneal patches and the number of dorsal/ventral alternating saddle patches.

Geographic, Seasonal, Diel, and Vertical Distribution: *Stemonosudis intermedia* was infrequent in our study area and is only represented in the 2011 samples by 25 specimens. As such, statistical analyses were problematic. Generally, this species appears to be better represented in the south-central portion of the study area, far out to sea, with the majority (20/5; 80%) of specimens caught at stations far from the shelf (see figures). Differences in abundance collected by solar cycle were noted with 17 specimens collected by night trawls and 8 by day. Only 4 individuals were captured in winter sampling months while summer sampling months produced 11 and spring collected 10. In terms of depth distribution, "shallow" HSRT trawls had significantly higher abundances (0.7 /10^6*m^3) than "deep" (0.3 /10^6*m^3) trawls and *S. intermedia* were exclusively found in depth bins 5 and 4 of the *Meg Skansi* MOCNESS.

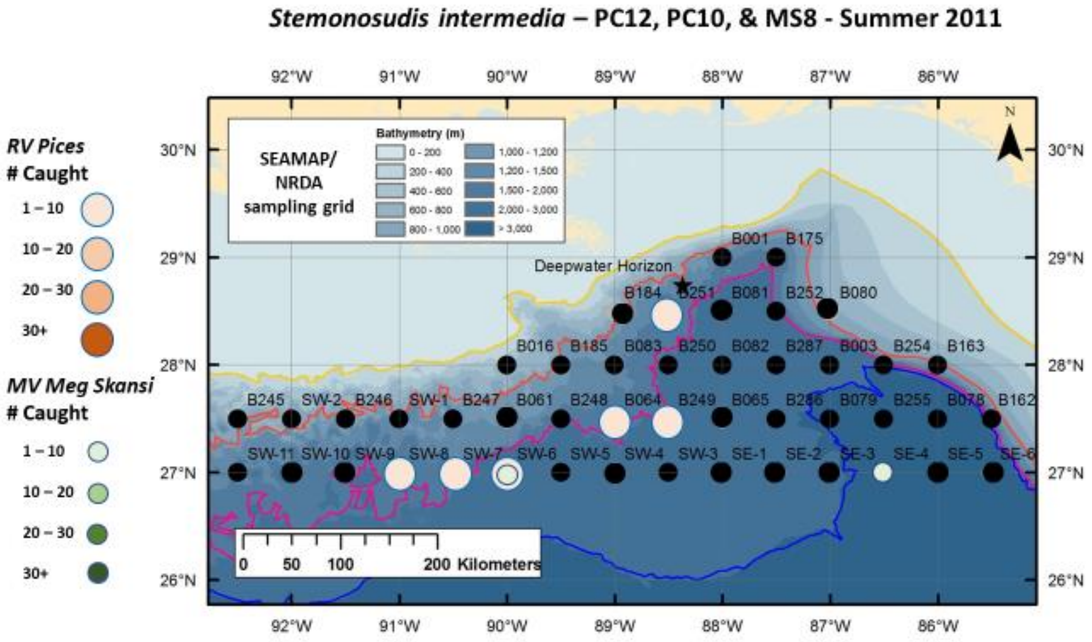


Figure 63 - Geographic distribution of the eel barracudina in the sampling region during the summer of 2011. The Pisces collected a total biomass of 24 g at an average SL of 188.7 mm. The Meg Skansi sampled a total biomass of 0.1 g at an average specimen SL of 78.5 mm. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

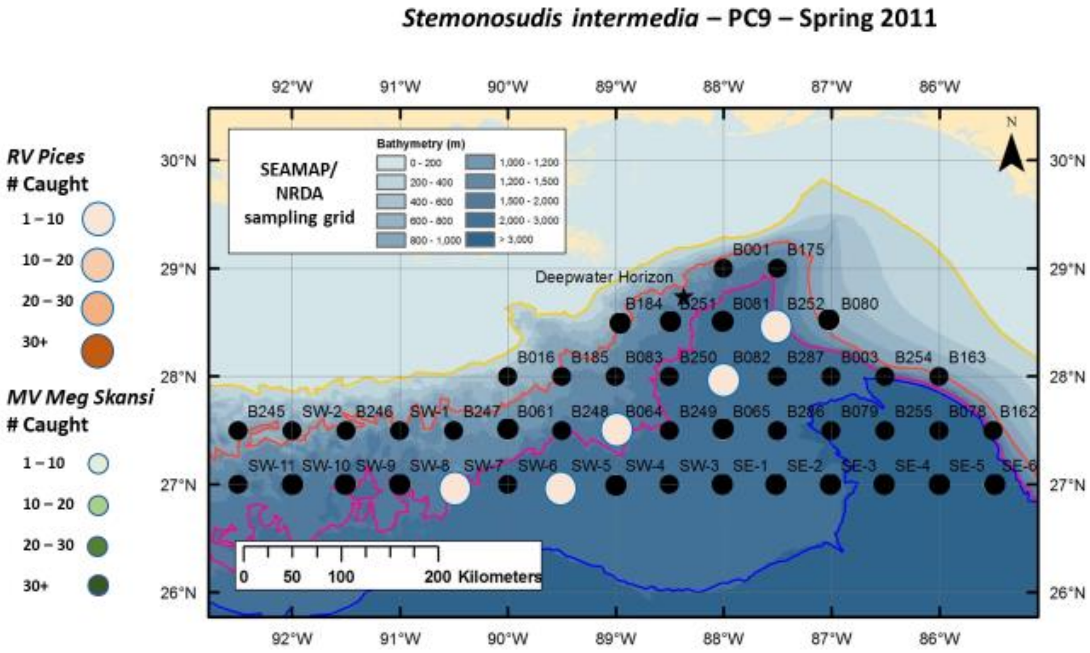


Figure 64 - Geographic distribution of the eel barracudina in the sampling region during the spring of 2011. The Pisces collected a total biomass of 5 g at an average SL of 115.9 mm. The Meg Skansi did not sample any *S. intermedia* specimens at this time. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

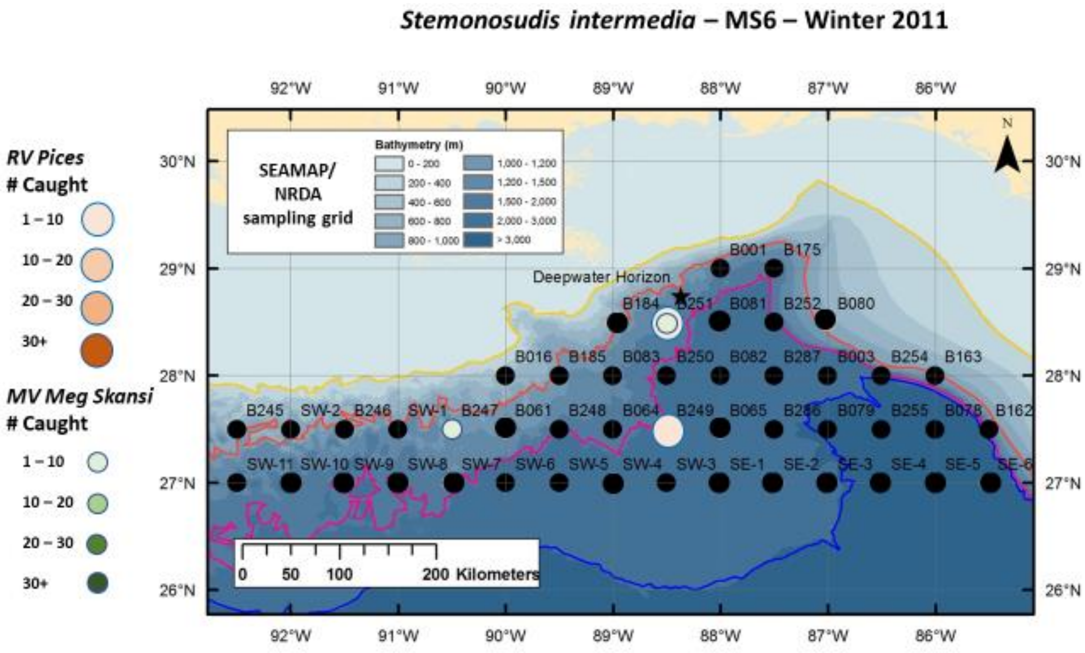


Figure 65 - Geographic distribution of the eel barracudina in the sampling region during the spring of 2011. The Pisces collected a total biomass of 2.1 g at an average 128.5 mm SL. The Meg Skansi sampled a total biomass of 0.9 g at an average SL of 54.5mm SL. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

Diet: Gut content surveys were conducted on 9 individuals, ranging in SL from 104 – 229 mm. Six of these specimens were found to have stomach contents but they were only identifiable to a single major group (Teleostei); all gut contents found in these specimens appear to have been highly digested fishes.

Ontogeny and Reproduction: More individuals were found during summer trawls and these were also, on average, the largest specimens, with an average SL of 169 mm. Spring produced the second highest number and average SL (114 mm), with winter months producing the least number and smallest individuals (91.5 mm SL). On average, individuals captured by "deep" HSRT trawls were larger (161.5 mm SL) than those captured "shallow" (135.7 mm SL). In the MOCNESS data, only a single specimen, 77 mm SL, was collected in net 4 (200 – 600 m) with the average SL of the remaining specimens from net 5 (0 – 200 m) being 63 mm SL. Of the *S. intermedia* dissected for gut surveys only a single individual, measuring 229 mm SL, possessed large, pigmented eggs. That individual was collected during a summer sampling period.

Stemonosudis rothschildi

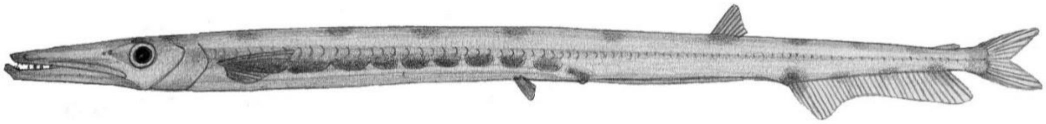


Figure 66 - The Rothschild's barracudina (*Stemonosudis rothschildi*). Max. recorded SL 230 mm (McEachran and Fechhelm, 1998). This barracudina has a range of pigment patterns and coloration not seen in other species of barracudina and is generally less elongate than other members of the genus *Stemonosudis*. Illustration by Ray Simpson.

Description: The "Rothschild's barracudina" is a medium sized barracudina of the sub-family Lestidiinae that almost completely lacks squamation (except for a single row of scales embedded along the lateral line). Although elongate, *S. rothschildi* is less elongate than many of its cogeners. The DFO is far posterior and is noticeably closer to the AFO than either the PVO or anus. The portion of the body above the AFO often appears taller than the preceding length of the body. Easily the most striking feature of this fish is its pigmentation which is obvious before and after preservation and throughout development. Much like *S. intermedia* and *S. gracilis, S. rothschildi* has a series of alternating saddle pigment clusters on its dorsal and ventral surfaces. However, unlike those former species, the distinct saddle blotches of *S. rothschildi* span most of the body from just behind the head to the caudal peduncle. There are 7 – 9 (usually 9) such saddles on the dorsal surface and 4 – 7 along the ventral. About half of the ventral saddles are located posterior to the anus and the other half are along the ventral keel, just below the peritoneal patches. The caudal peduncle is marked with a vertical band of dark pigment clusters like those of the saddle blotches. On some specimens, the last dorsal and ventral saddle blotches before the caudal peduncle are conjoined and the tail appears to have two vertical bands. Specimens <40 mm SL have pigment and peritoneal patches apparent and the dorsal fin often appears disproportionately long. Most mature specimens exhibit additionally distinct pigmentation that outlines the shape of the lateral line and the myosepta of the last 10 – 20 myomeres before the caudal and that gives the tail an overall brassy appearance in life. Living specimens range in appearance from mostly translucent, to a translucent with pink, red, or orange coloration apparent from deep tissues, to an almost opaque tan or beige superficial coloration (see Figure 65). Dark pigments are scattered along the margins of the upper and lower jaw and highlight the first few rays of the pelvic and anal fins. The gut is lined with 10, half-moon shaped peritoneal patches which conjoin to form a contiguous gut lining in very large (>100 mm SL) specimens, with numerous loops along the ventral surface where the distinct patches used to reside. Like other species of *Stemonosudis*, *S. rothschildi* has a lower jaw which projects distinctly beyond the upper, however, like *S. bullisi*, this develops later than most *Stemonosudis* species and is most apparent in specimens >80 mm SL. No luminous organ present.

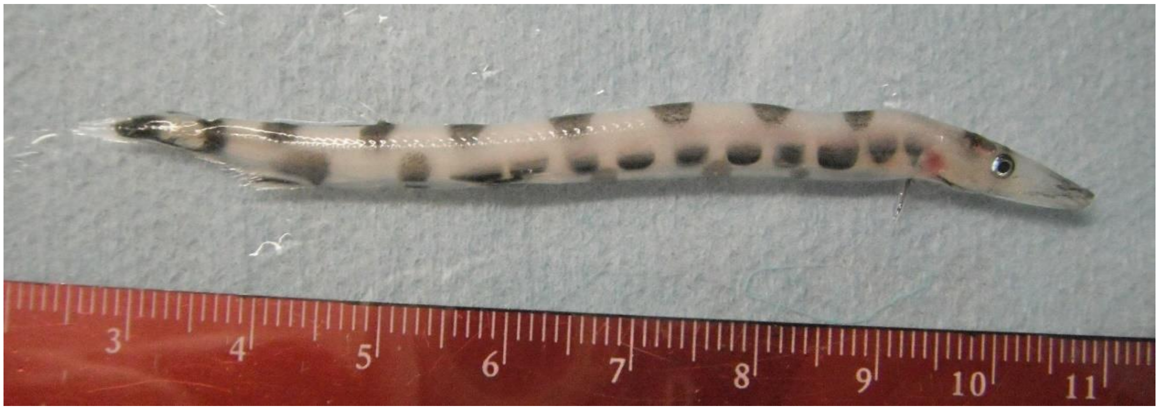


Figure 67 - A freshly caught subadult *Stemonosudis rothschildi*. Note the overall beige coloration of this fish. The ruler marks are in centimeters. Photo taken by Jon A. Moore.

