MARINE CAVES OF THE EASTERN MEDITERRANEAN SEA BIODIVERSITY, THREATS AND CONSERVATION

Edited by
Bayram ÖZTÜRK

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OF THE EASTERN MEDITERRANEAN SEA
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ISBN: 978-975-8825-45-5

Citation: Öztürk, B. (Ed.) 2019. Marine Caves of the Eastern Mediterranean Sea. Biodiversity, Threats and Conservation. Turkish Marine Research Foundation (TUDAV) Publication No: 53, Istanbul, Turkey. 258 pages.

Cover photo: © Adnan BÜYÜK

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Printed: Ekaform Matbaa Reklam Ajans
Org. San. Ve Tic. Ltd. Şti.
Esenkent Mah.Azade Sok. No: 1 Ümraniye, İstanbul
E-mail: info@ekaform.com
www.ekaform.com
Certificate no: 41753
Publication place: İstanbul
Publication year: 2019

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FOREWORD

Underwater caves are ‘natural cavities big enough to permit direct exploration by man’. Dark underwater caves are lightless enclaves of the marine environment, with lighting less than 0.01% and a fairly confined space, are often reservoirs of unknown biodiversity and refuges for generally very non-resilient communities.

Underwater caves are specific entities easily accessible because of their often-shallow depth and their nearness to the coast. Also, the caves, at least in their ‘semi-dark’ parts, constitute landscapes of high aesthetic or archaeological value and are therefore often visited, leading to mechanical harm particularly from divers. Using destructive methods (e.g. dynamite) in coastal development work is likely to significantly affect these habitats.

Underwater caves are particularly well represented in all the rocky karst or fractured coastlines and are probably very widespread at Mediterranean level. Although we do not have an exhaustive view of the situation, the Parties to Barcelona Convention adopted in 2013, the Regional Action Plan[1] commonly named “Dark Habitat Action Plan” to:

- conserve the habitats’ integrity, functionality (favourable state of conservation) by maintaining the main ecosystem services (e.g. carbon sink, halieutic recruitment and production, biogeochemical cycles) and their interest in terms of biodiversity (e.g. specific diversity, genetics),
- encourage the natural restoration of degraded habitats (reduction of human origin impacts)
- improve knowledge about dark populations (e.g. location, specific richness, functioning, typology).

As far as the Mediterranean European states are concerned, caves are natural habitats that come under Habitat Directive on the conservation of natural habitats and of wild fauna and flora and appear as such as priority habitats requiring protection (Directive 92/43).

To give greater efficacity to the measures envisaged for setting up the present Action Plan, the Mediterranean countries are invited to elaborate national plans for the protection of dark assemblages. Each national plan must bear in mind the specific features of the country and even the areas concerned. It must suggest appropriate legislative measures, particularly as regards impact studies for coastal development and to check the activities that can affect these

[1] Action Plan for the conservation of habitats and species associated with seamounts, underwater caves and canyons, aphotic hard beds and chemo-synthetic phenomena in the Mediterranean Sea

assemblages. The national plan will be drawn up on the basis of the scientific data available and will include programmes for: (i) gathering and continuous updating of data, (ii) training and retraining for specialists, (iii) education and awareness for the public, actors and decision-makers, and (iv) the conservation of dark populations that are significant for the marine environment in the Mediterranean. These national plans must be brought to the attention of all the concerned actors and as far as is possible coordinated with other pertinent national plans (e.g. emergency plan against accidental pollution).

In this context SPA/RAC is supporting the organisation of the national workshop on the marine cave habitats in turkey in line with the Dark habitat Action Plan and the Medkeyhabitats II[2] project financed by MAVA foundation.

Khalil ATTIA
SPA/RAC Director

[2] http://www.rac-spa.org/medkeyhabitats2

PREFACE

Turkey is surrounded by four different seas as a peninsula country and contains several hundreds of caves around it. The action plan for the conservation of habitats and species associated with seamounts, underwater caves and canyons in the Turkish part of the Mediterranean Sea is quite a new issue.

Because of limited data available for dark habitats which are very peculiar ecosystems and lack of experts is the main problem. Some fragmented information exists mainly about the monk seal caves in the Aegean and Mediterranean part of Turkey, but it presents far from a whole picture.

Besides, Dark Habitat Action Plan was also adopted in Istanbul in 2013 during the 18th Ordinary Meeting of the Contracting Parties to the Barcelona Convention. In addition, marine caves are considered as habitats of high priority in the Mediterranean Sea, i.e. EU Habitat Directive (92/43/ EEC).

Moreover, dark habitats in the eastern Mediterranean Sea are under human pressure, such as intense tourism, pollution, oil spill, ghost fishing, alien species and so on. Consequently, we organised first national workshop on dark habitats in Turkey on 13 December 2019.

Turkish Marine Research Foundation is pleased to publish this book with various aspects of the dark habitats with imminent experts from various countries along the eastern Mediterranean Sea. I am also very pleased to realize my dream for many years which is taking care of cave biodiversity. In my book titled "Marine Essays (Deniz Yazıları)" published in 2011, I underlined marine caves and their importance for marine biodiversity of Turkey.

I congratulate all the authors and reviewers who contributed to this first and very unique book about marine caves in all around the eastern Mediterranean Sea. At last but not least my sincere thanks are due to SPA/RAC for their financial support.

Beykoz, İstanbul, 2019
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Öztürk B. (Ed.) 2019. Marine Caves of the Eastern Mediterranean Sea. Biodiversity, Threats and Conservation. Turkish Marine Research Foundation (TUDAV) Publication no: 53, Istanbul, Turkey.

Mediterranean marine caves: a synthesis of current knowledge and the Mediterranean Action Plan for the conservation of "dark habitats"

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Introduction

The Mediterranean Sea is a hotspot for marine biodiversity and ranks among the most important of such regions worldwide although much research remains to be done to assess and monitor the biodiversity it supports, and to better understand its marine ecosystems. Despite numerous national and international programs of research on the flora and fauna of the Mediterranean Sea, its biodiversity still remains insufficiently studied. The description of new species, especially of invertebrates from poorly known groups or from groups which thrive in habitats that are difficult to explore such as the deep sea and marine caves, is an ongoing process and new discoveries continually add to previous estimates of overall Mediterranean species diversity. In particular, increased effort to study the species diversity and the ecology of poorly known habitats is required, as are long-term monitoring programs of marine species and habitats.

Underwater caves are 'natural cavities big enough to permit direct exploration by man'. Dark underwater caves are lightless enclaves of the marine environment, with lighting less than 0.01% and a fairly confined space.

In recent decades, systematic surveys of dark littoral submarine caves have received particular attention from the scientific community. The particular environmental conditions of these habitats, including the absence of light, oligotrophy, and reduced hydrodynamic action, make dark submarine caves enclave mesocosms of the deep aphotic zone in shallow coastal areas. In this respect, marine caves mimic the deep sea and therefore conveniently serve as natural laboratories and render unique opportunities for researchers to access organisms and processes that are otherwise very difficult to study. Dark underwater caves are often considered as reservoirs of unknown biodiversity and refuges for generally very non-resilient communities.

Furthermore, marine caves harbour rare species that are unique to such habitats. Due to their relatively small size and ease of accessibility, environmental stability, and presence of communities of endemic and specialized species dark submarine caves are excellent model habitats to address important ecological and evolutionary questions such as the influence of life cycle and habitat fragmentation on gene flow.

Overall, therefore, Mediterranean marine caves are of high ecological, scientific and conservation importance, yet the available information on cave ecosystems and their component species and conservation status is limited, which hinders effective monitoring and management.

The following elements are based on the desktop study (UNEP-MAP-SPA/RAC 2019), with modification, prepared for the regional Activity centre For Specially Protected Areas (SPA/RAC) by Gerovasileiou V. & Bianchi C.N. in the framework of the Medkeyhabitats II project financed by MAVA Foundation[1].

Distribution

Rocky substrates constitute more than half (54%) of the Mediterranean coastline with limestone being one of their most characteristic components. Through time, the ongoing geodynamic processes (e.g. karstic phenomena) in this semi-enclosed sea have resulted in the formation of a high number of more or less complex marine and anchialine cave systems. According to the latest census, approximately 3,000 marine caves (semi- and entirely submerged) have been recorded in the Mediterranean basin to date (Figure 1). Most of these caves (97%) are located in the North Mediterranean, which encompasses a higher percentage of carbonate rocky coasts and has been more extensively studied for this particular habitat type. Specifically, the highest numbers of known marine caves are located in the Eastern Adriatic, Aegean, Tyrrhenian, Provencal and Ionian coasts (Table 2.1), where they are sometimes densely concentrated in insular areas and rocky peninsulas (e.g. Aegean Archipelago, Croatian and Balearic Islands, and Corsica). At local or regional scales, detailed mapping initiatives have taken place in Italy, Corsica, Croatia and Greece. In addition, expeditions in the framework of the research projects MedKeyHabitats, MedMPAnet and LIFE BaĦAR for N2K have recently provided information on the distribution of this habitat type in previously understudied Mediterranean areas. However, given the logistic constraints involved in the inventorying of underwater caves, and especially

[1] http://www.rac-spa.org/medkeyhabitats2

the submerged ones, their number is assumed to be much higher at both Mediterranean and regional scales, and mapping efforts are required in order to fill current distribution gaps in the Eastern and Southern Mediterranean regions.

Detailed guidelines for the inventorying of dark habitats, including marine caves, have been recently provided by SPA/RAC-UN Environment/MAP& OCEANA (2017).

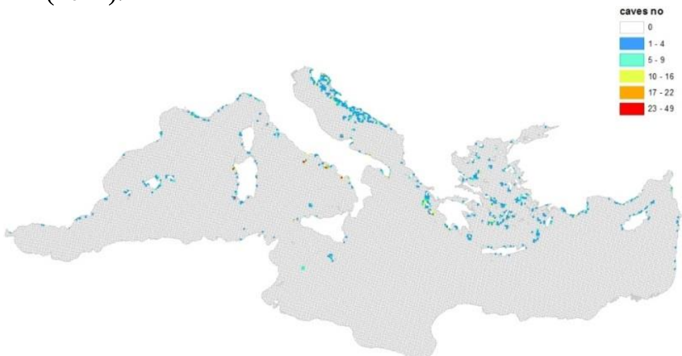

Figure 1. Distribution of marine caves in the Mediterranean Sea. Different colours indicate the number of caves recorded in cells of 10 x 10 km (modified from Giakoumi *et al.* 2013).