Similar Species in the Gulf of Mexico: *Stemonosudis rothschildi* is similar in many respects to *S. bullisi*, both are the least "eel-like" of the genus, however, the two are easily distinguished by the presence/absence of dorsal saddle blotches. *Stemonosudis rothschildi* may also be confused with *S. siliquiventer* but the presence of the dorsal saddle pigments, again, easily differentiate it. No barracudina in the GoMx possesses the unique pigment characters which *S. rothschildi* exhibits.

Geographic, Seasonal, Diel, and Vertical Distribution: *Stemonosudis rothschildi* was extremely uncommon in the 2011 cruises; overall abundances were low (N=30). As such, statistical analyses were not useful due to issues with the spatio-temporal dispersion of samples. Looking at data from the Pisces, not much difference was seen between abundances within 25 km of the 1000-meter isobath (0.5 /10^6*m^3) and those collected at stations farther offshore (0.6 /10^6*m^3), although raw counts differed noticeably among these two groups (20 offshore and only 5 nearshore). The *Meg Skansi* only produced *S. rothschildi* during the summer sampling period. Considering both cruises, overall abundances were highest in the summer (Σ counts = 26; avg. abn. = 7.1 /10^6*m^3). In the winter sampling period, only two individuals were collected, and in spring, only a single specimen was collected, both respective samples being captured by the *Pisces*. Again, considering *Pisces* data alone, documented average abundances were greater at night (0.7 $/10^6*m^3$) than they were at day (0.3 $/10^6*m^3$). Standardized MOCNESS depth data only documented this species in nets 5 (0 – 200 m) and 3 (600 – 1000 m). Standardized HSRT data found abundances of 0.8$/10^6*m^3$ in “shallow” tows and 2.9 $/10^6*m^3$ in “deep”.

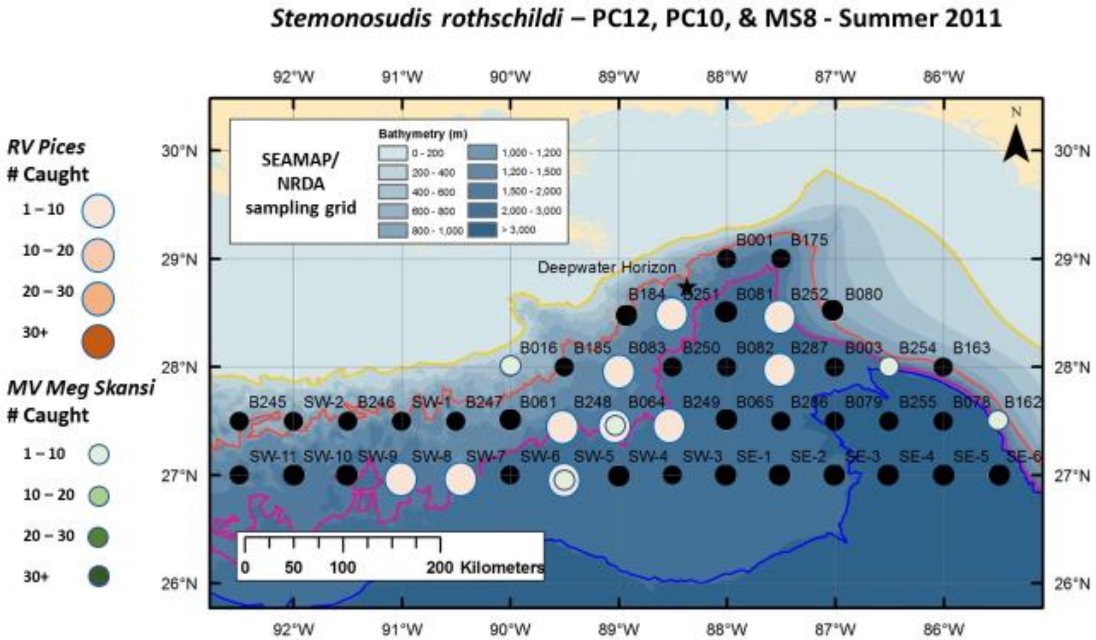


Figure 68 - Geographic distribution of the Rothschild’s barracudina in the sampling region during the summer of 2011. The Pisces collected a total biomass of 16.6 g at an average SL of 89.6 mm. The Meg Skansi sampled a total biomass of 1.4 g at an average of 51.8 mm SL. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

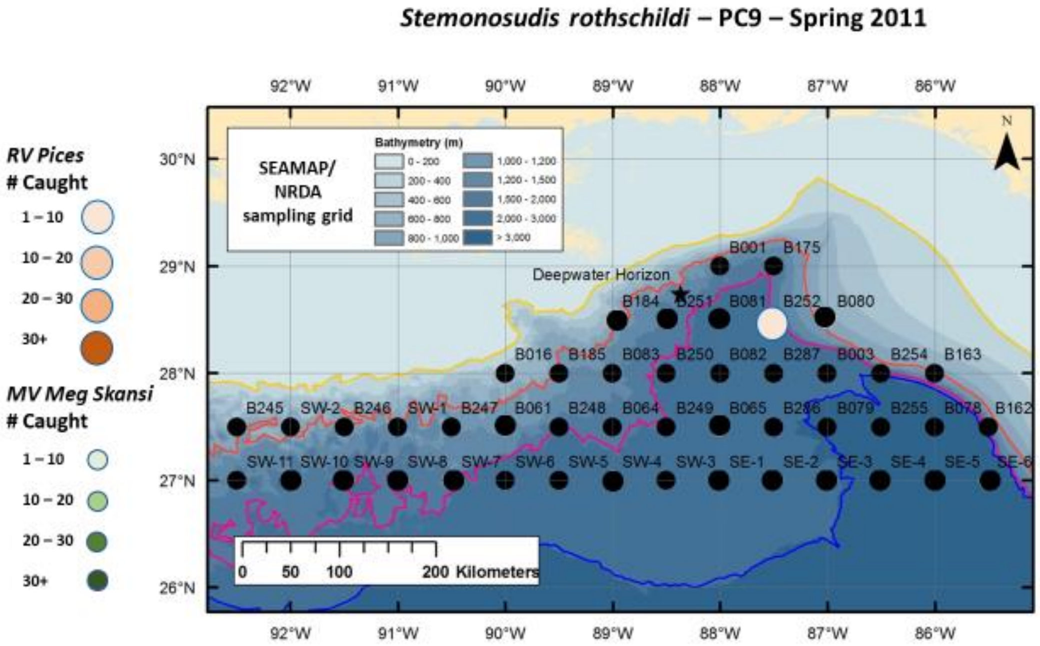


Figure 69 – Geographic distribution of the Rothschild’s barracudina in the sampling region during the spring of 2011. The Pisces collected a total biomass of 1.2 g at an average SL of 89 mm. The Meg Skansi did not sample any *S. rothschildi* specimens at this time. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

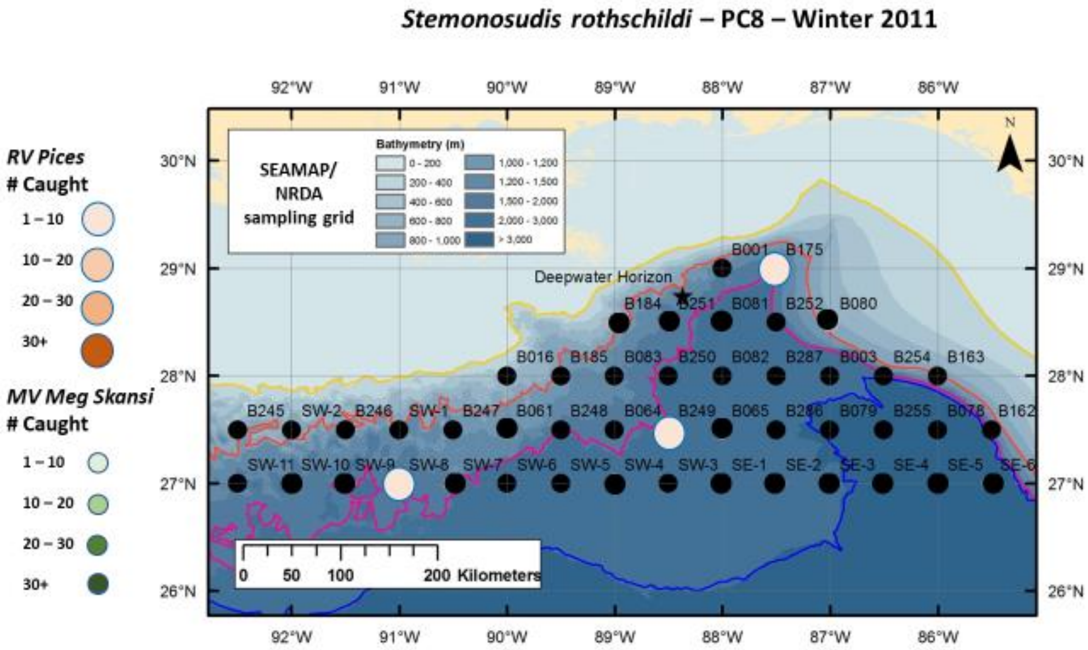


Figure 70 – Geographic distribution of the Rothschild's barracudina in the sampling region during the winter of 2011. The Pisces collected a total biomass of 2.1 grams at an average SL of 89 mm. The Meg Skansi did not sample any *S. rothschildi* specimens at this time. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

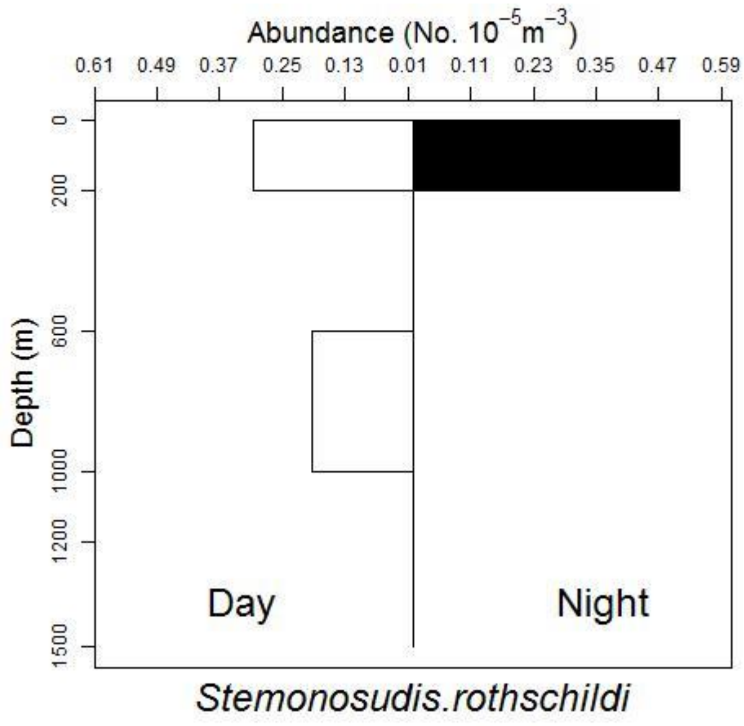


Figure 71 – Depth by Solar Cycle Diel, depth distribution of standardized abundances for the Rothschild's barracudina in the 2011 MOCNESS data. This species was largely epipelagic except for a few specimens caught in the lower mesopelagic.

Diet: Based on gut surveys of 20 individuals, ranging in size from 75 to 118 mm SL, adult *Stemonosudis rothschildi* prey upon mesopelagic fishes. Only 5 specimens were found to have contents in their stomachs, and all had evidence of fish tissues. One individual had a very full stomach and was found with a barely digested *Bregmaceros atlanticus,* which weighed 0.2 grams. That individual had been caught at night, in a deep tow, during the summer.

Ontogeny and Reproduction: Looking at *Pisces* data, average SL was greater in "deep" (94.6 mm) trawls than in "shallow" (83.9 mm), however, average lengths over all sampling depths was nearly identical for all sampling seasons (~89 mm SL) while raw counts collected from those respective sampling periods differed widely. Of the specimens dissected for gut content surveys, 12 contained eggs greater than 1 mm in diameter with orange pigment. The average SL for these specimens was 95 mm, the smallest was 79 mm, and all but one was collected during the summer sampling period. The one outlier had been collected during the winter sample period.

Stemonosudis siliquiventer

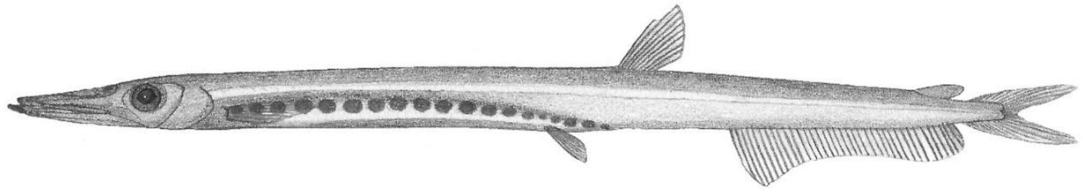


Figure 72 – The peapod barracudina (*Stemonosudis siliquiventer*). Max length 160 mm SL (fishbase.org). This species is named for the round and sequential appearance of the peritoneal patches (the species moniker *siliquiventer* refers to the latin *siliqua*, which is a seed capsule, and *venter,* or belly). These data represent the first record of occurrence for this species in the Gulf of Mexico. Illustration by Ray Simpson.

Description: The “peapod barracudina” is an elongate member of the Lestidiinae sub-family that almost completely lacks squamation (except for a single row of scales embedded along the lateral line) and is quite translucent in life. The snout is long and possesses numerous (70 or so) tiny teeth lining the maxilla and a series of 8 – 10 crooked fangs lining the mandible, asymmetrically pointing forward or back, and tipped with arrow-head like projections. The most distinctive character of *S. siliquiventer* are the high number of regularly spaced, ovoid, “pea-like” peritoneal patches, which number from 20 – 24. Pigmentation in specimens <70 mm SL is marked by a series of 10 – 15 dorsal pigment blotches, pigment along the very dorsal portion of the upper jaw, and an aggregation of chromatophores lining the occiput just above the brain. The midventral adipose fin, which often spans the entire area between the vent and the AFO in other barracudina species, ends well before the AFO in *S. siliquiventer* and is usually about coterminous with the end of dorsal fin. In larger specimens (>100 mm SL), dorsal pigment becomes a continuous strip or apparently absent and the dorsal portions of the peritoneal patches fuse and become a single, dark gut lining with small half-moons lining the ventral portion where the distinct peritoneal patches were (Post, 1970). Like other species of *Stemonosudis, S. siliquiventer* has a lower jaw which projects distinctly beyond the upper.

Similar Species in the Gulf of Mexico: *Stemonosudis siliquiventer* is most like its cogeners but is readily differentiated from them by a high number of peritoneal patches, an extremely truncated midventral adipose fin, and the number of AFR elements (36 – 38).

Because only one specimen of this species was produced by these sampling efforts, no natural history information is presented here regarding this species in the GoMx. This specimen does, however, represent the first documented occurrence of *Stemonosudis siliquiventer* in the GoMx.

Sudis atrox

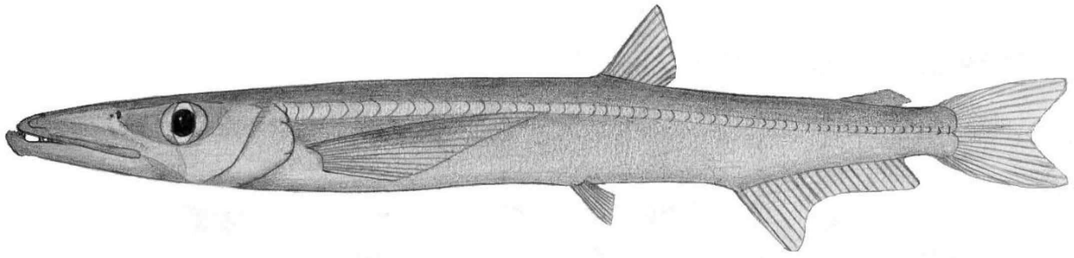


Figure 73 – The big-tooth barracudina. Max size 140 mm SL*. These barracudina are also called “big headed”, due to the comparatively large size of their heads. They are also sometimes referred to as “pike smelt” due to their superficial resemblance to a mixture of those two fishes, though they are not closely related to either pikes or smelts. Illustration by Ray Simpson.

Description: The “big-tooth barracudina” (aka “fierce pike smelt”; fishbase.org) is a medium sized barracudina in the sub-family Sudinae that almost entirely lacks squamation (except for a single row of scales embedded along the lateral line). The defining characters of the *Sudis* genus are the comparatively large head (which can be between 28 – 31% of SL), eyes, and large teeth along the mandible, which are much greater and more pronounced than any of other barracudinas. The premaxilla teeth are minute and fixed, with serrated edges in adults. Very small specimens (recently post-larval; 10 – 30 mm SL) possess numerous spikes and spines along the head, mandible, shoulder, and opercula. Two to three serrated, retrorse hooks extend from the posterior-ventral surface of preopercular spines and this feature defines *S. atrox* for SL <30 mm, however, this character quickly reduces with age. Lateral line scales are diamond shaped and possess 3 pores running along the dorsal and ventral edges. The pectoral fins are mottled with black pigment anteriorly and along the upper edge. The peritoneum is black and marked by 6 patches in smaller (<60 mm SL) sizes. Mature specimens have a brownish/black coloration to parts of the head and snout. Adult pigmentation in our samples was difficult to surmise for this species tended to lose a lot of its skin with capture. The pectoral fins become more elongate with age and can stretch to nearly mid-body.

Similar Species in the Gulf of Mexico: The two species of the *Sudis* genus are not easily mistaken with other barracudina but are easily confused with each other. Below 40 mm SL, the appearance of the preopercle spines, the relative length of the pectoral fins, and the number of peritoneal patches can all be used to diagnose this genus to species. Above

70 mm SL, very little distinguishes the two species besides vertebral count and the number of pores along the edges of the lateral line scales, which are 3 in *S. atrox*.

Geographic, Seasonal, Diel and Vertical Distribution: While uncommon, *S. atrox* was found to be widely distributed over the study region and over sampling seasons, with an apparent affinity for the epipelagic. No difference in abundances at sample stations was observed between stations near or far to the 1000-meter isobath for either gear type. No difference in abundance by east and west was observed for either gear type. No differences in abundance were determined among seasons or by solar cycle for either gear type, although the greatest numbers were captured during summer sampling at night. Greatest vertical abundances were documented in net 5 ($p<0.0031$) by the MOCNESS but was found at nearly every other bet depth (except net 2) in night trawls (see figure).

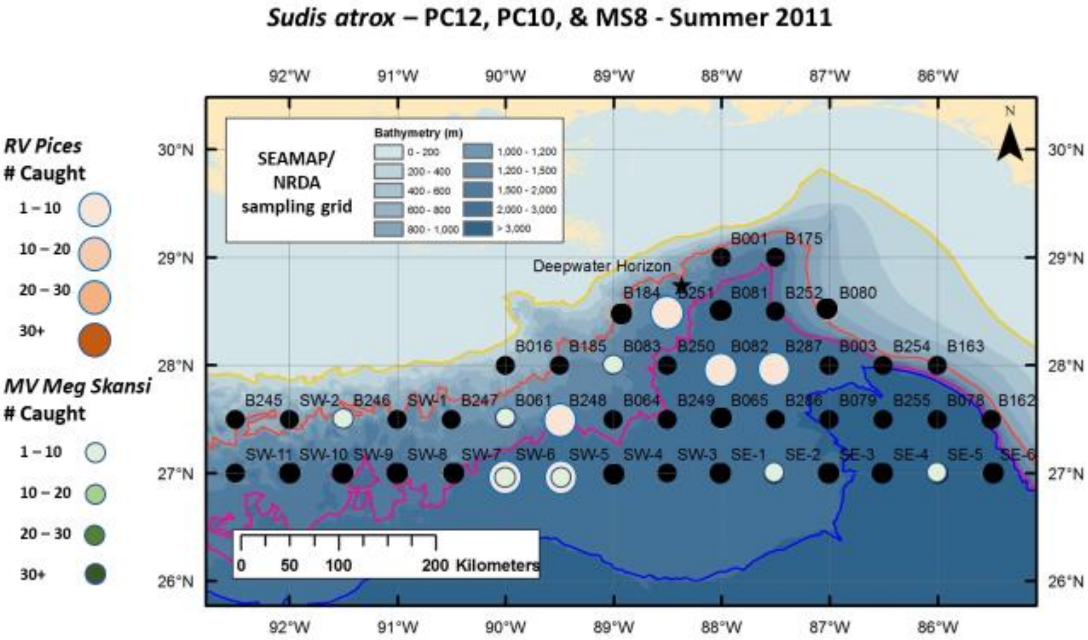


Figure 74 – Geographic distribution of the big-tooth barracudina in the sampling region during the summer of 2011. The Pisces collected a total biomass of 31.8 g at an average SL of 82.8 mm. The Meg Skansi sampled a total biomass of 5.1 g at an average of 18.6 mm SL. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

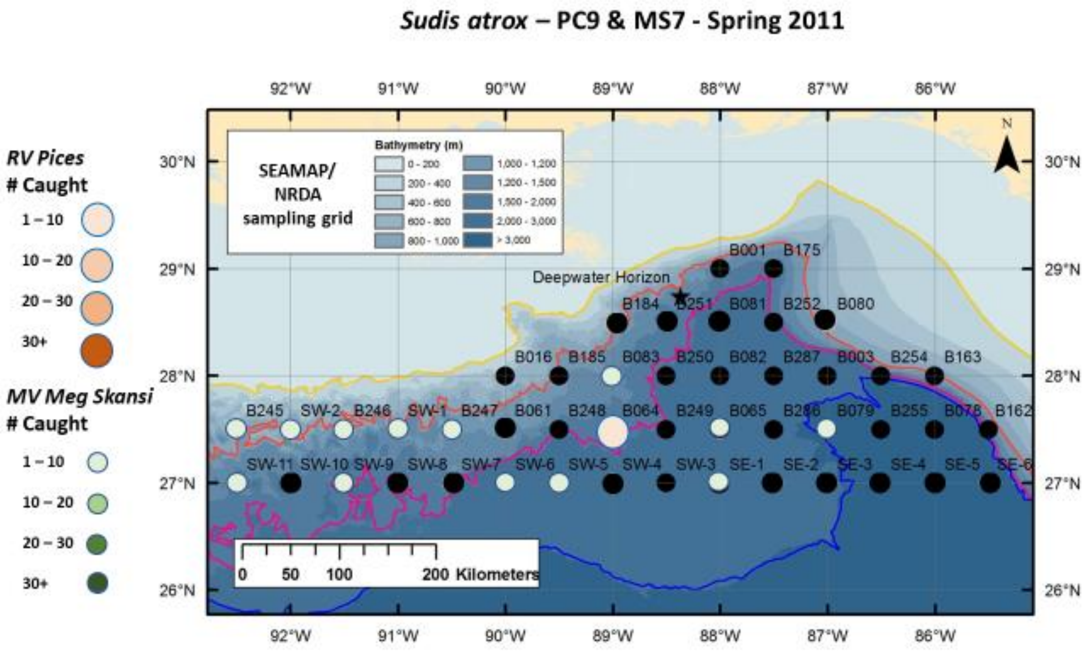


Figure 75 – Geographic distribution of the big-tooth barracudina in the sampling region during the spring of 2011. The Pisces collected a total biomass of 0.4 g at an average SL of 43 mm. The Meg Skansi sampled a total biomass of 1.4 g at an average of 16.3 mm SL. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

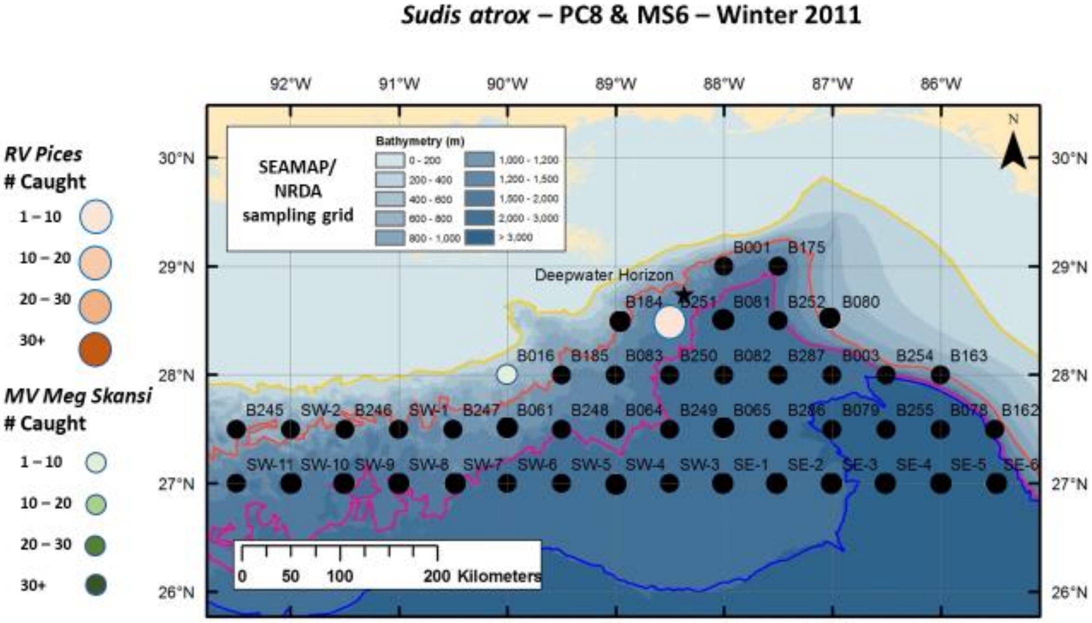


Figure 76 – Geographic distribution of the big-tooth barracudina in the sampling region during the winter of 2011. The Pisces collected a total biomass of 3.7 g at an average SL of 104 mm. The Meg Skansi sampled a total biomass of <0.1 g at an average of 10 mm SL. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

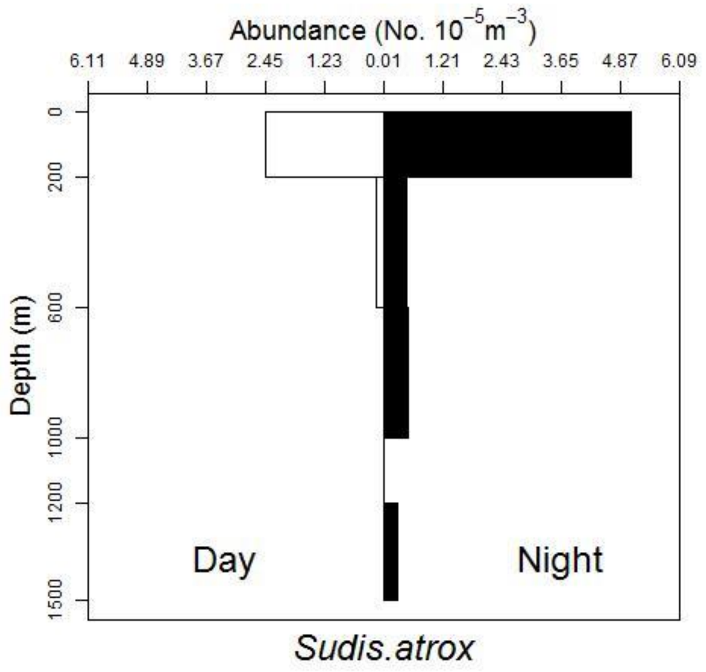


Figure 77 - Depth by Solar Cycle Diel, depth distribution of standardized abundances for the big-tooth barracudina in the 2011 MOCNESS data. While the majority of specimens were caught in epipelagic waters this species was present throughout the water column.

Diet: Of the *Sudis atrox* specimens collected by the *Pisces*, 8 were dissected to survey their guts, and of those specimens 6 were found to have stomach contents. All of these contained only evidence of fish predation with no identifiable components below the Teleostei taxon. No difference in apparent stomach fullness between day and night samples was observed.