The majority of existing marine cave records corresponds to shallow and/or semi-submerged caves, with a depth that rarely exceeds 15 m, which are generally easier to spot and access by both scientists and recreational divers. Information about deeper caves in the existing scientific and grey literature is limited, with only a small number of marine caves studied for their biota, having a maximum depth of 30-40 m. However, in several cases bathymetric data are lacking. The recent study of deeper areas with the use of Remotely Operated Vehicles (ROVs) has shown that hard substrates in deeper waters can also bear large overhangs and cavities.

Table 1. Number of marine caves recorded by Mediterranean ecoregion (according to Giakoumi *et al.* 2013; Sini *et al.* 2017 and data from MedKeyHabitats project).

Mediterranean Ecoregion	**Number of marine caves**
Alboran Sea	24
Algero-Provencal Basin	459
Tyrrhenian Sea	581
Tunisian Plateau/Gulf of Sidra	68
Adriatic Sea	708
Ionian Sea	307
Aegean Sea	622
Levantine Sea	209

Table 2. Number of studies and marine caves by Mediterranean area and taxonomic group. AL, Alboran Sea; CC, Catalan coast; BS, Balearic Sea; SS, Sardinian Sea; FC, French Coast; LS, Ligurian Sea; TS, Tyrrhenian Sea; TC, Siculo-Tunisian Strait; AN, North Adriatic; AS, South Adriatic; IS, Ionian Sea; NA, North Aegean; SA, South Aegean; LB, Levantine Basin; CE, Cave entrance zone; SD, Semi-dark cave zone; D, Dark cave zone. Updated from Gerovasileiou & Voultsiadou (2014).

Taxonomic group	**Mediterranean areas**														**Cave zone**			**Number of studies**	**Number of taxa**	**Proportion of Mediterranean diversity (%)**
	AL	**CC**	**BS**	**FC**	**LS**	**SS**	**TS**	**TC**	**AN**	**AS**	**IS**	**NA**	**SA**	**LB**	**CE**	**SD**	**D**			
Bacteria							+		+							1	10	7	12	-
Bacillariophyceae							+										5	1	5	0.7
Foraminifera		+	+	+		+	+				+	+	+		7	8	10	18	90	15
Myzozoa											+					1	1	1	1	-
Ciliophora											+				11	16	15	2	20	-
Radiozoa											+				2	2	2	1	2	-
Phaeophyceae			+	+	+	+	+	+	+		+	+	+		33	2		19	33	12.2
Chlorophyta		+	+	+	+	+	+	+	+	+	+	+	+		27	4		24	27	14.2
Rhodophyta		+	+	+	+	+	+	+	+	+	+	+	+	+	169	30		31	169	25.7
Porifera	+	+	+	+	+	+	+	+	+	+	+	+	+	+	137	213	189	160	329	48
Hydrozoa		+	+	+	+	+	+	+	+		+			+	49	60	17	33	108	23.6
Scyphozoa		+	+						+			+			2	2	1	2	4	20
Anthozoa	+	+	+	+	+	+	+	+	+	+	+	+	+	+	24	26	25	87	49	29.7
Ctenophora					+							+				1		3	1	3.3
Platyhelminthes							+		+			+			3	4	3	2	36	4
Nemertea							+		+		+				3	3	3	2	9	5.2
Nematoda																		3	37	5.3
Rotifera																		1	2	3.4
Kinorhyncha							+		+									1	1	3.6
Priapulida											+						1	1	1	20

Table 2. Continued

Gastrotricha										+	+						16	2	16	9.7
Entoprocta				+					+		+						2	4	4	21.1
Copepoda			+	+		+			+		+				49	38	53	17	113	28
Ostracoda				+			+									1	2	4	8	1.6
Cirripedia				+	+		+		+		+				1	1	4	13	7	17.5
Decapoda	+	+	+	+	+	+	+	+	+		+	+	+	+	23	43	34	42	73	19,1
Mysida		+	+	+	+	+	+	+	+	+	+		+		6	6	7	22	21	20,6
Thermosbaenacea			+														1	1	1	20
Facetotecta											+							1	1	-
Tanaidacea	+			+			+		+			+				3	4	6	6	14
Pentastomida											+						1	1	1	-
Isopoda	+			+			+		+		+	+			2	7	6	11	15	9,1
Leptostraca			+														1	2	1	16,7
Amphipoda	+	+	+	+	+		+					+			26	59	30	18	83	18.5
Cumacea	+			+			+									2	5	6	6	6.1
Branchiopoda											+				3	4	3	1	4	-
Pycnogonida				+			+								1	3	1	3	9	20
Acari							+											2	5	-
Insecta (marine)											+				1	1		1	1	0.4
Oligochaeta							+											4	2	-
Polychaeta	+	+	+	+	+	+	+	+	+		+	+	+	+	86	186	113	63	262	23.3
Sipuncula				+			+		+			+			2	5	3	9	6	16.7
Echiura			+		+				+			+			1		1	3	1	16.7
Polyplacophora				+			+								5			7	7	22.6
Gastropoda		+	+	+	+		+	+	+		+	+	+	+	68	76	39	37	134	8.6

Table 2. Continued

Bivalvia		+	+	+	+	+	+	+	+		+	+		+	31	41	29	42	90	22.5
Caudofoveata							+									1		1	1	3.4
Cephalopoda					+				+			+			3	2		3	3	4.6
Tardigrada				+			+			+	+						1	3	31	40.3
Bryozoa	+	+	+	+	+	+	+	+	+		+	+	+	+	121	168	132	60	228	41
Brachiopoda	+	+	+	+	+	+		+	+	+		+		+		7	8	20	9	64.3
Phoronida												+			1			1	1	20
Chaetognatha				+		+					+				1	1	5	3	5	25
Pterobranchia				+													1	1	1	20
Echinodermata		+	+	+	+		+	+	+		+	+	+		17	21	17	29	35	22.7
Tunicata		+	+	+		+	+	+	+		+	+	+	+	24	24	13	34	44	19.2
Pisces		+	+	+	+	+	+	+	+	+	+	+	+	+	45	46	29	40	96	14.8
Mammalia	+										+	+	+	+	1	1	1		1	4.3
Number of studies	12	15	31	87	21	12	67	17	28	15	40	24	16	27				**312**		
Number of caves	12	4	31	47	25	16	58	18	27	27	41	11	36	17						
Number of taxa	**70**	**287**	**408**	**670**	**141**	**252**	**897**	**180**	**383**	**154**	**711**	**314**	**161**	**178**	**985**	**1120**	**844**		**2267**	**13.3%**

Biodiversity

From the first pioneer biological studies in Mediterranean marine caves it became evident that they harbour rich benthic communities and several previously undescribed species. The historical monograph “Biologie der Meereshöhlen” by the Austrian zoologist Rupert Riedl (1966), which provided a first synthesis of existing knowledge, listed a total of 905 taxa from Mediterranean marine caves, estimating that the overall diversity could reach 2000 species. Many of these taxa (529 taxa belonging to 32 major groups) were recorded during the “Tyrrhenia-Expedition”, which focused mostly in marine caves of the Tyrrhenian Sea. Some decades later, a monograph on the existing information on marine caves of Italy, including chapters on different taxonomic groups, was published by Cicogna *et al.* (2003). More recently, a number of reviews, meta-analyses, checklists, and large-scale surveys on marine cave biota were published for particular taxa, such as sponges and fishes for the entire Mediterranean or particular regions.

Overall diversity and regional patterns

The overview of 312 literature sources (peer-reviewed and grey literature) showed that 2267 taxa belonging to 58 taxonomic groups were reported from ≈350 marine caves (mostly semi-submerged and/or shallow) in 15 Mediterranean countries (Gerovasileiou and Voultsiadou 2014). However, as expected, not all Mediterranean areas and taxonomic groups have received the same effort. The majority of the caves studied (93%) were located in the Northern Mediterranean coasts, with Italy, France, and Spain being the main countries where marine cave research has taken place (121, 86 and 52 studies, respectively).

Sponges were by far the most well-studied group (160 studies), followed by anthozoans (87), polychaetes (63), bryozoans (60), decapods (42), bivalves (42) and fishes (40) (Table 2). Very few studies examined microbes, planktonic taxa and miscellaneous “small” groups, such as soft substrate meio- and macrofauna. The number of species per taxonomic group and marine area were positively correlated to research effort, expressed as the number of studies and caves explored. Research in a greater number of marine caves in different Mediterranean areas is expected to lead to an increment in the number of known species, particularly within “inconspicuous” groups.

Most taxa were reported from the semi-dark zone of marine caves (1120), followed by the entrance (985) and the dark zone (844) while for 510 taxa the zone was not specified in the literature sources (Table 2). Macroalgae (mostly rhodophytes) dominated in terms of species richness in the entrance zone (23% of the species) while sponges dominated in the semi-dark and dark zones (19% and 22.4%, respectively). Bryozoans and polychaetes were also among the richest groups in all zones. A total of 332 taxa were recorded in sediments of the cave bottom and 53 taxa in anchialine/marginal caves.

Conservation Value & Current Threats

Conservation value

Marine caves are acknowledged as "refuge habitats" or "biodiversity reservoirs" of great conservation value, harbouring a rich biodiversity (40-65% of the Mediterranean sponge, bryozoan, tardigrade and brachiopod diversity), including a considerable number of rare, cave-exclusive, endangered, protected, and deep-sea species (Gerovasileiou and Voultsiadou 2012; 2014). Among the most emblematic species dwelling in this habitat type, are the Mediterranean monk seal *Monachus monachus* and the red coral *Corallium rubrum*, both listed as endangered (EN) in the IUCN Red List of Threatened Species. The monk seal shelters in coastal caves with internal beach and gives birth and raises its pups almost exclusively in this habitat. The red coral has been traditionally considered a typical species of the semi-dark cave biocoenosis, where it can form dense facies. Recent studies have suggested that the cave habitat provides natural protection from possible human induced disturbances, as shown by the finding of abundant and healthy populations, compared with exposed habitats. Several other protected species listed in Annex II of the Bern Convention and the SPA/BD Protocol of the Barcelona Convention, are commonly found in caves, such as the orange coral *Astroides calycularis*, the gastropods *Erosaria spurca* and *Luria lurida*, the date mussel *Lithophaga lithophaga*, the hatpin urchin *Centrostephanus longispinus*, the slipper lobster *Scyllarides latus* and the brown meagre *Sciaena umbra*. In addition, all protected sponges are also found in caves, including the deep-water species *Lycopodina hypogea*, which was first described from the famous 3PP Cave of Marseille, and typical cave-dwelling species, such as the relict calcareous sponge *Petrobiona massiliana*. The four Mediterranean bath sponges, listed in Annex III of the Bern and Barcelona Conventions have been reported from numerous marine caves.