Ontogeny and Reproduction: No differences in major size classes were noted by season nor time of day for individual respective gear types, but overall size classes and samples, slightly larger specimens were more frequently captured at day ($p<0.0245$) and significantly larger specimens were captured during summer ($p<0.0012$ compared to spring and $p<0.0409$ compared with winter). Of the specimens dissected for gut contents surveys, only one had large, pigmented eggs present, and that individuals was 140 mm SL and collected during the summer sampling period.

Sudis hyalina

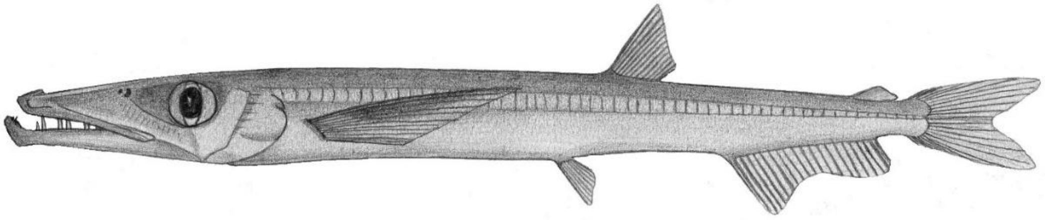


Figure 28 - The glassy big-tooth barracudina (*Sudis hyalina*). Max recorded SL 407 mm (Garibaldi et al., 2012). This species is one of the largest barracudina known and possesses comparatively large head, eyes, and teeth. It is sometimes called a “pike smelt” for its superficial resemblance to a hybrid of those two fishes, though it is not closely related to either pikes nor smelts. Illustration by Ray Simpson.

Description: The “glassy big-tooth barracudina” (a.k.a. “pale pike smelt”; fishbase.org) is a large barracudina in the sub-family Sudinae that almost entirely lacks squamation (except a single row of scales embedded along the lateral line). The defining character of the *Sudis* genus is the comparatively large size of the head (which can be between 28 – 31% of SL) and large teeth along the mandible, which are much greater and more pronounced than any of the other barracudinas. In *S. hyalina*, the premaxilla teeth are minute and fixed, with serrated edges in adults. Non-serrated, non-retrorse, hooked spines extend from the posterior-ventral surface of both preopercles at sizes <30 mm SL and the head and shoulders have markedly less spination than *S. atrox*. At SL <70 mm, the pectoral fins are extremely elongate and extend up to or beyond the dorsal fin and this is a defining character of *S. hyalina* at those size classes. As *S. hyalina* matures, the pectoral fins reduce and stabilize to about the same proportional length as the snout. Lateral line scales are diamond shaped and possess 4 – 7 pores running along the dorsal and ventral edges. The pectoral fins are mottled with black pigment anteriorly and along the upper edge. The peritoneum is black and marked by 6 patches in smaller (<60 mm SL) sizes which become fused and occluded by tissue with age. Mature specimens have a brownish/black coloration to parts of the head and snout. Adult pigmentation in our samples was difficult to surmise for this species as most specimens lost most of their skin with capture. The pectoral fins become elongate with age and can stretch to nearly mid-body.

Similar Species in the Gulf of Mexico: The two species of the *Sudis* genus are not easily mistaken with other barracudina but are easily confused with each other. Below 40 mm SL, the appearance of the preopercle spines, the relative length of the pectoral fins, and the number of peritoneal patches can all be used to diagnose this genus to species. Above 100 mm SL, very little distinguishes the two species besides vertebral count and the number of pores along the edges of the lateral line scales, which are between 4 – 7 in *S. hyalina*.

Geographic, Seasonal, Diel, and Vertical Distribution: The glassy big-tooth barracudina was uncommon and not found to exhibit trends in spatial or temporal distribution; it appears to be widely distributed throughout the GoMx and throughout vertical strata. No differences in abundances were found between the stations near and far from the 1000 m isobath and did not tend more toward stations east or west for either sampling campaign. No statistical difference in abundances among seasons for either gear type was found, however the greatest numbers and sizes were collected during the summer months by the *Pisces*. No difference in abundances were detected between samples collected by day or night or solar cycle. No significant trends were seen in abundance by depth strata.

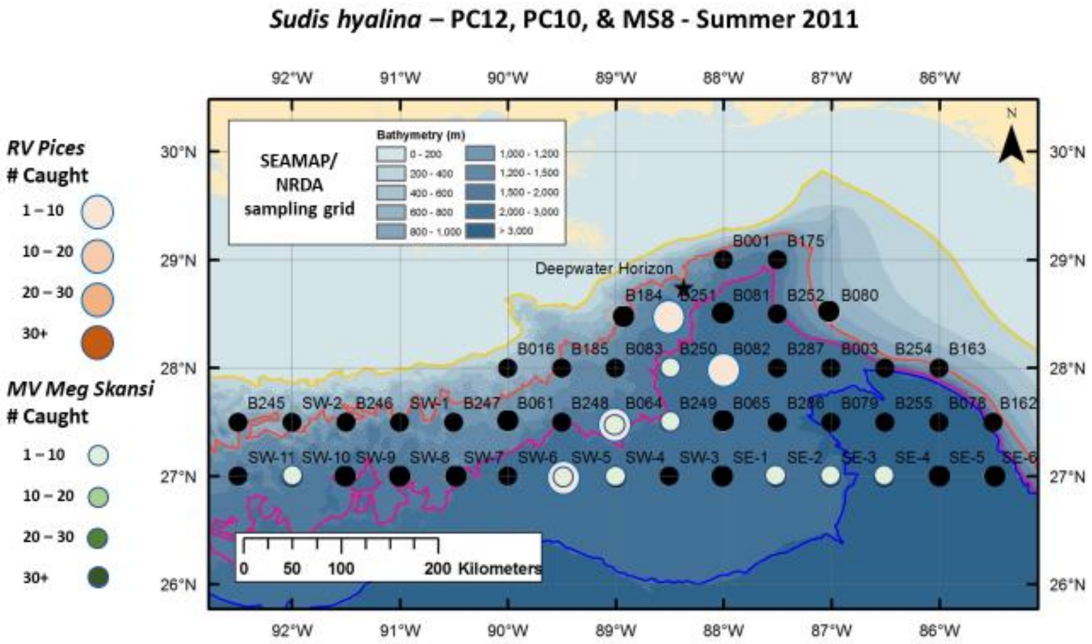


Figure 79 – Geographic distribution of the glassy big-tooth barracudina in the sampling region during the summer of 2011. The Pisces collected a total biomass of 58.3 g at an average SL of 113.3 mm. The Meg Skansi sampled a total biomass of 0.9 g at an average of 22.6 mm SL. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

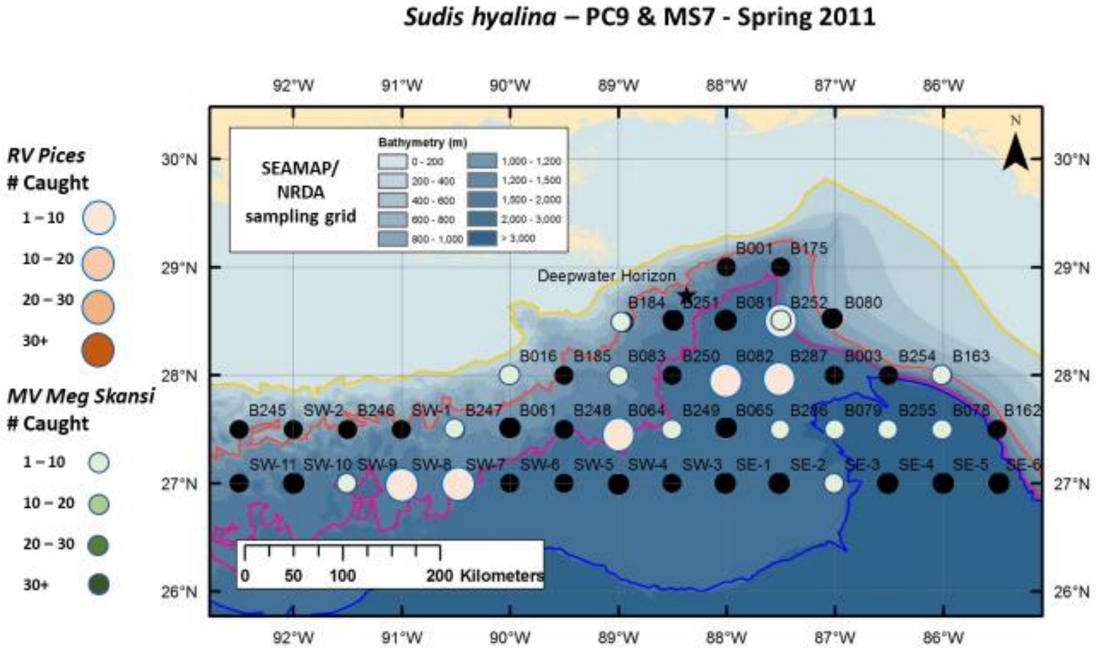


Figure 30 – Geographic distribution of the glassy big-tooth barracudina in the sampling region during the spring of 2011. The Pisces collected a total biomass of 3.8 g at an average SL of 90.3 mm. The Meg Skansi sampled a total biomass of 1.4 g at an average of 23.8 mm SL. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

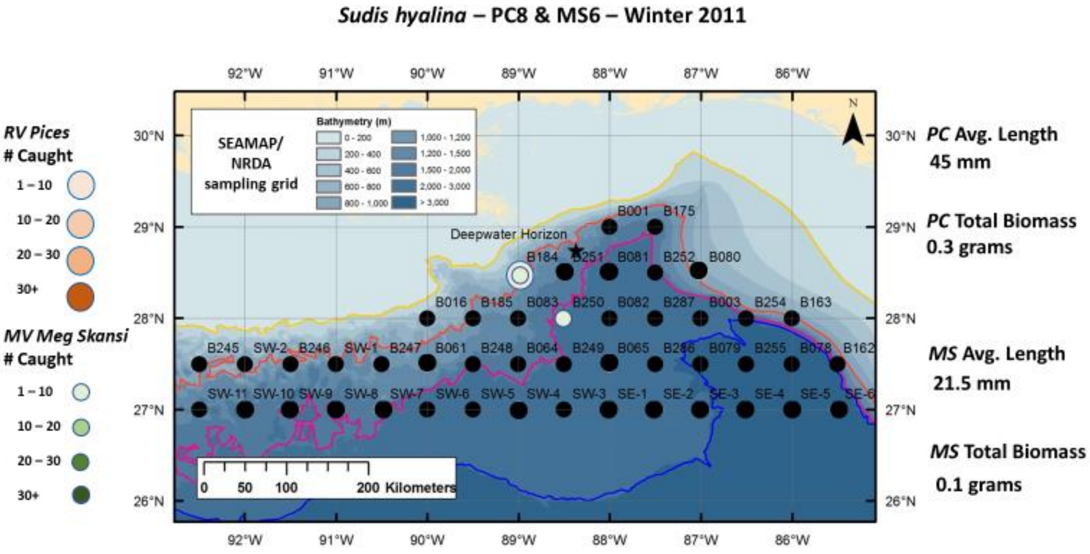


Figure 81 – Geographic distribution of the glassy big-tooth barracudina in the sampling region during the winter of 2011. The Pisces collected a total biomass of 0.3 g at an average SL of 45 mm. The Meg Skansi sampled a total biomass of 0.1 g at an average of 21.5 mm SL. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

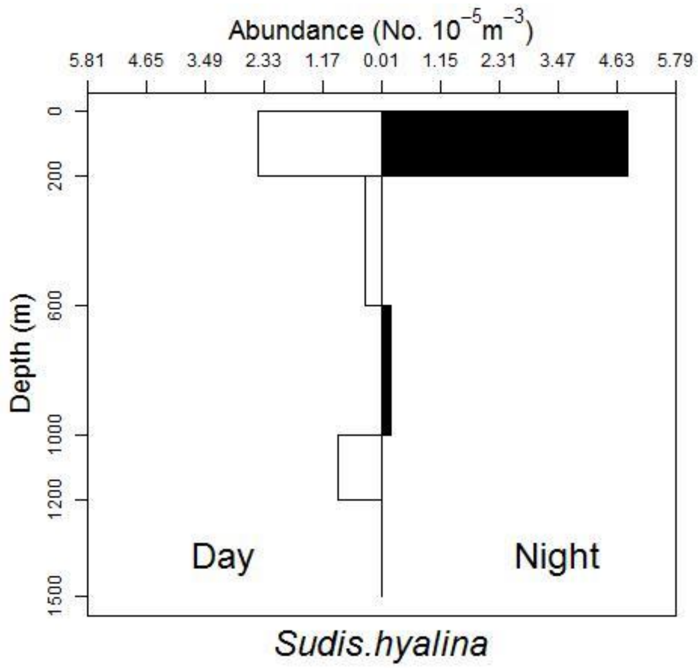


Figure 82 – Depth by Solar Cycle Diel, depth distribution of standardized abundances for the glassy big-tooth barracudina in the 2011 MOCNESS data. While most specimens were caught in epipelagic waters this species was present throughout the water column.