Several benthic taxa are considered, so far, exclusive to this key habitat; most of these are recorded from a small number or only from a single marine cave, although future research could show that some could be also distributed in other cryptic or deep-sea habitats. Thus, marine caves have been characterized as "natural laboratories" or "deep-sea mesocosms" in the littoral zone, because they provide direct human access to bathyal-like conditions in the scuba diving zone. In addition to the cave-exclusive and deep-sea faunal elements, marine caves harbour a considerable percentage of the total Mediterranean endemic fauna. This does not only concern sessile taxa, but motile fauna as well, such as the rare gobids *Corcyrogobius liechtensteini*, *Didogobius splechtnai*, *Gammogobius steinitzi* and *Speleogobius trigloides*, which dwell in marine caves and other cryptic habitats.

The presence of caves in rocky coasts has been suggested to provide additional resources for fishes (e.g. food availability, refuge against predators, sand patches within a rocky matrix) compared to rocky reefs without caves, thus affecting local species richness and distribution patterns (Bussotti and Guidetti 2009; Bussotti *et al.* 2015). Several fishes and crustaceans which seek for shelter in marine caves (e.g. during cold seasons) or use them occasionally as nursery habitats, are of commercial interest.

The rich and unique biodiversity of marine caves, coupled with their geomorphological complexity and high aesthetic value, make them popular “hot-spots” for marine-based recreational activities, such as boat tours, snorkelling and SCUBA diving throughout the Mediterranean basin. In addition, a number of marine caves were found to present paleontological, archaeological and paleo-climatological interest.

For all the above reasons, marine caves are protected by the EU Habitats Directive (92/43/EEC – habitat code 8330 “Submerged or partially submerged sea caves”) and, at the Mediterranean level, under the “Action Plan for the conservation of the coralligenous and other calcareous bio-concretions” [2] (UNEP-MAP-RAC/SPA 2008) and the “Dark Habitats Action Plan” for the conservation of habitats and species associated with seamounts, underwater caves and canyons, aphotic hard beds and chemo-synthetic phenomena in the Mediterranean Sea of the Barcelona Convention (UNEP-MAP-RAC/SPA, 2013). The number of marine caves included in Marine Protected Areas (MPAs) is unknown, although the habitat is represented in 33 Mediterranean MPAs (Abdulla *et al.* 2008).

Threats and impacts

Marine caves are fragile ecosystems, vulnerable to both natural and human disturbances. Severe storm waves can occasionally reach the inner parts of the caves, bringing in sediment and detritus and abrading walls and ceilings, thus causing mortality of the cave-dwelling organisms. Marine heat waves, which cannot be considered as a natural disturbance, as the present sea water warming is mostly of anthropogenic origin, have been shown to cause important modifications on both the motile and the sessile components of the cave community (Parravicini *et al.* 2010; Sempere-Valverde *et al.* 2019.

Despite being difficult to access, when compared to open sea habitats, there is increasing evidence of local impacts caused by human activities, such as illegal red coral harvesting, spearfishing (e.g. *Sciaena umbra* and *Phycis phycis*),

[2] Coralligenous and semi-dark cave communities have been integrated into the Action Plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea (UNEP-MAP-RAC/SPA 2008).

urbanization and construction of coastal structures, waste outflows, litter and multiple unregulated visits by tourist boats and divers (Giakoumi *et al.* 2013).

Sessile benthic communities in marine caves have low recovery potential, since the development of communities in a "mature" state could take more than a decade (Harmelin *et al.* 1985; Rastorgueff *et al.* 2015). Several sessile invertebrates with erect morphologies, as well as their bioconstructions, are slow-growing, fragile, and thus highly vulnerable to mechanical damages caused by unintentional contact with divers, which are more likely to happen in caves and overhangs. Sediment re-suspension and accumulation of exhaled air bubbles at the cave ceiling can be also have detrimental effects on sessile filter feeders. Coastal constructions (e.g. jetties) alter sediment transport and may cause sediment deposit in the innermost part of the caves, with consequent suffocation of the encrusting fauna (Nepote *et al.* 2017; Montefalcone *et al.* 2018).

An additional potential threat to Mediterranean marine cave communities is related to the continuous spreading of non-indigenous species, especially in the eastern and southern regions (Gerovasileiou *et al.* 2016). A total of 56 non-indigenous (NIS) and cryptogenic taxa have been reported so far from approximately 50 marine caves and tunnels of the Mediterranean, including molluscs (15), cnidarians (9), bryozoans (7), polychaetes, crustaceans (6), macroalgae, fishes (3) and tunicates (2). Most of these taxa (66%) were found in caves of the South-eastern Levantine Sea, with shipping and Lessepsian migration through Suez Canal being their main pathways of introduction. These taxa were mostly reported from the entrance and semi-dark zones of shallow and semi-submerged caves and tunnels. The impacts of these taxa on native cave dwellers have not been investigated to date. Nevertheless, their presence in most studied marine caves of the Levantine Sea, and the population explosion of alien fishes (e.g. *Pempheris rhomboidea*) in caves of this area should be further studied and monitored.

The "Dark Habitats Action Plan" for the conservation of habitats and species associated with seamounts, underwater caves and canyons, aphotic hard beds and chemo-synthetic phenomena in the Mediterranean Sea of the Barcelona Convention

The Parties to Barcelona Convention adopted in 2013 a regional Action Plan for the conservation of habitats and species associated with seamounts, underwater caves and canyons, aphotic hard beds and chemo-synthetic phenomena in the Mediterranean Sea commonly named "Dark habitat action Plan"**.** Although they do not have a binding legal character, the Action plan as regional strategies setting priorities and activities to be undertaken. In particular, it calls for greater solidarity between the States of the region, and for co-ordination of efforts to protect the species in question. This approach has been proved to be necessary to ensure conservation and sustainable management of the concerned species in every Mediterranean area of their distribution.

The objectives of the Action Plan are to:

- conserve the habitats' integrity, functionality (favourable state of conservation) by maintaining the main ecosystem services (e.g. carbon sink, halieutic recruitment and production, biogeochemical cycles) and their interest in terms of biodiversity (e.g. specific diversity, genetics);
- encourage the natural restoration of degraded habitats (reduction of human origin impacts);
- improve knowledge about dark populations (e.g. location, specific richness, functioning, typology).

To give greater efficacy to the measures envisaged for setting up the present Action Plan, the Mediterranean countries are invited to craft national plans for the protection of dark assemblages. Each national plan must bear in mind the specific features of the country and even the areas concerned. It must suggest appropriate legislative measures, particularly as regards impact studies for coastal development and to check the activities that can affect these assemblages.

The national plan will be drawn up on the basis of the scientific data available and will include programmes for: (i) gathering and continuous updating of data, (ii) training and retraining for specialists, (iii) education and awareness for the public, actors and decision-makers, and (iv) the conservation of dark populations that are significant for the marine environment in the Mediterranean. These national plans must be brought to the attention of all the concerned actors and as far as is possible coordinated with other pertinent national plans (e.g. emergency plan against accidental pollution).

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Geomorphological properties of marine caves of eastern Mediterranean Sea (Between Enez to Yayladağı, Turkey)

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Introduction

Caves; natural caves and man-made artificial caves (Caves of Nevşehir-Cappadocia and Kars-Ani underground cities, etc.) are divided into two types. Natural caves are generally found as karstic caves, tectonic caves, lava caves, wind caves, ice caves and sea caves. The first five of them developed on land and formed land caves; the last one, sea caves can develop under the influence of both land and marine processes. In addition, each type of cave formation can offer transitions in terms of formation with each other (Pekcan 1995; Hoşgören 1998; Erinç 2001).

Turkey; limestone, marble, dolomite, travertine, gypsum, halite due to the presence of soluble rocks, is a rich country concerningkarstic caves. Therefore, there are nearly 40.000 caves. Approximately 800 caves have been researched by experts until now (01.09.2019). Of those, 50 caves in land and several sea caves were opened to tourism and welcomes visitors. In our country, caves are used for especially tourism; besides mushroom cultivation, corral, cheese and fruit storage area, scientific and military purposes.

The longest sea cave in the world is the Matainaka Cave in southeastern New Zealand. Located on the shore of Otago, this cave is 5051 m long and opened in sandstones. The longest known cave in Turkey is Derya Cave in Antalya and it is 124 m long (Bunnel and Kovarik 2013; Güldalı *et al*. 1982).

Turkey is rich in marine caves. These caves were developed only by the coexistence and erosion of karstic, tectonic and marine processes in areas where soluble rocks and coasts are mostly limestones (Figure 1). Some of the deep sea caves were formed by the flooding of the old canyons as a result of the melting of glaciers at the beginning of the Holocene. Part of it, on the contrary, while having been a sea cave, became a partially dry and fossil cave where the waves reached from time to time with the rise of the land as a result of the effect of tectonic movements, and in some of them the marine effect was completely eliminated.

In this paper, the sea caves to be discussed are the sea caves on the Eastern Mediterranean coast extending between Enez district of Edirne province and Yayladağı district of Hatay province (Figure 2 and Table 1). Therefore, Edirne, Çanakkale, Balıkesir, İzmir, Aydın, Muğla, Antalya, Mersin, Adana and Hatay sea caves were taken into consideration in the provinces of the Aegean Sea and the Mediterranean Sea in the Eastern Mediterranean. Of these, but only in Çanakkale, İzmir, Aydın, Muğla, Antalya, Mersin and Hatay, there are sea caves on the developed coasts of the high cliff bedrock. Sea caves have not been encountered due to the fact that the other provinces have low coastal shores such as beach shores, coastal plains, delta shores and delta plains, or because they are mostly composed of non-melting volcanic and metamorphic rocks. The so-called (1) "Sea cave" in caves generally have an inlet from the sea; sometimes even boats can enter the sea cave. A part of the so-called (2) "Submarine cave", is a sea cave that has either been flooded after the sea levels rose or has been completely flooded with sea water after the land collapsed. A part of our subject is not included in the sea caves since they were transformed into a fossilized "Cave", when it was a sea cave, because they have now become caves on terrastrial area. However, there is one (3) "Cave or Seashore cave which was later revealed to be connected to the sea, because they have now become caves in land. In addition, the sea caves on the shores of the Sea of Marmara and the Black Sea are not discussed in this article; they remain outside our subject. The caves are considered here sea caves where the sea is actively entered or where the sea water is constantly in the gallery.