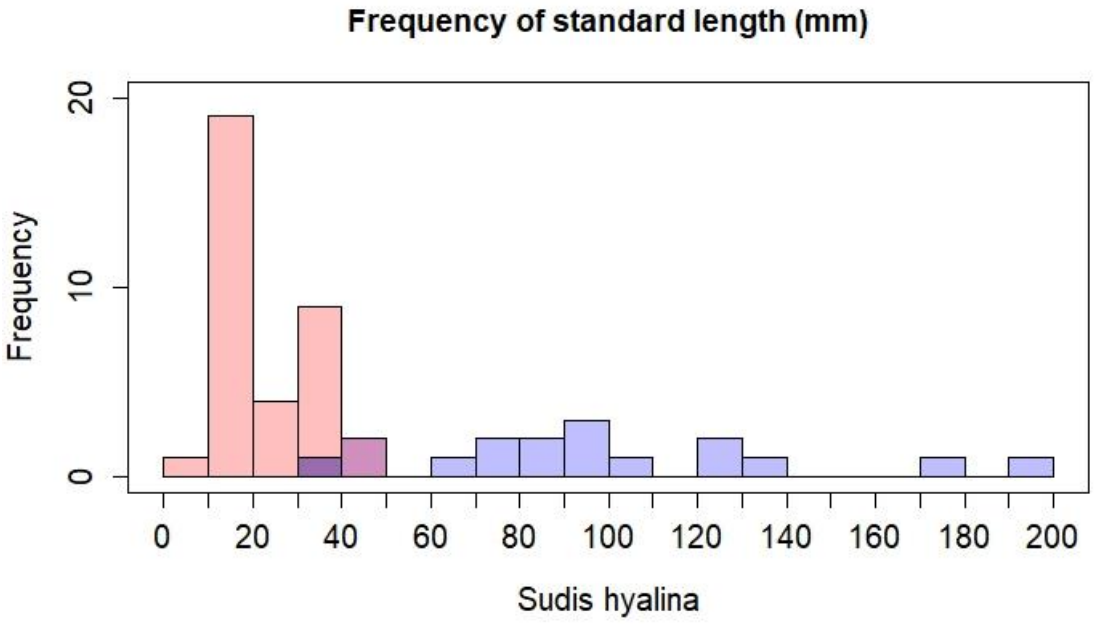


Figure 83 – Frequency of standard lengths by cruise. The *Pisces* (in blue) caught significantly greater numbers (Welch's ANOVA; p<0.0001) than either MOCNESS (*Meg Skansi* = Salmon; *Point Sur* = Purple) geared vessel and nearly all the data on the largest size classes are represented by *Pisces* samples.

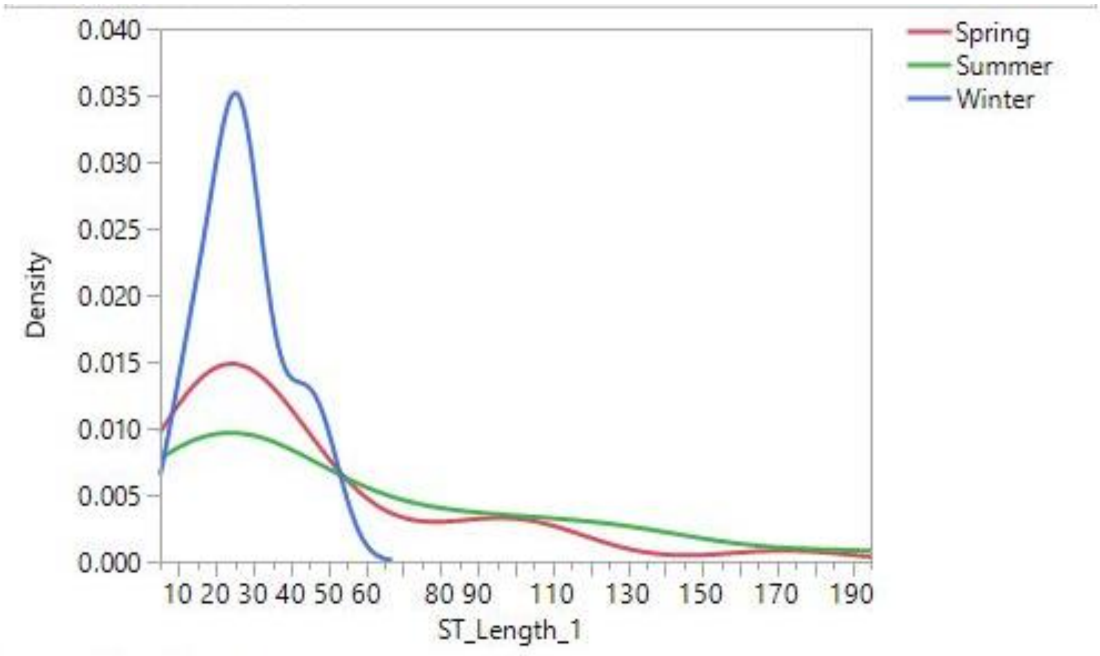


Figure 84 – Frequency of SL for all size classes of *S. hyalina* by season. The greatest number of individuals caught were subadult specimens during the winter.

Diet: Of the *Pisces* collected specimens, 7 were dissected for gut content surveys. Of those 7, 5 were found to contain gut contents. All contained evidence of fish predation, with one specimen containing a partially digested *Vinciguerria* species. Another individual was found to contain some remains of a squid including beak parts. Apparent stomach fullness was significantly greater in night collected specimens ($p<0.0219$), however, the positively identified *Vinciguerria* was documented in a specimen collected at day.

Ontogeny and Reproduction: The smallest size classes of *S. hyalina* were most frequently collected during the winter months (see Figure 81). No such difference among seasons was noted among the larger size classes. No statistical difference was determined among size classes collected by depth for either gear type. Of the specimens dissected for gut content surveys, only one had large, pigmented eggs and that specimen was 175 mm SL and collected during the spring sampling period.

Uncisudis advena

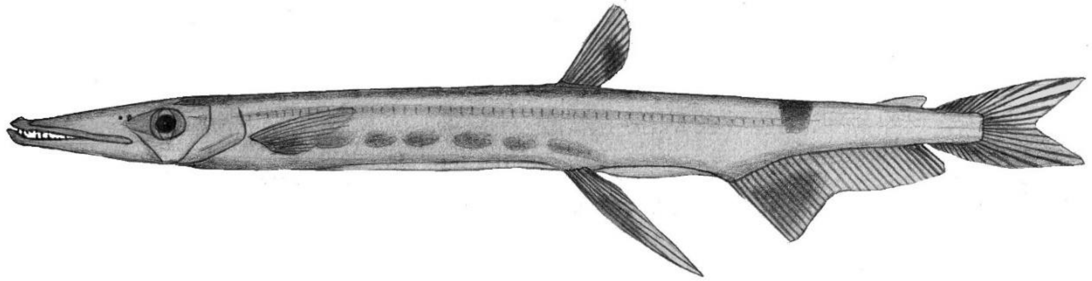


Figure 85 – The long finned barracudina (*Uncisudis advena*). Max recorded size 82 mm SL*. The smaller sized *Uncisudis* genus is unique among barracudina for the duck-billed shape of their snouts and the relatively elongate nature of their pelvic fins. Illustration by Ray Simpson.

Description: The "long finned barracudina" is a small barracudina of the Lestidiinae sub-family that almost completely lacks squamation (except for a single row of scales embedded along the lateral line). It is a slender fish with a lower jaw that extends slightly beyond the upper and appears slightly upward curved; the DFO is very slightly anterior to the PVO. *Uncisudis advena* is distinguished from other barracudina by the shape and proportion of its head (about 25% of SL) and snout (about 15% of SL), by its unusually long pelvic fins, and by a single, distinct saddle blotch located on the posterior, dorsal portion of the body. The single dorsal blotch is located above the anal fin and is darkly pigmented. Similar dark pigments occur in oblique blotches along the posterior edge of the dorsal fin, the anterior edge of the pelvic fins, and the anterior edge of the anal fin, respectively. The species has 7 distinct, ovoid peritoneal patches. No luminous organ is present.

Similar Species in the the Gulf of Mexico: *Uncisudis advena* is most like its cogener in the GoMx, *Unicisudis quadrimaculata*. The two species can easily be distinguished from each other by the number of dorsal saddle blotches, as *U. quadrimaculata* has 4 evenly spaced along its length while *U. advena* only has one located posteriorly. In addition, the number of peritoneal patches are usually distinct and the lower jaw of *U. advena* extends beyond the upper, which is generally not the case in *U. quadrimaculata*. *U. advena* might be confused with *Lestidium atlanticum* due to the relative placement of the DFO and the PVO, but the length of the pelvic fin makes this species distinct from *Lestidium*.

Geographic, Seasonal, Diel, and Vertical Distribution: The long finned barracudina was rare in the study area during 2011. While not enough data were available to derive meaningful statistical inferences on distributions, abundances appeared to be greatest in summer along the eastern portion of the study area and in the epipelagic. Again, while no statistical differences were determined, the numerically greatest abundances of *U. advena* were collected at night and farther than 25 kilometers from shore. 88% of the specimens captured were collected by net 5 of a MOCNESS (0 – 200 meters). A single individual was captured in a MOCNESS tow that reached 500 meters and another individual was captured in a HSRT trawl that reached 1400 meters.

Diet: A single individual was dissected to survey its gut contents and found to contain fish remains not identifiable to a lower taxonomic unit than Teleostei.

Reproduction and Ontogeny: Significantly larger individuals were collected during the winter months than any other time of year (p<0.0049; see Figure 90). The sole specimen dissected for gut contents did not possess large, pigmented eggs.

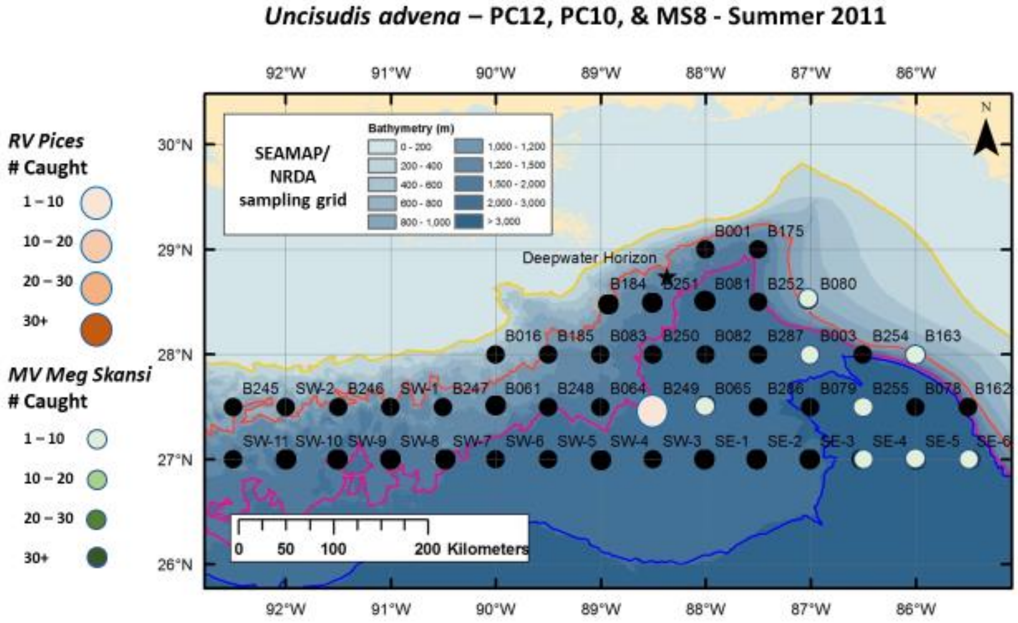


Figure 86 – Geographic distribution of the long finned barracudina in the sampling region during the summer of 2011. The Pisces collected one incomplete (damaged) specimen. The Meg Skansi sampled a total biomass of 0.4 g at an average of 26.5 mm SL. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

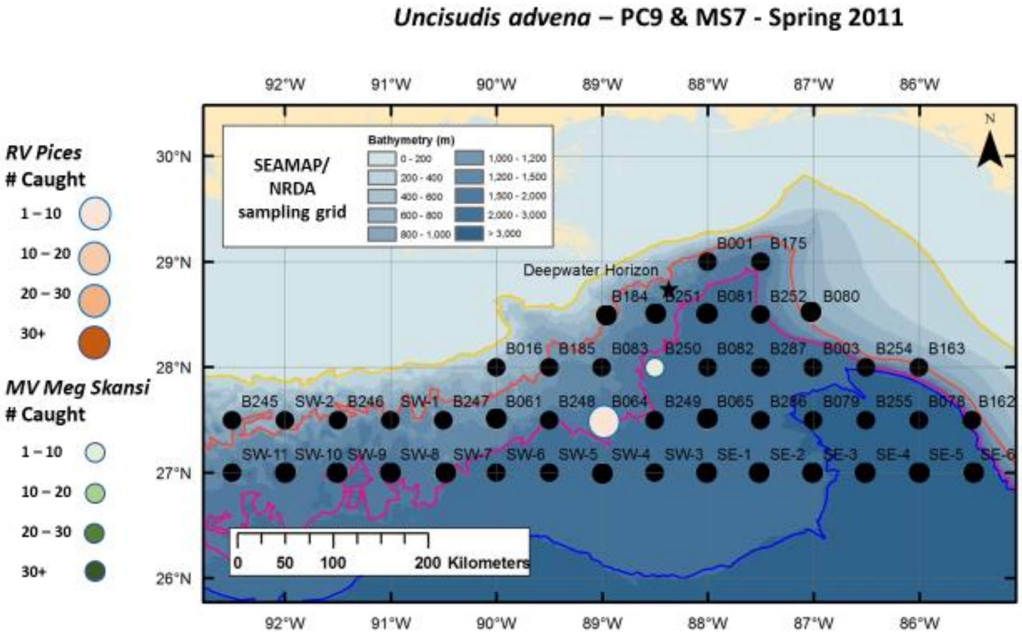


Figure 87 – Geographic distribution of the long finned barracudina in the sampling region during the spring of 2011. The Pisces collected a total biomass of 0.8 g at an average SL of 84 mm. The Meg Skansi sampled a total biomass of 0.1 g at an average of 30 mm SL. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