Turkey sea caves

The sea caves are found on the high cliffs and generally limestone coasts of Çanakkale, İzmir, Muğla, Antalya, Mersin and Hatay provinces of Turkey from the Enez in the northern Aegean Sea to the Yayladağı in southern Anatolia. They were formed as a result of the expansion of the cracks and diaclase systems of the bedrock caused by tectonism and earthquakes by marine processes such as waves and currents, and generally the dissolution of limestones by karstic processes, thus the collapse and fall of the blocks on the ceilings. The length, width, height and depth are not much. However, there are also some of them that are large enough to easily enter boats, canoes, etc.

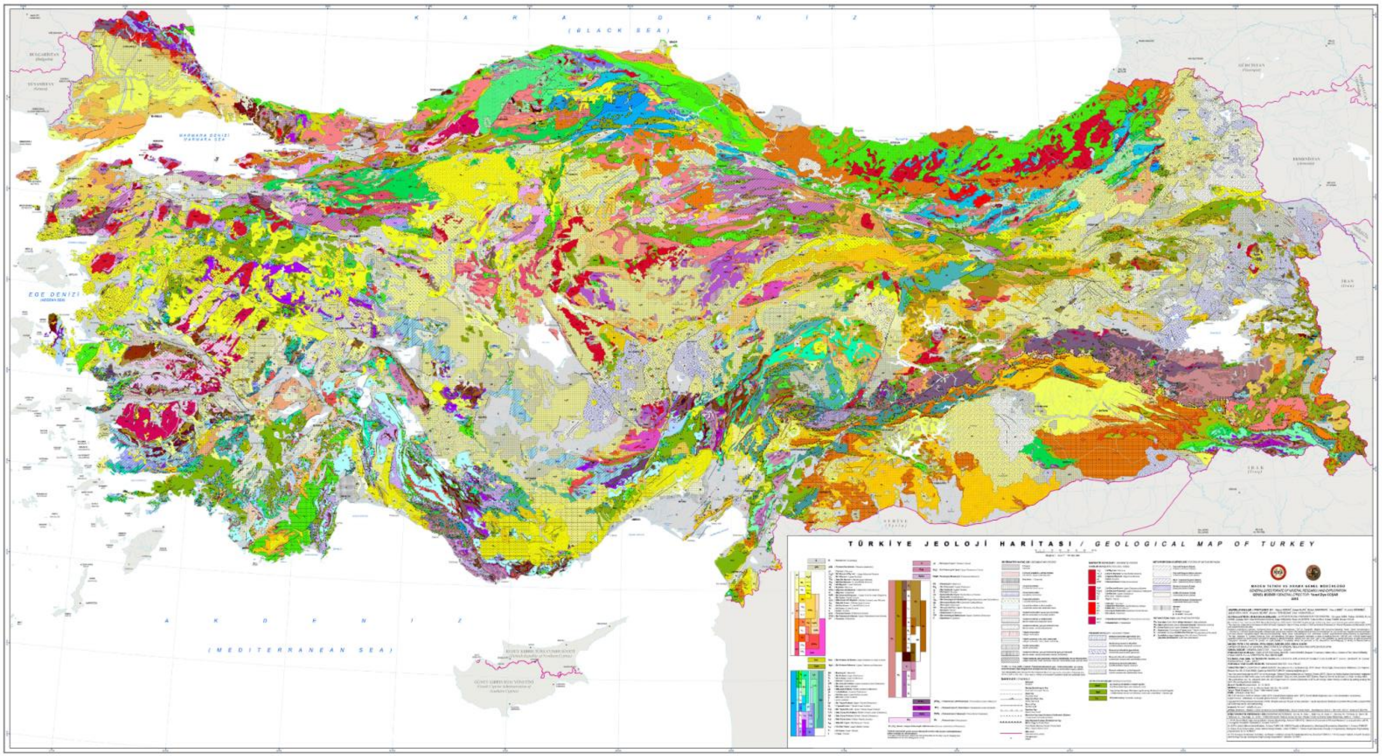

Figure 1. Geological map of Turkey (MTA 2015)

Figure 2. Location map of Turkey sea caves and submarine caves (between Enez to Yayladağı) (see Table 1)

Table 1. List of Turkey sea caves and submarine caves (see Figure 2).

Legend	Cave Name	District
1	Gökçeada-Gizli Liman Sea Cave	Gökçeada-Çanakkale
2 to 8	Foça Fok Sea Caves	Foça-İzmir
9	Üç Gözlü Güvercin Sea Cave	Söke-Aydın
10	Gökçebel Sea Cave	Bodrum-Muğla
11	Karaada Thermal Sea Cave	Bodrum-Muğla
12	Delikli Submarine Cave	Bodrum-Muğla
13	Marmaris Sea Cave	Marmaris-Muğla
14	Patika Submarine Cave	Ortaca-Muğla
15	Dağdelen Submarine Cave	Ortaca-Muğla
16	Fok Submarine Cave	Ortaca-Muğla
17	Derin Submarine Cave	Ortaca-Muğla
18	Selin Submarine Cave	Ortaca-Muğla
19	Afkule Submarine Cave and Türk Hamamı Submarine Cave	Fethiye Muğla
20	Güvercinlik Sea Cave and Güvencin Sea Hole	Kalkan-Antalya
21	Mavi Sea Cave	Kalkan-Antalya
22	Mivini Submarine Cave	Kaş-Antalya
23 to 27	Altuğ Submarine Cave and other submarine caves	Kaş-Antalya
28	Kekova Island Sea Cave	Demre-Antalya
29	Aşırlı Sea Cave	Demre-Antalya
30	Korsan Sea Cave	Demre-Antalya
31	Suluin Submarine Cave	Finike-Antalya
32	Gök Submarine Cave	Finike-Antalya
33	Kırlangıç Cape Sea Caves	Finike-Antalya
34	Büyük Submarine Cave	Kemer-Antalya
35	Derin Submarine Cave	Kemer-Antalya
36	Bacalı Submarine Cave	Kemer-Antalya
37	Derya Sea Cave	Antalya
38	Fener Sea Cave	Antalya
39	Previous Antalya Harbour Sea Cave	Antalya
40	Yerköprü Sea Cave	Antalya
41	Konakaltı Sea Cave	Antalya
42	Rambo Submarine Cave	Alanya-Antalya
43	Orta Submarine Cave	Alanya-Antalya
44	. Korsan İni Sea Cave	Alanya-Antalya
45	Aşıklar Sea Cave	Alanya-Antalya
46	Fosforlu Sea Cave	Alanya-Antalya
47	Ayhan Submarine Cave	Aydıncık-Mersin
48	Aynalı Çarşı Submarine Cave	Aydıncık-Mersin
49	Yanışlı Sea Cave	Gülnar-Mersin
50	Gilindire Cave	Gülnar-Mersin
51	Kaynar Submarine Sea Cav	Silifke-Mersin
52	Kubbe Submarine Cave	Silifke-Mersin
53	Nergis Submarine Cave	Silifke-Mersin
54	Turgutlar Sea Cave	Silifke-Mersin
55	Dana Island Submarine Cave I – II	Silifke Taşucu-Mersin
56	Eşkina Submarine Cave	Silifke-Mersin
57	Büyük Submarine Cave	Yayladağı-Hatay

The geographical, geological and geomorphological characteristics of the Turkey sea caves of the coastal provinces of the Eastern Mediterranean are explained below.

1. Çanakkale Sea Caves

Since the coasts of Çanakkale are mostly composed of loose sediments and partly volcanic, the sea cave was found according to the available data by us only in a location west of Gökçeada. On the northern shores of Gökçeada, there are many sea caves the Mediterranean monk seals used for nesting and breeding.

Gökçeada-Gizli Liman Sea Cave (Çanakkale)
This sea cave is located at the western end of Turkey. It is located to the west of Uğurlu Village in Gökçeada and south of Gizli Liman Bay and also to the west of Gizli Liman Beach. The cave was opened in light gray and white Middle Eocene reef limestones (Figure 3 a.b.c). It is inclined to 25 south-west. There are abundant fossilized crystallized limestone layer surfaces from sea crusts such as NW-SE direction, nummilite, pecten etc. (Sarı *et al*. 2015). The entrance of the cave from the sea is wide enough that only one person can enter; it is up to 50 cm. The cave starts with 5 m indentation; the sea enters more than 5 m; and has a length of 8 m on land. The total length of the cave is 18 m. The first 10 m is watery. Last part is anhydrous and dry. Layer thickness is between 30-40 cm. This cave, which is 10 m long inland south of İnce Burun (Avlaka Burnu), was formed by the wave erosion of a crack system on the slopes towards the sea and the collapse of the ceiling blocks. The depth of the watery part of the cave is 4-5 m. Inward depth decreases gradually. The ceiling height on the land reaches 3 m. To the east of the cave there is another narrow entrance which can be easily entered by a person. It is a small sea cave with sea watery and dry part. Sea urchins live on the sea side.

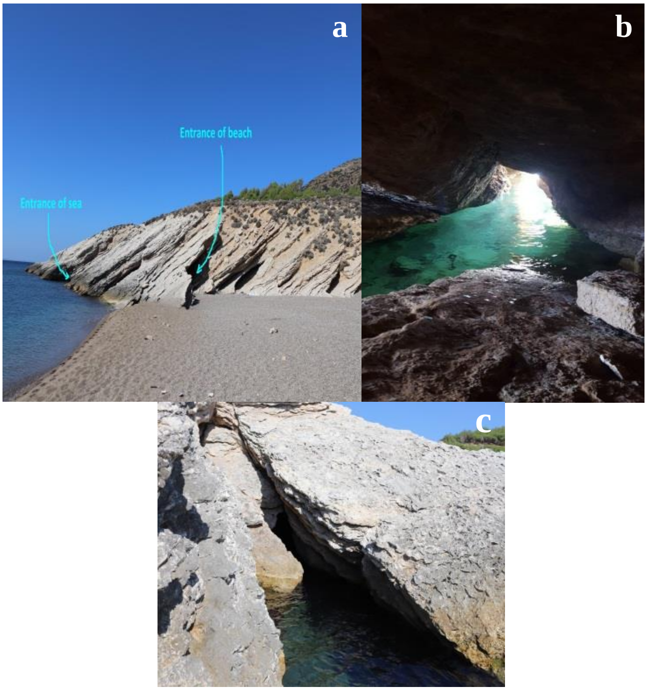

Figure 3. Gökçeada-Gizli Liman Sea Cave photographs; general view from beach **(a)**, inside of cave **(b)**, main sea entrance of cave **(c)** (Ahmet Ertek archive, 7.9.2019)

2. İzmir Sea Caves

The coasts of İzmir are composed of both tectonic, volcanic and dissolvable rocks. For this reason, sea caves are not encountered much in terms of karstification. Seven sea caves and seven caverns have been identified on the shores where Mediterranean monk seal lives in Foça and its vicinity (Öztürk and Dede 1995; Şenel 1995). These sea caves are opened in basalts from volcanic rocks as a result of wave erosion. (MTA 1964; Dönmez *et al*. 2017).

Foça Monk Seal Caves (İzmir)

These caves are found on the coast of Foça between Aslan Cape and Eskifener Cape (MAD 1994; Öztürk and Dede 1995; Şener 1995; Semenderoğlu 2011). According to Öztürk and Dede (1995), Foça Caves are as follows:

No cave with the entrance above the sea surface was found on the coastline between Aslan Cape and Eskifener Cape. In this area, there are suitable flat rocky places for monk seal only near Sığınak Cape. One cave at İncir Island and six caves at Orak Island were determined. The cave at İncir Island (Cave No: 7) was not deep, more like a shelter (has a small stony beach with an entrance accessible to man and visible to boat traffic). On the other hand, seven shelters in total were found, three at Fener Island, one at the İncir Island, one at the Hayırsız Island and two at Orak Island. All the caves at Orak Island were in Siren Rocks and three of them (Cave No 1, 2, 3) next to each other (Figure 4). There were not enough spaces for a seal in caves No 1 and 5, therefore these caves are not used by monk seals (Öztürk and Dede 1995) (Figure 4).

Cave No. 2: The cave had an entrance from the surface. The entrance, 2,5 m wide narrowed approximately to 1.5 m and there was a circular opening at the end. This opening continued for 10-12 m inwards. At the end of the cave, there was a 1-2 m wide stony beach. This beach might be useful for seals as a resting place, but not as a breeding area because of its beach size (Figure 5a).

Cave No. 3: There was an entrance from the surface, 4.5 m wide. It continued 8-10 m inwards and ended at a stony beach of 120 cm in width. The ceiling above the beach was 75 cm. This cave might also be suitable for seals as a resting place (Figure 5a).

Cave No. 4: This cave, that had an entrance from the surface, 4-5 m wide, bore an opening on its ceiling in the shape of a crack, of 3 m wide. The length of cave was 10 m and ended at 3-4 m long stony beach. This cave could be used for breeding and inhabiting by seals (Figure 5b).

Cave No. 6: This was the largest cave with an entrance from the surface, 4 m wide. A second passage (6-7 m) started on the left just beyond the entrance and at the end of the passage there was 10 m^2 area of rocks. The largest one among these rocks had a flat surface exposed above the water. The rest of the cave was circular and 10-12 m long. The bottom of cave was covered with sand and gray-white Stones. The ceiling was rather high ranging between 3-7 m. The cave could be a useful area for seals (Figure 5b).

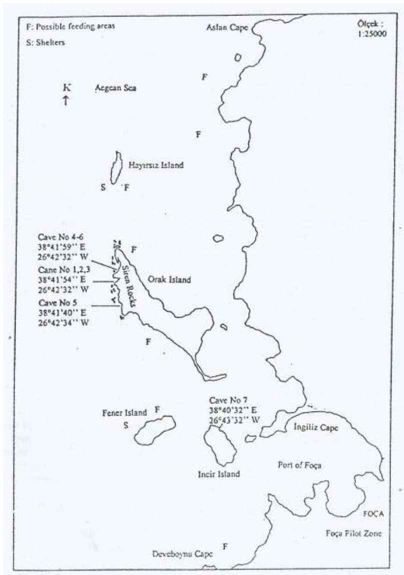

Figure 4. Location map of Foca monk seal caves (Izmir)
(Öztürk and Dede 1995)

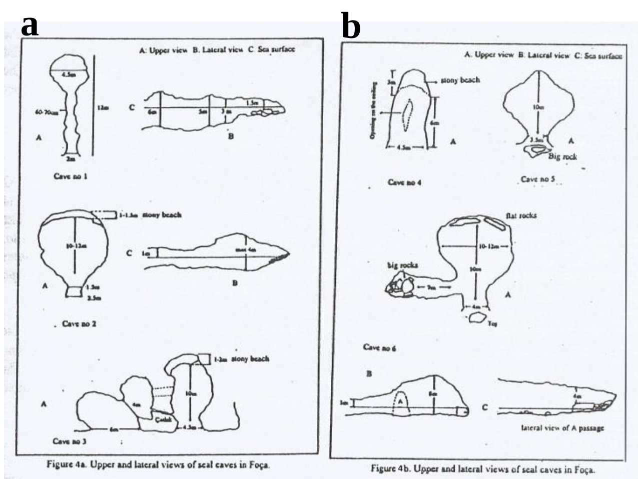

Figure 5. Upper and lateral views of monk seal sea caves in Foça
(Öztürk and Dede 1995)

Şener (1995), mapped 6 monk seal caves in Foça together with the Mağara Araştırmaları Derneği (MAD=Cave Researches Association) team. Caves are 5-30 m long caves, excursion boats can not approach the cave due to wave activity so both seals and caves are protected. The caves, which end with blocks and pebbles, are suitable places to meet the natural needs of monk seals such as calving and sleeping (Figure 6). He states that one of these sea caves, which is the subject of research in Foça, is located on Hayırsız Island, the other is on Orak Island and the remaining four are also on Orak Island. In later researches, he and his team were once again on Orak Island; they explored and mapped 4 seal caves, 3 of which were on the shores of Foça.

Figure 6. One of the monk seal caves in Foça (http://www.foca.bel.tr/haber)

3. Aydın Sea Caves

Except for the shores of the Dilek Peninsula which protrude to the Aegean Sea of the Sason Mountains, which consist mainly of limestones and marbles; deltas, coastal plains and wetlands in coasts of Aydın Province. For this reason, sea caves are not encountered much in terms of karstification. Only one sea cave was identified on the shores of the Dilek Peninsula (Semenderoğlu 2011).

Üç Gözlü Güvercin Sea Cave (Aydın)

You can reach Doğanbey Village by passing from Söke, the Aydın Province, in front of the ruins of Priene. Karine is reached from the village. When you go by boat from here, the cave is reached after the Karakol Cape. It is a sea cave where waves play an important role in its formation. It was reported that pigeons made nests. There is a possibility that the Mediterranean monk seals frequent it. On both sides there are window-shaped eyes facing the bays. The cave can be accessed by boat. The region is within the borders of Dilek Peninsula-Büyük Menderes Delta National Park. In addition, Karine region is important for nature and cultural tourism. Therefore, sea cave tourism is an important resource especially for eco-tourism. However, if the monk seals are found to take shelter and reproduce in the area, it may be necessary to close the visit (Semenderoğlu 2011).

4. Muğla Sea Caves

Sea caves are found in local areas especially in limestone sections of coasts of Muğla Province. The reason for this is that it prevents karstic caving due to the fact that the shores of Bodrum and Reşadiye Peninsula are composed of volcanic rocks and thus do not consist of dissolvable rocks.

Gökçebel Sea Cave (Muğla)

The cave is located on the shores of Gökçebel in Bodrum-Yalıkavak. In 1993, MAD organized an event for lifesaving and diving training. It is a sea cave. The entrance of the cave is narrow enough to allow a person to pass. Cave; after the entrance, expands and narrows by 4 m (Semenderoglu 2011). It is about 17 m long and extends up to 4 m transverse after the entrance and ends up narrowing (Uysal 1993).

Karaada Thermal Sea Cave (Muğla)

A hot spring water from the cave on the Karaada opposite Bodrum Bay is in high demand by tourists going to Bodrum. Numerous visitors put the mud in the cave on their faces and bodies to beautify it. For this reason, the cave was named "Güzellik Mağarası (Beauty Sea Cave)". Thermal water with a temperature of approximately 35°C (this water temperature varies according to earthquakes and years) emerges from the sea. The flow rate of this thermal cave spring is quite high (Aygen 1984; Semenderoğlu 2011).

Delikli Sea Cave (Muğla)

It is another interesting dive point behind Bodrum-Karaada. The cave, entered from the -12th meter, is approximately 4 m in diameter see Figure 7.

Figure 7. Delikli Sea Cave (Karaada-Bodrum) (Şenok 2011)

Marmaris Sea Cave (Muğla)
The cave can be reached by boat from the sea, in Marmaris. However, it is in the form of a small cavity (Aygen 1984). It is located on the south side of Cennet Island. It is also called "Fosfor Sea Cave" because of the reflection of the water in the cave and the colour of green and turquoise.

Patika Sea Cave (Muğla)
It is a submarine cave on the Sarıgerme coast in Muğla-Ortaca and -7 m above sea level. The entrance of the cave is about -13 m. The bottom structure is rocky. Therefore, more than one person can enter easily.

Dağdelen Sea Cave (Muğla)
It is a submarine cave on the Sarıgerme coast in Muğla-Ortaca. The width of the cave is very wide and close to the sea surface.

Fok Sea Cave (Muğla)
It is a submarine cave on the Sarıgerme coast in Muğla-Ortaca. Since the Mediterranean seal was seen in time, the cave is called with this name. However, another name of this place is "Tatlısu Sea Cave" due to the fresh water source at the bottom. This cave is usually the second dive site. The depth 10-13 m.

Derin Sea Cave (Muğla)
It is a submarine cave located in Sarigerme, Mugla. Its entrance at -35 m is about 10 m wide. The first room enters about 30 m. Bottom has sedimentary deposite.