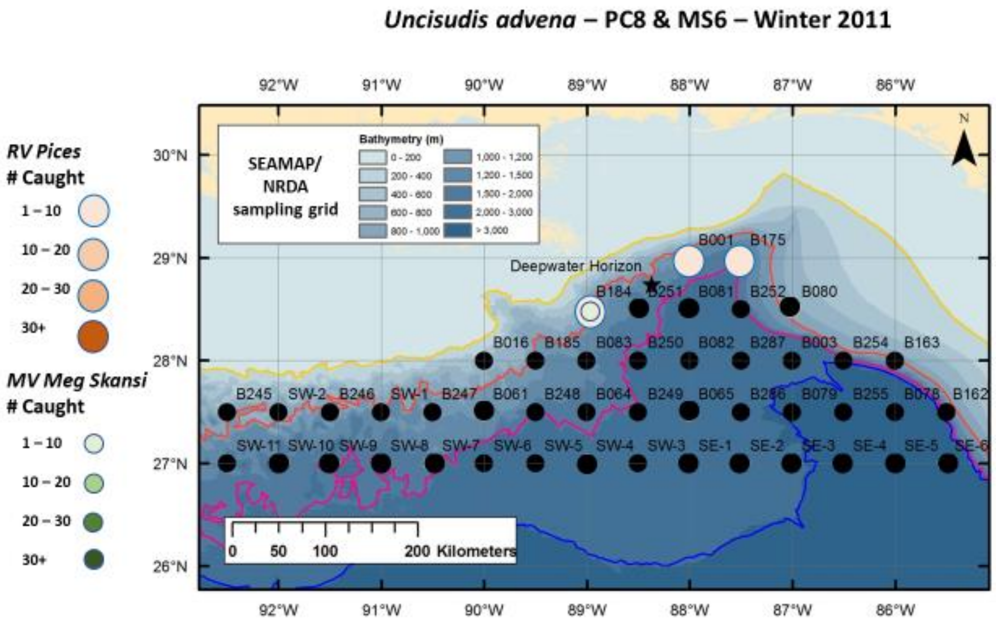


Figure 88 – Geographic distribution of the long finned barracudina in the sampling region during the winter of 2011. The Pisces collected a total biomass of 0.1 g at an average SL of 60.7 mm. The Meg Skansi sampled a total biomass of 0.1 g at an average of 28 mm SL. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

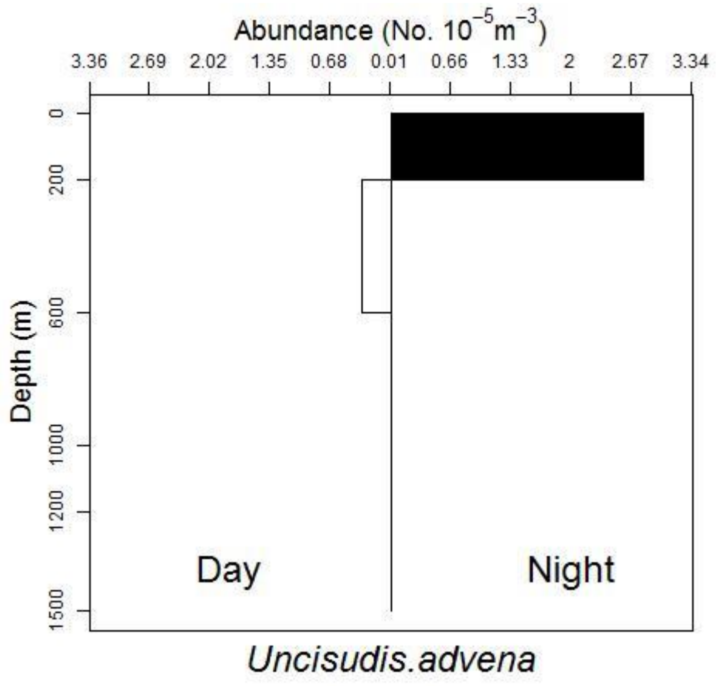


Figure 89 – Depth by Solar Cycle Diel, depth distribution of standardized abundances for the long finned barracudina in the 2011 MOCNESS data. This species was documented entirely in the epipelagic and upper mesopelagic. The mesopelagic specimens caught in net 4 were found only at day and the epipelagic specimens in net 5 were only found at night. However, the overall numbers are too low to allow inference of diel migration habits with confidence.

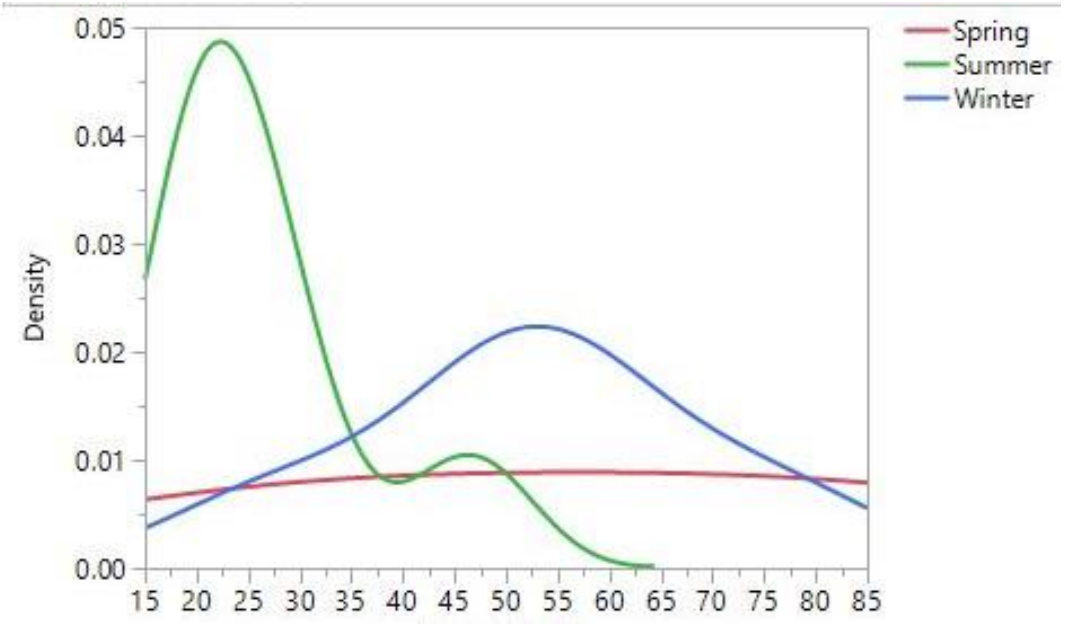


Figure 90 – Density of SL for all sizes of *U. advena* by sampling seasons in 2011. The smallest size class was almost exclusively found during the summer.

Uncisudis quadrimaculata

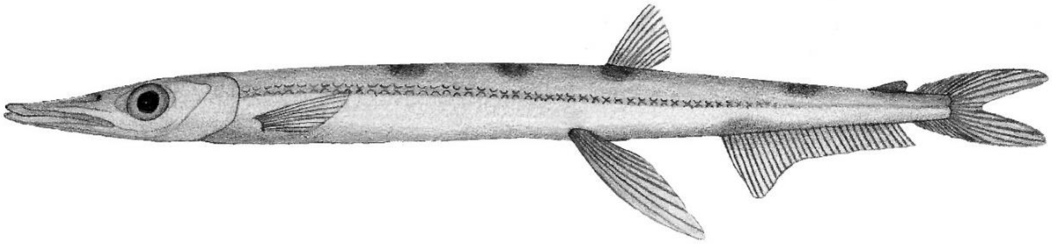


Figure 91 – The four spot barracudina. Max recorded size 104 mm SL*. The small sized *Uncisudis* genus is unique among barracudina for the shape of their snouts and the relatively elongate nature of their pelvic fins. Illustration by Ray Simpson.

Description: The "four spot barracudina" is a small barracudina of the Lestidiinae subfamily that almost completely lacks squamation (except for a single row of scales embedded along the lateral line). The PVO is very slightly anterior to the DFO. *Uncisuds quadrimaculata* is distinguished from other barracudina by the shape and proportion of its head (about 24% of SL) and snout (about 13% of SL), by unusually long pelvic fins, and by four distinct saddle blotches located in even intervals along the dorsal. Similar pigments occur along the posterior dorsum, and the pelvic fins are often darkly pigmented along all fin rays. The species has 6 distinct, ovoid peritoneal patches. No luminous organ is present.

Similar Species in the the Gulf of Mexico: *Uncisudis quadrimaculata* is most similar to its cogener in the GoMx, *Unicisudis advena*. The two species can easily be distinguished from each other by the number of dorsal saddle blotches, as *U. quadrimaculata* has 4 evenly spaced along its length while *U. advena* only has one located posterior to the dorsal fin. In addition, the number of peritoneal patches is usually different, the pigment on the pelvic fins rays of *U. quardimaculata* is more extensive, and the lower jaw of *U. quadrimaculata* does not extend beyond the upper whereas *U. advena* has a lower jaw longer than the upper and less extensive pigmentation of the pelvic fins. *U. quadrimaculata* might be confused with *Lestidium atlanticum* due to the relative placement of the DFO and the PVO, but the length of the pelvic and the dorsal saddle blotches readily differentiate the two.

Geographic, Seasonal, Diel, and Vertical Distribution: The four spot barracudina was extremely rare in the study area during all cruising periods. Almost all specimens were collected farther than 25 kilometers from shore, in the summer, and by day. A single individual was collected during a spring sampling month at night. The deepest tow that produced a *U. quadrimaculata* specimen was 730 meters (a HSRT “shallow” trawl).

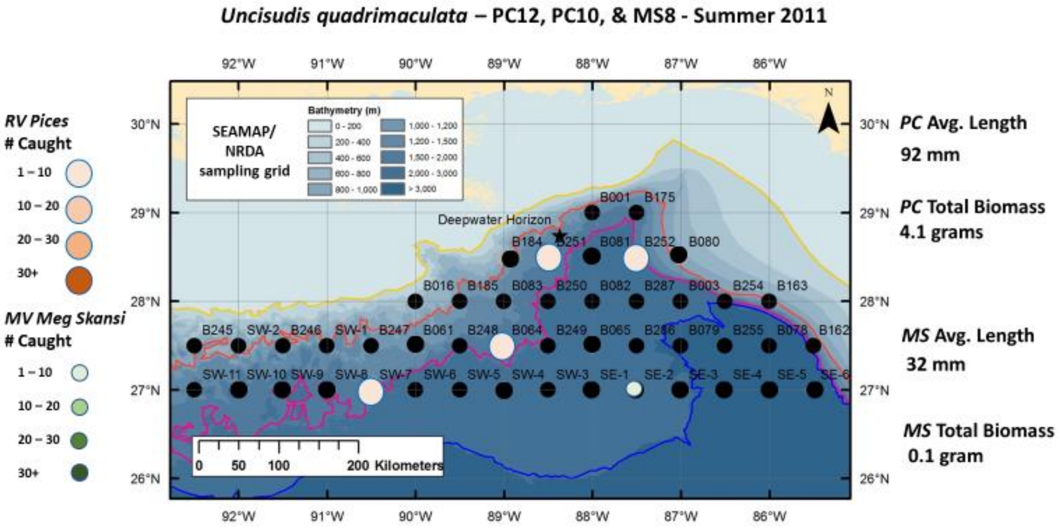


Figure 92 – Geographic distribution of the four spot barracudina in the sampling region during the summer of 2011. The Pisces collected a total biomass of 4.1 g at an average SL of 92mm. The Meg Skansi sampled a total biomass of 0.1 g at an average of 32 mm SL. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

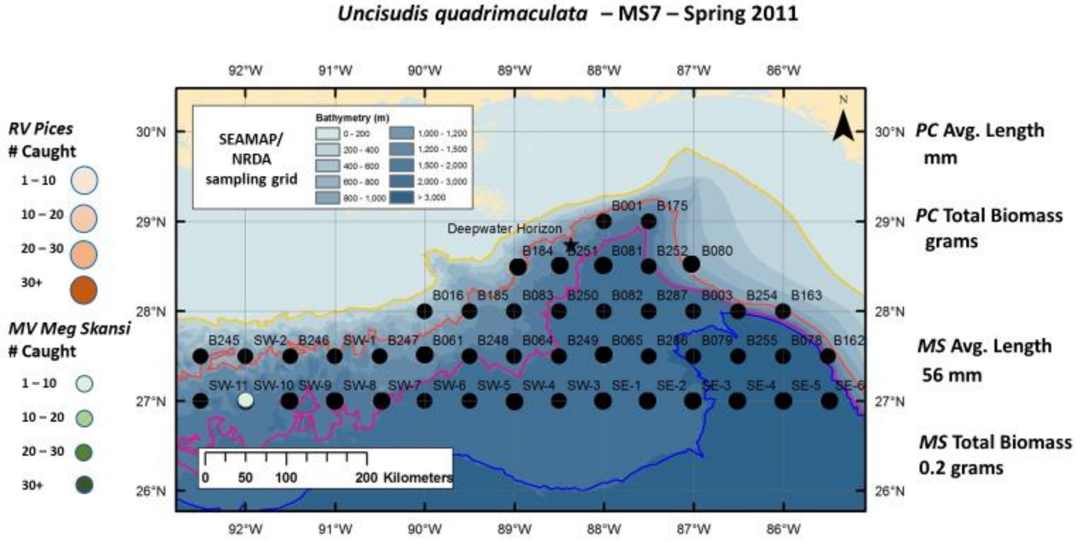


Figure 93 – Geographic distribution of the four spot barracudina in the sampling region during the spring of 2011. The Pisces collected no specimens of this species at this time. The *Meg Skansi* sampled a total biomass of 0.2 g at an average of 56 mm SL. On this map, the 200 m isobath is represented in yellow, the 1000 m in orange, the 2000 m in pink, and the 3000 m in blue.

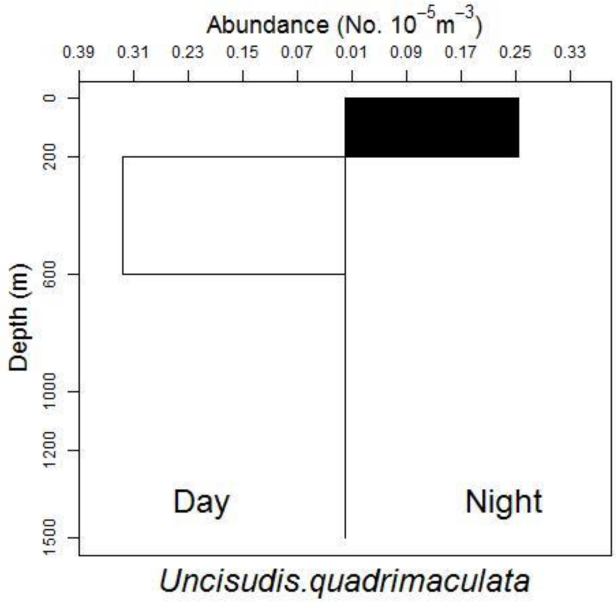


Figure 94 – Depth by Solar Cycle Diel, depth distribution of standardized abundances for the four spot barracudina in the 2011 MOCNESS data. This species was documented entirely in the epipelagic and upper mesopelagic. The mesopelagic specimens caught in net 4 were found only at day and the epipelagic specimens in net 5 were only found at night. However, the overall numbers are too low to allow inference of diel migration habits with confidence.