Selin Sea Cave (Muğla)
It is a submarine cave located in Sarıgerme-Muğla. It is the first of 4 caves side by side located at the bottom of Aşı Bay. It has two separate entrances. The west entrance has a diameter of about 2 m and rises upward with a slight slope.

Afkule Sea Cave ve Türk Hamamı Sea Cave (Muğla)
These are two submarine caves located 10 km southwest of Fethiye.

5. Antalya Sea Caves
Karstification in Taurus Mountain Belt increases to 2000-3000 m above sea level and and again descends below sea level. Therefore, the Ovacık, Kaş-Kalkan submarine springs and the coastal aquifers along the Mediterranean coast are the best evidence of this. For all these reasons, many sea caves are encountered in Turkey due to the fact that the coasts of Antalya are mostly limestones. Although they are not very long sea caves, they were formed as a result of the development of crack and diaclase systems of monocline, folded and horizontal limestone layers. In addition to the effectiveness of tectonic lines,

karstic and marine processes have an impact on their formation. For this reason, the crack systems based on the rise of the Taurus Mountains; this sea cave has been enlarged due to the dissolution of limestones, contributing to karstification, as well as the impact of waves and currents and the fall of ceiling blocks. For these reasons, Antalya sea caves were generally opened in limestone containing $CaCO_3$ (calcium carbonate) and partly in travertines on the coast of Antalya (Minister of Tourism 1992; Pekcan 1995; Erinç 2001; MTA 1963).

Güvercinlik Sea Caves (also known as Güvercinlik Sea Cave and Güvencin Hole) (Antalya)

There are two caves behind İnce Cape which is about 2 km from Kalkan. One of these caves, which are approximately 100 m apart, is called "Güvercinlik Sea Cave" and the other is called "Güvencin Hole". Güvercinlik Sea Cave has a large entrance and an underground creek emerges into the sea. The second cave, Güvencin Hole, is located about 100 m opposite the first cave. It has a rather narrow entrance. However, boats and canoes can be entered in and out. The sea enters into the cave in the form of a thin corridor up to 60 m. The ceiling is also quite high. This cave is actively used by pigeons and Mediterranean monk seals. It can be a breeding area especially in winter months. During the summer season, some tourists enter this cave by boats or by diving and they are sometimes disturbing the pigeons and leaving the seals in the summer months (Figure 8) (Aygen 1984; Baykan 2012).

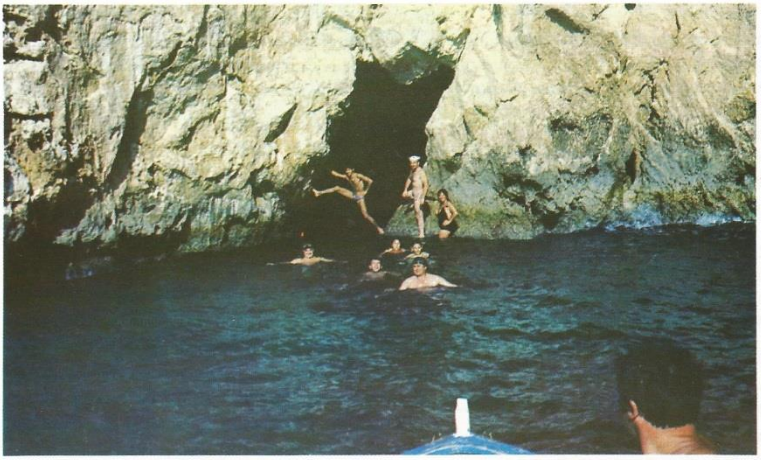

Figure 8. Güvercinlik Sea Cave near Kalkan (Aygen 1984)

Mavi Sea Cave (Antalya)

This sea cave can be reached from the Antalya-Kalkan coast road. The cave is located on the seashore between Kaş and Kalkan. Kalkan is 7 km and Kaş is 19 km away. Turkey's most famous sandy beach is just west of Kapıtaş Beach. It is an active sea cave opening to the sea about 20 m below the coast road passing by the sea. The cave is 50 m long, 40 m wide and 15 m high. It is a very large cave with different galleries, chambers and canals. The cave is divided into two as inner and outer galleries. It takes its name from the blue light that enters the outer corridors. The interior galleries, which allow access to the air gap, are all dark. Both the interior and exterior galleries of the cave draw attention to soft coral formations and lively diversity. Depending on the period, shrimp flocks are seen in the inner galleries. This cave is actively used by Mediterranean monk seals. It can be a breeding area especially in winter months. It was excavated in the Cretaceous limestones of the Mesozoic geological periods. It is known that seals lived the in the past. In 1972, Blue Cave was covered by examining geologist Dr. Temuçin AYGEN, Turkey Cave Research and Promotion Association (Türkiye Mağara Araştırma ve Tanıtma Derneği) members, from France, one from the city of Mende speleologists (cave explorers) group. The sun's rays enter the cave by reflecting from the sea bottom. Therefore, it is called "Blue Cave" because it produces blue bright phosphorescent colour. It is also called as "Kapıtaş Sea Cave" in the region. It is one of the most important sea caves of touristic importance on the Mediterranean coast. It is large enough to accommodate tourists with boats; it is one of the most important tourist attraction of Turkey (Figures 9 and 10) (Aygen 1984; Baykan 2012).

Figure 9. General view of Mavi Sea Cave and Kapıtaş Beach (Kalkan-Antalya)

Figure 10. Mavi Sea Cave

Mivini Sea Cave (Antalya)

The cave is a submarine cave located 10 km west of the Kaş district in Antalya. The monk seal was identified in the search and protection project (AFAG). The gallery, which was previously a fossil cave, is filled with sea water due to the rise of sea level and exhibits a different formation (Eğilmez 2014). The entrance of the Mivini Cave, where the first dive was carried out on 30 August 2003, starts at a depth of 2.5 m and extends into the depths with an inclination of approximately 45°. In August 2003, the air was inhaled to a depth of 53 m and the halocline from the freshwater-salty mixture was encountered at depths below 25 m. In the second dive in September 2003, it was observed that the halocline reached the surface of the cave and the fuzzy layer continued for about 3-5 m and disappeared at a deeper depth. Observations made at deep points where visibility was increased revealed traces of karstic dissolution triggered by sweet-salty mixture on the surface of the cave. In the November 2003 dive, it was observed that a small amount of fresh water followed the ceiling of the cave and reached the surface. During the dives using mixed gas, in August 2004, it was found that the cave extends to a depth of 74 m by following the slope in the upper parts. The cross-sectional profile of the Mivini Sea Cave indicates that it developed along the surface of the freshwater-salt water mixture. The mixing of fresh and salt water at certain proportions increases the carbonated rock dissolving capacity of the mixing water. Therefore, karstic dissolution processes that are effective in the formation of Mivini Cave are thought to be continuing today (Öztan *et al*. 2011).

Altuğ Sea Cave and Other Submarine Caves (Antalya)
The cave is a submarine cave located 8 km south of the Kaş district in Antalya. Altuğ Cave was discovered by local divers in December 2002 before Öztan and his team worked in 2011. The well-underwater entrance of the cave is located at a depth of 11 m from the sea surface. In September 2003, the dive, halocline from the entrance of the cave, intense water outflow and freshwater-salt water mixture were observed. In another dive conducted in the same period, it was found that the cold water layer was down to a depth of -30 m. The cave expands after a vertical, chimney-shaped descent of 25 m. The bottom depth reached was -63 m from the surface. It is understood from the cave profile that the development took place mostly in the land environment, that the chimney section was an improved melting shaft in the unsaturated zone, and that the expansion in the lower section occurred due to the chemical dissolution from the oscillation in the water table at the point where the shaft reached the water table. Later, the surface karst is erased by erosion and the entrance is thought to have taken the present submarine position with the rise of sea level and / or increase of the tectonic origin of the land section (Öztan *et al*. 2011).

According to Öztan *et al.* (2011) Mivini Cave is the 4th place between Kalkan and Demre. There are 6 submarine caves named Prenses, Mivini, Likya Batığı, Altuğ, Buza and İlker Kaptan caves from west to east. These are the drowned and submarine caves, both as a result of freshwater discharges into the Mediterranean Sea and as a result of the rise of sea level with the melting of glaciers in the Holocene.

Kekova Island Sea Caves (Antalya)
It is a sea cave located on the southern sea shore of Kekova Island in Demre, next to Salyangoz (Karalos) Port. It has two entrances; one large, another narrow. The second small mouth of the small sea cave entrance is very narrow, there is another cave reflecting the blue of the sea water. These small sea caves, which are located in the nummilitic limestones of the Mesozoic, do not have much touristic importance. The walls of the cave are generally seen with algae, reptiles and corals and Mediterranean seals. It can be a breeding area for seals, especially in winter; therefore, tourists who dive during the summer season should be careful during diving (Aygen 1984; Baykan 2012).

Aşırlı Sea Caves (Antalya)
This sea cave is located between Demre and Kaş, about 3 km southwest of Çayağzı, the port of Demre. On the way to the Kale from Demre-Çayağzı, Aşırlı Sea Cave is located just under the highway that can be entered by boat. This sea cave, which was opened in the nummilitic limestones of the Mesozoic, which is one of the geological periods, is the place of visit of yachts and boats coming to the region (Figure 11) (Aygen 1984).

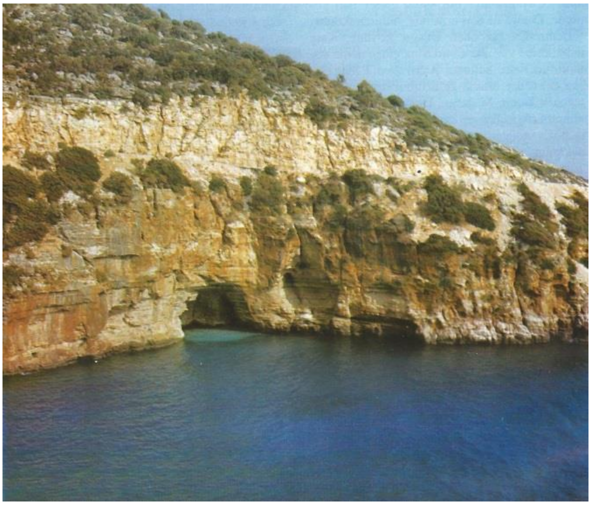

Figure 11. Aşırlı Sea Cave (Demre/Antalya) (Aygen 1984)

Korsan Sea Cave (Antalya)

Blue, violet, red and brown seaweed and algae are worth seeing in this cave located on Aşırlı Island on Kekova road from Çayağzı coast of Demre (Aygen 1984). The cave, which has a sandy beach where seals rest, is a place where canoeists stop by (Figure 12) (Türe 2004).

Figure 12. Korsan Sea Cave (Demre-Antalya) (Türe 2004)

Suluin Sea Cave (also known as Suluin, İncirli Sea Cave or Gök Sea Cave) (Antalya)

It is a sea cave located in Finike district of Antalya. It is 18 m above sea level on the 2nd km of the Finike-Kaş motorway, with an 80 m entrance and a total length of 128 m. The cave was formed as a result of the underground melting in ancient times, the ceiling had migrated in the later period and opened to the outside world in this way. The limestones in which the cave is located are massive, very pure and gray in colour. As it develops vertically from the entrance of the cave, there is a pond at the bottom of the cave. This pond, which gives the impression of a deep pond with the effect of the algae covering the water, is actually the gate of the cave extending downwards to the outer world. In 1955, it was reported that two of the American divers, who wanted to do research in the cave, reached a depth of -122 m, but died here, so a ban on entry and diving was introduced. In the dive by American divers, they found that Suluin Cave was the largest submarine cave in the Asian continent. As a result of the diving carried out by Atlas Magazine team in 1995, it was descended to 122 m from the sea and a 250 m long line was installed. According to the sea cave records, it is the deepest and deepest cave ever documented in Asia. But they have not reached the end of the cave yet. The water in the cave is fresh when it enters immediately, and when it goes down, salt water starts. From the salt water in the lower section, it is evident that the cave has a connection with the sea, although it cannot be discovered. Suluin, which is located 1 km from the district centre in Finike and attracts attention with its mysterious appearance, is known as "İncirli Cave" among the people and preserves its mystery as a truly undiscovered secret from history to the present day. Suluin Cave, one of its natural riches, attracts everyone who comes to Finike an important port city in ancient times (http://www.finike.gov.tr/suluin-magarasi,http://finike.8m .com/m agaralar.htm).

Gök Sea Cave (Antalya)

The Gök Sea Cave is a submarine cave in Finike and one of the freshwater springs that attract the attention of cave divers. However, after an average depth of -15 m, cave water is mixed with salt water. The presence of stalactites in the cave descending to the bottom with a wide corridor is one of the signs that it was a dry cave.

Kırlangıç (Gelidonya) Cape Sea Caves (Antalya)

These are the small sea caves at Kırlangıç Cape and Adrasan Cape between Finike and Antalya. These are the caves in the form of sea holes located to the west of Antalya Gulf under the influence of the Antalya Fault (Aygen 1984). They were opened in the fracture and diaclase systems of the folded limestones of the Western Taurus Mountains during the Jurassic-Cretaceous era of the Mesozoic (Aygen 1984).

Büyük Sea Cave (Antalya)
The diving cave of the Büyük Cave in Kemer Üçadalar is between -6 and -33 m. Therefore, it is a submarine cave. Even at the deepest point, light can be seen from the exit point. There are dozens of sea creatures that live in without light or little light. Apart from sponges, algae, corals and fishes, underwater caves are host to another very importantanimal; Mediterranean monk seals. Seals who choose submarine caves to build nests prefer caves with air gaps that rise after entering them (Baykan 2012).

Derin Sea Cave (Antalya)
Kemer is a very large diving area in Üç Adalar with nine reefs and two submarine caves. Derin Cave is one of the submarine caves. The depth of the cave varies between -5 and -31 m. As in the big cave, there are dozens of submarine creatures that live their lives in low or no light conditions (Figure 13) (Baykan 2012).

Figure 13. Derin Sea Cave (Baykan 2012)

Bacalı Sea Cave (Antalya)
This submarine cave is located in Kemer, Antalya. When you reach the -20 m in the clear waters of the Mediterranean Sea, you will encounter a hole in the rocks. Only a diver can pass through this entrance, which is quite small in diameter.

Derya Sea Cave (Antalya)
It is located in Atatürk Park on the west coast of Antalya between Konyaaltı Street and the seashore, 50 m south of the central station. Some time ago, Derya Motel was on top of this cave. This motel was demolished due to the construction of the park. Inspired by this motel, the cave was named "Derya Cave". The deepest point of the cave, which is 124 m in length, is -35.65 m. It is vertical but dry cave type. It is referred to as both cave and sea caves because it is in the sea. Since the cave was dry, its development was partially completed.

The parts of the cave at sea are covered with sea water. A small amount of stalagmites and wall travertines develop in the large hall; stalactites and stalagmites are increasing towards south. In this part, fresh water sources come out of the cracks and mix into sea water. The main entrance of the cave is 40 m wide and the second entrance to the west is 0.5 m wide. Antalya travertines have been formed due to the fact that the abundant chalky waters coming from the Kırkgöz Springs remain under the cascades and remain in travertines as chambers. In later periods, these chambers expanded by melting and the fall of rock blocks from their ceilings. Both entrances of the cave were previously used as garbage dumps. The large hall and the western section of the cave are connected by very narrow and flat passageways. The cave is cooler in the summer (Güldalı *et al*. 1982).

Fener Sea Cave (Antalya)
This submarine cave in Antalya cliffs consists of two caves. Dive point is reached by boat, the first descending depth is between -7 m and -10 m. Swim through the cliffs and pass through a canyon where a single 45 m long diver can advance. Ten meters after the exit of this canyon, there is an air gap where the regulator can be removed from the mouth and one can breathe normally. At the same point there is a second cave as known "Jesus Cave". To reach this cave, which is half freshwater and half saltwater, continue 100 m into the city from the cliffs. The distance between the ceiling and the floor of the cave is between 4 and 5 m. This is a diving point which consists of many chambers and has different entry and exit routes to the same point. It is possible to see stalactites and different rock formations in the cave (Baykan 2012).

Previous Antalya Harbour Sea Caves (Antalya)
These are a few small sea caves located in the travertines on which Antalya city centre develops. It is hidden by the Düden Stream and Waterfall which spills over 40 m into the sea. With waterfall, rain water and sea water erosion, these sea holes and caves were formed (Aygen 1984).

Yerköprü Sea Cave (Antalya)
It developed in travertine in Antalya city centre. The cave has a total length of 110 m and the deepest point of the cave is -27 m. Its development has stopped. It is a sea cave due to its connection with the sea. The cave is dry. The floor of the hall, which is connected to the sea, is partly covered with sea water. The temperature of the cave is cooler than the open air. Yerköprü Cave is a sea cave which was formed as a result of the collapse of the ceiling of a cave which is at least 150 m long in the east-west direction completely within the Antalya travertines.

Konakaltı Sea Cave (Antalya)
It is located on the cliff shore of Atatürk Park in Antalya. The cave is accessible from the sea. The 60 m long cave is a horizontal cave type. It can also be

considered as a sea cave due to its partial connection to the sea. It is usually dry. Some of the eastern hall is under sea water. There are puddles in the west hall due to waves. The cave has two entrances to the east and west. The entrance of the cave is 3 m above sea level. The bottom of the eastern section goes down to sea level. The eastern hall of the cave is completely covered with rock blocks. The western hall is partly covered with stalactites, stalagmites and columns. The two small rooms connected to the western hall are covered with travertine and located right by the sea, which increases the touristic value. The cave is cooler than the open air.

Rambo Sea Cave (Antalya)
This cave is the last point among the diving points in Alanya, in terms of distance to the habour and 5 km west of the district centre. Close to Kleopatra Beach, Alanya is perhaps the most popular dive site. The distance to Alanya harbour is about 25 minutes by boat. -13 m deep, 4-5 divers can enter side by side and 6-7 m long through a tunnel, half of the air-filled cave is reached. It is one of the submarine caves in Alanya. There are stalactites and stalagmites. The air gap above the water surface in the cave sometimes reaches 8-10 m (Baykan 2012).

Orta Sea Cave (Antalya)
It is a submarine cave 3 km west of Alanya. Orta Cave is 12 minutes away from Alanya habour. It has a minimum depth of -15 m and a maximum depth of -34 m. The entrance of the cave is -15 m deep. This area is suitable for experienced divers and deep water dives. The bottom structure is rocky. Grouper, octopus, bandit, moray eel, spiny lobster and bream can be seen in terms of sea creatures (Baykan 2012).

Korsan İni Sea Cave (Korsanlar Sea Cave, Antalya)
The Korsan Ini Cave, which is located in the south of the historical Alanya Peninsula, where the Alanya Castle is located, is also called “Kızlar Cave”. This cave, which was once a pirate shelter, was named after the pirates as it was narrated by the pirates. You can enter the cave with boat. Inside is a large hall. Although it is known that this hall was connected to Alanya Castle, which was located 150 m in the upper part, the connection with the sea cave was broken due to the collapse of the road (Aygen 1984). It is one of the first touristic sea caves visited by boat tours around the peninsula. It’s entrance has a width of 10 m and a height of 6 m. Small boats can enter the cave. It is suitable for both experienced divers and educational dives. Korsan İni Sea Cave is open to the public and is a large touristic cave. The depth at the entrance of the cave is 12 m (Baykan 2012).

Aşıklar Sea Cave (Antalya)
It is located on the southern tip of the Alanya Peninsula. The cave is a 75 m long corridor. It is a corridor open in the east-west direction on the southern

promontory of the peninsula. Aşıklar Sea Cave is in the historical peninsula, which crosses the other end, thus it has two entrances. Alanya Peninsula, close to the sea on the slope of the boat towards the cliffs of Dilvarda Cape is entered after climbing the rocks. A few steps lead to the low entrance of the cave. Due to its low ceiling, it is sometimes necessary to lean forward in the cave. The western mouth of the cave on the side of Damlataş Cave is 8 m high from the sea level and it can be jumped into the sea from here. The depth varies between -10 m and -34 m. It is suitable for experienced divers and educational dives. The bottom structure is rocky. It is a region rich in underwater life (Aygen 1984; Baykan 2012).

Fosforlu Sea Cave (Antalya)
It is a small sea cave on the west side of the Alanya Peninsula. It is called "Phosphorus Cave" because when the boat enters, light games and sparkles resembling occur during the playing of the paddles. It is frequented by tourists who make boat tours from the sea (Figure 14) (Aygen 1984).