Diet: A single specimen was dissected for gut content surveying and found to have the remains of something that could either be a thin piece of plastic or a piece of a squid's gladius.

Reproduction and Ontogeny: No data on reproduction or ontogeny were available due to the scarcity of sampled specimens.

Chapter Four: Discussion

While some of these results confirm previous knowledge and/or speculation on the ecology of this group (see Rofen, 1966) the extensive nature and regional specificity of these findings are novel and likely characterize a major portion of barracudina life histories in the GoMx basin, especially in “common water”. Complete life history, behavioral, trophic, intraspecific, and water mass associated characterizations remain far from complete. However, this thesis provides a comprehensive list of basic life history descriptions and distributions to begin informing a baseline useful to future efforts and surveys in the GoMx. These findings expand basic knowledge on the Paralepididae and represent some superlative information for a few of the rarer varieties.

New records of species occurrence in the Gulf of Mexico include: *Anotopterus pharao, Paralepis coregonoides*, *Stemonosudis siliquiventer* and *Uncisudis quadrimaculata.* The presence of *Paralepis coregonoides* and *Anotopterus pharoa* are especially novel findings for the Gulf of Mexico (GoMx). These two species of barracudina are more commonly found in the temperate waters of higher latitudes, and although there were only two individuals of either species captured, their presence represents a major range expansion, especially for the *Anotopterus* genus. Many years ago, Hubbs *et al*., 1953, had asserted that the *Anotopterus* have a purely anti-tropical distribution, and few data were collected in the ensuing century to confirm or deny that assertion. Later work concerning the overlap in distribution between *Anotopterus* spp. and Pacific salmon (*Oncorhynchus* spp.) seemed to verify this assertion although a lack of data muddled understanding of their distributions in more northerly climes (Nagasawa, 1993). The occurrence of eurybathic species at either pole has led to theories like latitudinal submergence (Markle *et al*., 1988) and isothermal submergence (Ekman, 1953; Randall, 1982) which provide possible explanations as to how a single species can straddle the two poles by migratory passage under the subtropics and tropics, living at deeper depths where the water is cold enough to maintain low thermal tolerances. For example, recent tracking of basking sharks has demonstrated the possibility of such migratory patterns in those temperate limited fish as individuals were documented to pass through tropical waters at great depths (Skomal *et al*., 2009). Indeed, *Anotopterus* itself has been documented in tropical waters previously, as in the findings of Kim *et al*. (1997) regarding the gut contents of yellow-fin tuna (*Thunnus obesus*) in the tropical west Pacific, where *Anotopterus* comprised a sizable portion of diets there. The finding of this species in the subtropical GoMx is a fascinating addition to our understanding of the global distribution of the genus and may underscore the potential for connectivity between the temperate north Atlantic and the temperate/subtropical northern GoMx.

The data for this thesis also constitute the first reported collection of *Stemonosudis siliquiventer* and *Uncisudis quadrimaculata* in the GoMx, which are extremely rare species previously known only from a handful of specimens collected in the tropical south Atlantic and Caribbean (Post, 1969a; Post, 1970).

The largest specimens on published record to date were also collected by these efforts for *Lestidiops affinis, L. mirabilis, Stemonosudis bullisi, Sudis atrox, Uncisudis advena*, and *U. quadrimaculata* (McEachran and Fechhelm, 1998; fishbase.org, 2018). Furthermore, several specimens collected exhibited anomalous phenotypes that markedly deviated from descriptions in the available literature. This was especially the case with certain pigmentation and fin ray counts of a few of the Lestidiinae specimens. Two fish that had the meristic characters of *Lestidium atlanticum* had pigments that were atypical for that species. One possessed a dorsal saddle pigment, like that seen in *Uncisudis advena*, as well as snout proportions like that of an *Uncisudis*. However, this specimen lacked the long pelvic fins of *Uncisudis*, possessed meristic counts like those of *L. atlanticum*, while the relative position of the DFO and PVO were unlike either of those species. Another specimen had meristic counts like those of *L. atlanticum* but possessed distinct ventral and dorsal melanophores quite atypical for that species. Further work will be required with those specimens to ascertain if these aberrant traits are simply intraspecific variation or potentially undescribed species. The largest specimens of *Stemonosudis bullisi*, a potentially endemic barracudina to the GoMx, were also quite different from the previously described holotype and an additional specimen (Rofen, 1963, 1966). However, because this species was only previously known from those two juvenile individuals that were a third of the size of the largest we found and a fraction of the numbers we collected, the differences in description are likely merely ontogenetic. This work is simply adding 2 to 3 more AFR element counts to the meristic ranges and a more complete characterization of adult pigmentation.

Much of the work contributed by Rofen (1963, 1966) as well as Ege (1930, 1953), Post (1969a & b, 1970, 1971, 1978, 1984, 1987), and more recent compilations (McEachran and Fechhelm 1998) remained as accurate descriptions of these species given our specimens, and ultimately very little in the way of species descriptions from our specimens differs from those accounts. At the very least, the synthesis presented here of Paralepididae varieties found within the GoMx and the accompanying descriptions of adult characters will help to guide future researches through their identification of these taxa when working in the Gulf and adjacent regions.

The distributional data presented here will be informative to ecological baselines because they present a sizable geographic, vertical, and seasonal spread within a single year (2011) of sampling. Unfortunately, many of the specific barracudina captured by these campaigns were found in comparatively low numbers and the spread of the data by species were not robust enough to make definitive spawning or water mass association inferences. Furthermore, the respective barracudina captured by the *Point Sur* campaigns in the years following 2011 were even fewer in numbers and species, making interannual comparisons challenging because few or no specimens were captured in similar water masses during the post-2011 cruises. Given these data as they are, an apparent decrease in both species abundances and species richness seems to have been documented. By comparing the *Meg Skansi* cruises in 2011 with those by the *Point Sur* in the years following the oil spill (compare Tables 1 and 3) a net loss of abundances and species is apparent. However, the variability of water masses and climate make accurate comparisons among years nearly impossible without additional data. Was 2011 an especially good year or was there a decrease in barracudina following the spill? Are the water masses of the loop current influencing the observed abundances of certain barracudina or was the spill a defining disturbance to their abundances? Unfortunately, these are questions that would require a more robust baseline of data prior to the oil spill to properly address.

Despite certain short-comings with these data and analyses, some apparent patterns have arisen from this work with relevance to the characterization of barracudina life histories, albeit, with more confidence for the descriptions of some more abundant species over others. Almost every barracudina species collected had no observed association with the continental shelf escarpment and were highly oceanic in distribution. Several Lestidiinae species (*Lestidiops mirabilis, Lestidium atlanticum,* and the two *Uncisudis* species collected) seemed to have distributions that put them exclusively farther than 25 kilometers from shore, at least by numbers collected. Only the most common species*, Lestidiops affiinis*, was found to be statistically more abundant at stations within 25 kilometers of the 1000-meter isobath, and this was only true with the MOCNESS data in 2011. Since the MOCNESS tended to capture the smaller size classes of this species (see Figure 14) this finding tentatively confirms the findings by the USGS (Lyczkowski-Shultz *et a*l., 1993) that larval and post-larval *L. affinis* tend to be more common near the shelf during the spring months. Similarly, very few species had any association with the eastern or western halves of the sampling region. With species that were grossly represented by the HSRT data of 2011 (e.g. *Lestrolepis intermedia*; see Figure 36) their longitudinal distributions were skewed to the western side of the study area due to the specific survey track of the *Pisces* and those findings should be interpreted, at best, as a tendency for net evasion bias in the MOCNESS data. However, the small barracudina *Uncisudis advena* was found more commonly in the eastern half of the study area in the MOCNESS data. This could be interpreted as a loose association of this species with the water masses near the loop current or with the undersea features of the Desoto canyon. However, the overall low numbers collected for *U. advena* and lack of multi-year baselines make such inferences uncertain given the high degree of environmental variability in the pelagic environment.

Like previous reports (see Harry, 1953; Rofen, 1966) we found barracudina are, overall, likely evading research-grade nets. However, the extent to which this is true seems to be limited to only the largest size classes (see Figure 7) or certain species (e.g. *Lestrolepis intermedia*; see Figure 36) and does not represent a terribly huge discrepancy in comparative abundance or species richness overall (see Tables 1 and 2). Given that MOCNESS data is cautiously representative of overall abundances, some evidence is apparent from these data that diel, vertical migration may weakly occur in some species, although the extent of this behavior seems to vary, specifically and generically. With *Lestidiops jayakari, Magnisudis atlantica, Paralepis brevirostris, Stemonosudis bullisi, S. rothschildi,* and the two *Uncisudis* spp., there are slight vertical trends towards greater abundances in shallower depths at night in the MOCNESS data. The same was true for the ubiquitous *Lestidiops affinis* which was statistically more abundant in solar night MOCNESS trawls, potentially hinting to a nyctoepipelagic synchronous migration pattern (Sutton *et al*., in press). But because no significant difference between solar day and night samples were found for these species in HSRT data it could be that visually facilitated net evasion of the MOCNESS is occurring instead. However, it is also true that the broad depth strata sampled by the HSRT likely missed much of the vertical variability of lower epipelagic/upper mesopelagic distributions and could have been too course a vertical resolution to capture subtle trends in migratory habits which are more visible in the MOCNESS data.

These uncertainties regarding vertical distribution and life history underscore the importance of *in situ* behavioral observations on deep pelagic nekton. If the behavioral habits of a taxon are known, then patterns in distributional and dietary data can be inferred with much greater confidence. However, such work is exceedingly rare due to the extreme and remote nature of the deep pelagic habitat itself. Barham (1970) describes key findings from the *Deepstar* submersible dives of the late 1960s off the coast of California to make a case for lethargy and vertical orientation among myctophids and deep-sea smelts in the mesopelagic. Based on his observations and those of others, he speculates that many common diel, migrating fishes are orienting themselves vertically and likely “breathing their way” up and down the water column as they pump water over their gills, producing thrust in the still waters of the mesopelagic. He reasons that this is an adaptive trait in the deep-sea where metabolisms are slow, meals are infrequent, and energy expenditure is at a premium. He also notes that the natural escape response of these fishes immediately disadvantages horizontally towed nets as the fish are vertically oriented, “cocked and primed”, ready for short burst away that evade capture. Barham even opines that the rope-based, vertical trawling protocols of the original deep-sea biology surveys were the reason that the biomass loads of those surveys were so much heavier on average than more contemporary efforts. Barham also noted “unidentified barracudina” from his dives in the *Deepstar*, but unlike the lethargic myctophids, he describes them as being seen “vertically oriented, but in a highly active state”. This would indicate that barracudina are even more likely to evade horizontally oriented trawls, but it also indicates that barracudina are orienting themselves in a similar fashion to the diel, vertical migrators. More recent observations from submersibles have confirmed the tendency for vertical body orientation and described large aggregations of paralepidids in deeper waters (500-750 m)(Janssen et al., 1992; Netburn et al., 2018; Okeanos Explorer cruise EX1705 in 2017 with an image of *Magnisudis atlantica* in head-down position – see Fig. 1). Given these observations, and given that diel vertical migration is only weakly represented by the vertical distributions of certain barracudina in our data, it is likely that barracudina are following the vertical migrators up and down the water column, feeding on them as the “shift changes” occur in the great diel migration at dawn and dusk. This is further supported by the fishes that compose a large portion of the diets of those same species of barracudina and their apparent chronology of feeding. Such speculation, however, would be much more reasonable with accompanying behavioral observations.

In our surveys, both the MOCNESS and HSRT net types were towed in oblique vertical transects, so both horizontal and vertical vectors occurred during sampling. Despite the somewhat vertical orientation, given the data presented here, a degree of net evasion is likely as the largest size classes are missed by the smaller and slower MOCNESS and better represented by the larger, faster HSRT. While this obviously hinders some analysis, this discrepancy could be unintentionally presenting ontogenetic patterns in depth distributions within and among the species. Smaller size classes (i.e. those captured by MOCNESS) could be mild nyctoepipelagic synchronous migrators while larger size classes (i.e. the majority of those captured by the HSRT) are more static in their depth distribution and are found deeper. Since the early days of deep sea exploration, conjecture on the observed relationship between fish size and depth of occurrence has existed. The hypothesis of “bigger is found deeper”, or “Heincke’s Law”, emerged as a causal explanation for observations (Polloni *et al*., 1979). Heincke's "Law" generally states that smaller, larval and juvenile fish are found at shallower depths while larger, mature individuals of the same species are found deeper. It has been argued that this trend can be explained by the physiology of planktonic fish eggs and the requirement of larvae with limited mobility to have access to planktonic food, which is more consistently available in the epipelagic, followed by a vertical descent with age to avoid predation by large epipelagic predators (Sutton, 2013). Research in the 1980s and '90s provided a mixed view of this hypothesis. With some areas and some taxa, it was supported (Gordon & Mauchline, 1996; Koslow *et al*., 1997; Smith and Brown, 2002) and in others it was not (Merrett *et al*., 1991; Stefanescu *et al*., 1992). More recently, physiological modelling with Pacific salmon (*Oncorhynchus spp*.) by Morita *et al*. (2010) demonstrated that ideal growth temperatures for that fish decreased with age hinting to ontogenetically determined habitat preferences (as colder waters are found deeper). Opponents of Hienke's "Law" have often sited sample bias, arguing that larger fish may be more easily caught at depth where visual cues of a trawl's presence are obscured while individuals of the same size closer to the surface are more able to see the net and avoid it than their smaller counterparts lack the swimming strength to follow suite (Haedrich *et al*., 1997; Kaardvedt *et al*., 2012; Handegard *et al*., 2013; Klevjer *et al*., 2016).

The results shown here for barracudina seem to epitomize this debate on "bigger=deeper" as net avoidance is highly likely, but also many of the data clearly show a trend for larger individuals to be found with increasing depth (for example, see Figure 17 on frequency of SL with depth in *Lestidiops affinis*). One could explain these observations from either position: larger individuals could be avoiding all net types in the well-lit shallow waters during the day and could be less able to do so in darker depths and/or at night. Or it could be larger individuals are simply found deeper and the data reflect reality and not sampling bias. It is difficult to make such inferences with certainty given the sample sizes available here and dearth of direct observations. However, compounding evidence for our most data abundant barracudina, *Lestidiops affinis*, indicates that the bigger=deeper hypothesis may be true for at least that species. *Lestidiops affinis* had their greatest abundances consistently documented in the epipelagic/upper mesopelagic, but they occurred commonly throughout the water column, and the largest individuals were more frequently encountered with increasing depth compared with smaller ones (e.g. Figure 17). While some small individuals were documented in deeper nets, indicating that random mixing could have potentially produced these results, the greatest abundances by far occurred in comparatively shallow depths, thus indicating that random mixing is less likely. The basic logic that larger forage fishes (i.e. barracudina) need to live in the depths to avoid visually acute predators (i.e. tuna and billfishes) is potentially supported by the apparent segregation of the larger "scaly" barracudina within the mesopelagic as seen with the above data. The Paralepidinae lack the naturally translucent appearance of the Lestidiinae and Sudinae, which seem to utilize the epipelagic much more than their scaly counterparts, indicating a potential phenotypic basis for vertical niche partitioning among the Paralepididae.

The dietary analysis of adult and subadult barracudina indicates that the sub-families may further partition niches by dietary selectivity. While all barracudina are micro-nektonivores, it appears from these data that a clear distinction exists between the Paralepidinae and the Lestidiinae/Sudinae of the GoMx in terms of prey selection, the former consuming mostly euphausiid shrimps and the latter two consuming almost entirely mesopelagic fishes. Whether this is a product of their respective depth distributions or purely of dietary selection is unclear from the present analysis. The morphological tendency of *Magnisudis* and *Paralepis* to reduce and/or lose dentition over the course of their lives indicates an ontogenetic reduction in piscivory and an increased reliance on smaller prey types, such as shrimps, with age. The teeth of Lestidiinae and Sudinae remain comparatively large and sharp throughout their lives, indicating sustained piscivory. This view is supported by the findings here, although the sample sizes are too low to extend this conclusion to each species found. Given the lowest taxonomic identities of the prey fishes found in the Lestidiinae specimens examined, it is likely that these species are targeting the migrating myctophids, photichthyids, gonostomatids, etc. as they pass through the lower epipelagic. Furthermore, as previously mentioned, it is likely that they are picking off these migrators in the dawn hours given that most of the identifiable stomach contents and full stomachs were collected from specimens caught in solar day trawls. Meanwhile, the strictly mesopelagic Paralepidinae species (namely *Magnisudis atlantica*) appear to have no apparent relationship between stomach fullness and time of day, indicating that solar periodicity has little influence on their feeding behavior.

Table 13 – Species by category of general vertical distribution and likely spawning pattern. A * indicates that not enough data were available to make a definitive conclusion on spawning periodicity but there were some to speculate on.

	Epi - upper mesopelagic	Mesopelagic
Seasonal spawning	*Sudis hyalina* *Stemonosudis bullisi**	*Magnisudis atlantica* *Paralepis brevirostris**
Year-round spawning	*Lestidiops affinis* *Lestidium atlanticum* *Lestrolepis intermedia**	-

Table 14 – Species by category of general vertical distribution and general dietary habit.

	Epi - upper mesopelagic	Mesopelagic
Mesopelagic fish diet	*Lestidiops affinis* *Lestidium atlanticum* *Lestrolepis intermedia*	-
Euphausiid shrimp diet	-	*Magnisudis atlantica* *Paralepis brevirostris*

The reproductive and ontogenetic analyses reported in this work were opportunistically added, with distribution and standard-length data allowing the assessment of potential ontogenetic distinctions in habitat preference. The presence of large, pigmented eggs found during gut surveys offered the opportunity to construct a rough estimate of size-at-maturity for some species. While a gonado-somatic index would have been more precise regarding this last consideration, it was not convenient since the gut survey protocol implemented here was originally designed to only assess gut contents and not size-at-maturity and specimens had been preserved in ethanol for many years prior to dissection, possibly altering the relative masses of certain tissues. Furthermore, specimens without mature eggs had extremely small, underdeveloped gonads which barely registered on the scale that was employed, which was accurate to 0.01 grams.

Despite these limitations, however, these findings represent the most extensive treatment of size-at-maturity recorded for any barracudina species, as far as this author is aware.

Given these post-hoc considerations of the reproductive/ontogenetic data, some patterns are apparent and, again, appear largely divided by the major sub-family groupings. The various species of Lestidiinae appear to be year-round spawners whose abundances increase appreciably in the spring and summer months. These species have evidence of multiple size classes co-existing during all seasons (e.g. *Lestidiops affinis*; see Figure 17).

The Paralepidinae, on the other hand, (mostly represented by *Magnisudis atlantica* in these data) are distinctly seasonal spawners, with certain size classes appearing distinctly at certain seasons (see Figure 47). With *M. atlantica*, it appears that spawning may occur during the winter or spring months with the greatest abundances of the smallest specimens being almost exclusively collected in the spring. However, the presence of large, pigmented eggs was only documented in adults collected during the spring and summer months. Whether this indicates that spawning is occurring in summer as well as winter, that growth rates of the smallest size classes are slow in this species, or that this species is being continuously imported from waters elsewhere is unclear. However, if this seasonal spawning has an underlying ecological strategy for this species it is likely to increase the exposure of juvenile individuals to abundant crustacea, their apparent food selection, during the months of highest primary production.

The Sudinae species appear to be seasonal spawners as well but with a possible trend toward spawning in summer with the statistically greatest abundances of smaller size classes being collected during the winter months. However, as with many of these findings, restrictions of the data limit the confidence that can be placed on such inferences.

In sum, the major findings of this work are as follows: 1) the Lestidiinae and Sudinae sub-families share mesopelagic fishes as prey and likely benefit from vertical migrators descending at day, while the Paralepidinae tend to be eating mostly Euphausiid shrimps without any distinct feeding chronology; 2) the Lestidiinae, Sudinae and Paralepidinae, respectively, occupy distinct depth strata while the entire water column is occasionally frequented by the more common Lestidiinae and both species of Sudinae; 3) the three sub-families appear to have slight differences in the seasonal timing of their reproduction; 4) larger individuals of some species (e.g. *Lestidiops affinis*) are more likely to be found deeper while abundances are greatest shallower; 5) net evasion is prevalent among all barracudina species (as evidenced by the difference in frequency of SL by gear type) but the degree to which net evasion occurs likely does not greatly impact estimations of abundance for most species; 6) the geographic extents of several barracudina species are greater than previously known; 7) far fewer species and lesser abundances were collected in the years following 2011 than were in 2011. The implications of these various findings are at least applicable to the Gulf of Mexico common water if not beyond. The utility of describing the ecology of these obscure, but ubiquitous, fishes is likely to become increasingly apparent as valuable mesopelagic fisheries, such as swordfish and big eye tuna, are exposed to increasing pressures and concerns begin to extend to the sustainability of the ecosystems which support those economically valuable fishery targets.

Ecosystem-Based Management (EBM) and Ecosystem Approaches to Fisheries (EAF) have now had a decades long appeal as alternatives to the frequently inadequate single-species based approaches historically implemented by fishery managers (Cury & Christensen, 2005; Collie *et al.*, 2014). However, successful implementation is rare and complex, and EAF is frequently confounded by numerous intrinsic difficulties (Cury & Christensen, 2005; Collie *et al.*, 2014), not least of which is a prevailing lack of knowledge regarding even the most basic aspects of life histories within and among ecologically important taxa, such as mesopelagic forage fishes (St. John, et al., 2016). Critical to successful implementation of EBM/EAF is the development and delineation of suites of indicator taxa that accurately reflect the progress of previously defined management goals (Cury & Christensen, 2005; Link, 2005; Collie *et al*., 2014). EAF goal formation is usually complex and often expressed in indices or gradients based on a host of indicator taxa rather than as binary decision criteria for a single taxon (Link, 2005). An unfortunate side-effect of this approach is that EAF is almost always conservative in the sense that only surveillance, and not prediction, is feasible and goal success or failure is only coherently indicated if ecosystems are strongly impacted by perturbations or management changes (Cury & Christensen, 2005).

To reduce the complexities of EBM/EAF and enhance the databases informing it, indicator taxa are usually suites of abundant types that can be easily quantified and whose natural histories are well understood and discretely connected to structural elements of the ecosystem in question, such as phytoplankton (Platt & Stathyendranath, 2008) or waterbirds (Ogden *et al*., 2014) in coastal marine systems. In the pelagic realm, size-based indicators of common fishery target taxa are the contemporary method of indication (e.g. the frequency of the largest tunas caught indicates the state of stocks). While single-species indicators have received considerable attention, analysis of single-species vs. ecosystem harvest strategies shows that there is likely a need to provide explicit protection for those species whose value derives in part from support of other species as well as from harvesting (Cury & Christensen, 2005), which could soon encompass mesopelagic forage fishes as fish oil markets expand (St. John *et al*., 2016). However, many factors complicate the use of deep-sea forage fishes as indicator taxa beyond the apparent difficulty in sampling. These include the potential for competition of resources between early stages of large fishes with forage fishes, the unpredictable influences of climate on forage fish abundances, and poorly understood life histories for most taxa (Therriault *et al*., 2009; Budge *et al*., 2014; St. John *et al*., 2016). As such, successful EAF in deep pelagic fisheries will require accurate identification of as many mesopelagic taxa as possible, relevant understandings of their respective life histories, and explicit knowledge of their interrelationships with other functional components of the ecosystem. This is a daunting task, especially given the extremely remote and vast nature of the open oceans. Barracudina, while not as common as other deep pelagic varieties, are frequently found in the stomachs of fishery target taxa which may lend them special status as indicators. The overall ubiquity but localized rarity of barracudina make them especially suited as EBM indicator criteria, acting as the proverbial “canaries in the coal mine” for deep mid-waters.

As shown in the present work, the varieties of barracudina exhibit subtle differences in life history and abundances which could be used to infer the state of the greater pelagic ecosystem, and, because they can be sampled from the guts of large predatory taxa, sampling for EAF could be simplified with respect to fishery targets. However, specimens sourced from stomachs may be degraded reducing the taxonomic resolution needed to make inferences on the ecosystem. Recent efforts (Choy *et al*., 2013; Choy & Drazen, 2013) in gut surveying lancetfishes (*Alepisaurus* spp.) are promising because those fishes have extremely slow rates of digestion and very little dietary selectivity. Furthermore, barracudina are a common food item for lancetfish and lancetfish are a common bycatch in longline fisheries; the Alepsauroidei clade may yet provide a ready suite of indicators for EBM/EAF that is much more accessible to researchers and managers than other methods of surveying the deep pelagic. Regardless of these hypothetical surveying potentials, EAF will necessarily require continued fishery independent sampling and trawling to characterize the ecosystem itself and provide a baseline status to compare with. Precise vertical distribution data is especially important to fisheries managers (Loeb, 1986) and is not easily replicated by any other available methods or technology at this time. Simply having baseline abundance and ecological knowledge of the various barracudina species available will be useful to EAF in explicating ecosystem relationships that pertain to the sustenance of large, migratory predators.

To complicate matters further, advances in genetic surveying methods have illuminated previously overlooked intraspecific diversity among pelagic fish populations previously thought to be homogenous (Bickford *et al*., 2007; Ward *et al*., 2008; Andrews *et al*., 2016). The implications of this to EBM/EAF could be that ecologically important variations in natural history are being overlooked simply through misidentification. Even before cryptic speciation and overlooked metapopulation diversity was explicated by genetic findings, community analysis of deep water ecosystems hinted to a high degree of multi-dimensional niche partitioning facilitated by subtle variations in feeding ecology within and between ocean basins (see Hopkins *et al*., 1996; Robison *et al*., 2010; Ross *et al*., 2012). Furthermore, recent modelling efforts support the notion that demographic heterogeneity and intraspecific diversity are likely important to the persistence of metapopulations among pelagically dispersed taxa (Shima *et al.*, 2015). While the over-arching functional group of "forage fishes" is key to healthy pelagic fisheries and ecosystems, understanding the subtle variations within and among populations of forage fishes is likely critical to understanding the persistence and resilience of that functional group itself on a regional basis and should be considered in future such efforts.

Chapter Five: Conclusion

The findings published here represent a regional synthesis on a ubiquitous yet poorly studied mesopelagic fish group that has well-known trophic relationships with economically important, pelagic fishery targets. The hope is that this work will be a resource on basic life history information for abundances at depth, time of day, and time of year as well as dietary habits, reproductive timing and ontogeny, information that is crucial to informing future assessment and modelling efforts. Additionally, because barracudina are often difficult to identify to species or even genus, this work aims to provide a convenient resource to managers in their identification.

In the case of barracudina, much ecological information remains obscured and further work with this group may help to produce useful products for ecosystem-based management of the pelagic Gulf of Mexico. Much additional work is required to explicate further details on the topics defined here. Such future work could include, but would not be limited to, stable isotopic analysis to assess dietary patterns further; genetic barcoding to determine interspecific variation and the potential for mis-identification of cryptic species; congruent surveys of the gut contents of tuna and swordfish in the area, to assess the overlap of species collected by fishery independent sampling in the Gulf of Mexico and those collected in the guts of fishery targets in the Gulf of Mexico. This work will constitute an important first step toward better understanding barracudina in the Gulf of Mexico, specifically, and perhaps in tropical/subtropical waters, globally.

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