Figure 14. Alanya-Fosforlu Sea Cave

6. Mersin Sea Caves
Karstification in Taurus Mountain Belt increases to 2000-3000 m above sea level and again descends below sea level. Therefore, the Aydıncık, Ovacık, Taşucu submarine springs and the coastal aquifers along the Mediterranean coasts are the best evidence of this. For all these reasons, many sea caves and submarine caves are encountered in Turkey due to the fact that the coasts of Mersin are mostly limestones. Although they are not very long sea caves, they were formed as a result of the development of crack and diaclase systems of monocline, folded and horizontal limestone layers. In addition to the effectiveness of tectonic lines, karstic and marine processes have an impact on their formation. For this reason, the crack systems are based on the rise of the Taurus Mountains; this sea cave has been enlarged due to the dissolution of limestones, contributing to karstification, as well as the impact of waves and currents and the fall of ceiling blocks or some dry caves in land drowned to the sea waters because of the melting glaciers in Holocene geological period. Therefore, these caves in land are returned to, one by one, submarine caves. Mersin sea caves seen in Aydıncık-Taşucu, were generally opened in limestone

containing $CaCO_3$ (calcium carbonate) in high coast cliffs. Other low coasts of Mersin (for example; Göksu and Çukurova deltas, etc.) sea caves are not seen due to the deltas, fan-deltas, alluvial fans and cones, piedmont plains, coastal plains and wetlands (Ministry of Tourism 1992; Pekcan 1995; Erinç 2001; MTA 1962).

Ayhan Sea Cave (Mersin)
It is a submarine cave in the Aydıncık district of Mersin. The presence of fine element silts on the ground of the cave filled with sea water makes diving and exploration difficult because of the presence of underwater dust. Its length is 26 m and its depth is 27 m (Akdağ 2013).

Aynalı Çarşı Sea Cave (Mersin)
It is a submarine cave in the Aydıncık district of Mersin. It is 6 m long and 12.5 m deep (Akdağ 2013).

Yanışlı Sea Cave or Mavi Çini Sea Cave (Mersin)
It is located within the borders of Gülnar of Mersin. The interior of the cave is completely covered with a sandy beach. However, sea water can enter the cave during wavy times. Partly the sea cave can be considered as a cave in land (Figure 15).

Figure 15. Mersin -Yanışlı Sea Cave

Gilindire Cave (Mersin)
It is a polygenic cave located at the coast of the Gülnar district of Mersin, the entrance of which is 46 m above sea level. It was formed in a region where the Mediterranean Sea was descending or tectonically descending. It was developed due to NE-SW and NW-SE oriented faults in the limestone and dolomitic limestones of the Cambrian. There are marine terraces in and around the cave. The cave consists of three interconnected sections. The first section, 22 m high from the entrance, was connected to the surface and opened in the Quaternary

(Tyrrhenian). The inner part of the cave sediments was formed in Pliocene and is older. The total length is 555 m. Located at the end of the main gallery, the lake has a depth of 46 m. According to the hydrogeochemical measurement analysis conducted by Nazik *et al*. (2001); the first 10 m depth is of lake water character, while the lower depth is completely salty. It is understood that in this part of the cave, which is on the land about 250 m away from the sea, salty interference could easily occur along the faults and cracks in the sea. Gilindire Cave is a cave in the land that developed in Plio-Quaternary and has a multi-period development processes. The upper entrance of the cave was in Tyrrhenian, the last part was in Würm, and the last part of the lake, which developed due to the rise of the Mediterranean Sea, was submerged in the sea (Nazik *et al.* 2001)

Kaynar Sea Cave (Mersin)
It is a submarine cave in Aydıncık-Taşucu, which was discovered during the DEMA (Sea Caves Inventory Project) activity in 1998 and explored with a submarine entrance of -7 m. A strong fresh water outlet was observed from the mouth of the cave towards the sea. From the entrance of the cave, blurred images of salt and fresh water were encountered. The blurred layer, which continues for about 20-25 m into the cave, fades further and increases the visibility. This cave is a melting / dissolution cave. The Kaynar Sea Cave is estimated to be approximately 120 m with a horizontal length of 84 m. However, the discovery of the entire cave has not been completed yet. In 2001, Kaynar Cave exploration activity was organized in the region and it was observed that the cave continued to a depth of -57 m and the mapping was completed to a depth of -37 m (Hamarat *et al*. 1998).

Kubbe Sea Cave (Mersin)
This cave in Aydıncık-Taşucu has a total length of 38 m with two separate submarine entrances. In the last part of the cave, there is an air hall. The air hall is completely fresh water, but there is no discharge movement. Although there is no pebble ground on the shore, it forms an area that the Mediterranean monk seals can use for short-time housing. The maximum depth is -10 m. The total length of the two galleries is 38 m. (Hamarat *et al*. 1998).

Nergis Sea Cave (Mersin)
Nergis submarine cave in Aydıncık-Taşucu has two underwater entrance ports, one of which is -18 m and the other is -3 m. It is a cave full of sea water. Despite its large volume, the total length is 23 m (Hamarat *et al*. 1998).

Turgutlar Sea Cave (Mersin)
This sea cave in Aydıncık-Taşucu has a large overflow entrance and a total length of 36 m (Hamarat *et al*. 1998).

Dana Adası Sea Cave I and II (Mersin)
Dana Island Sea Caves are developed in the eastern part of Dana Island, which is located southwest of Taşucu, with submarine entrance of -9 m. These submarine caves, which are adjacent to each other on the sea floor, are sea caves formed by both dissolution and erosion. The cave was opened in the Jurassic-Cretaceous limestones. The presence of very thin silty elements on the floor of the caves, reduces the vision by reacting easily by entering the cave (Hamarat *et al*. 1998).

Eşkina Sea Cave (Mersin)
This submarine cave in Aydıncık-Taşucu has a depth of -12 m and a total length of 58 m. The formation was formed by complete dissolution. The cave consists of a single gallery approximately 2.5 m wide and shows a horizontal development. There is only one body of water consisting of salt water. It takes its name from 3-4 king fishes living in it (Hamarat *et al*. 1998).

7. Hatay Sea Caves
The shores of Hatay Province is generally made up of low coast like deltas, fan-deltas, alluvial cones and fans, piedmont plains, coastal plains and wetlands. Except for the Yayladağı shores of the Amanos Mountains, which are composed oflimestones and marbles. For this reason, sea caves are not encountered much in terms of karstification. A sea cave was identified on the shores of Yayladağı.

Büyük Sea Cave (Hatay)
It is located in Yayladağı district of Hatay. This submarine cave, at the foot of the Keldağı Mountain, which is an inactive volcanic mountain, is at an altitude of 1736 m and can be accessed by diving deep into -19 m above sea level. The main entrance of the cave is between -19 and -27 m. After about 50 m there is a second entrance with a width of 2 m and a height of 3 m at a depth of 20-23 m. The farthest point of the cave is about 120 m. This submarine cave consists of 2 large, 2 small galleries, 2 tunnels and 5 connection channels. There are stalagmites, stalactites and columns at a depth of 0-5 m in the second big gallery of the cave. There are formations similar to travertine in the connection channels.

Conclusions and suggestions

The sea caves seen in Turkey's coasts are of great importance in that it contains scientific data. From this perspective, they keep the geological, geomorphological, ecological and biological records of the past and present. They are also very sensitive and important natural assets that are expected to be protected because of their natural beauties and payed close attention by humanity.

In this respect, the balance of use, protection and conservation should be optimally maintained. Otherwise, as observed in places where this balance is not achieved, our sea caves can turn into dumps just like our seas. Therefore, the best use of our sea caves should be within the framework of certain plans. From time to time it is also beneficial to have the sea caves cleaned by the surrounding municipalities and voluntary organizations. The sea caves serve primarily tourism; and the underwater sea caves attract more people interested in diving. These will contribute greatly to the development of the country as additional destinations for cave, summer and marine tourism.

Based on field observations and compilation work it does, in Turkey's eastern Mediterranean coasts between Enez-Yayladağı, 7 provinces have 57 sea caves and submarine caves. 1 of these is located in Çanakkale, 7 in İzmir, 1 in Aydın, 10 in Muğla, 27 in Antalya, 10 in Mersin and 1 in Hatay. Twenty eight of these caves are sea caves and 28 of them are submarine caves and 1 is a multi-stage cave in land and near shore. However, in Turkey, which is a karstic country, it is clear that the number of sea caves is much higher than this value and that new caves will be discovered through future researches.

Nevertheless, Turkey does not have a full inventory of sea caves. In order to make this inventory, the coastal zone between Hopa and Yayladağı in our seas should be scanned both by boat and by diving and with the measurement studies, an inventory of “Sea Caves” and “Submarine Caves” should be prepared.

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Development of coastal and submarine caves in the south-western part of Turkey

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Introduction

The land caves are difficult to explore because of their harsh ambient conditions such as, absolute darkness, rugged morphology, high humidity, extreme temperature gradient etc. These difficulties are compounded by additional skills required for working under the water. Consequently, information regarding marine caves (both coastal and submarine) is limited globally. However, these caves are regarded as important groundwater discharge sites in water-deficit regions, as critical shelters and breeding sites for endangered marine animals like Mediterranean Monk Seals and may host important ecosystems which are not discovered yet.

A cave may be described as avoid developed in rocks into which a human can penetrate. Many of the caves are developed in carbonate rocks due to dissolution by carbonic acid. This process results in a unique surface and subsurface morphology and hydrogeological conditions which is known as karst and is widespread in Taurus Mountains Belt that extends along the Mediterranean coast of Turkey.

Bayari *et al*. (2007, 2011) and Bayari and Ozyurt (2008, 2014) systematically explored for the first time in Turkey the presence and distribution of marine caves along the coastal zone between Patara at the west and Kumluca at the east. These revealed interesting results regarding the development and present hydrogeological function of the marine caves. A summary of the findings of these studies are presented in the following.

Study area

Location, morphology and climate

The study area, is located between the Yali Horn (36°13'48.47"N, 29°21'17.17"E) in the west and the Yardimci Horn (36°12'35.84"N, 30°24'17.57"E) in the east of the southwestern Mediterranean coastline of Turkey (Figure 1). Bird’s eye extent of the explored coastline is about 120 km (Figure 1). The land zone is called Teke Taurids (mountains) where the elevation reaches 3,070 m above sea level (asl) (Kizlarsivrisi Peak). Esencay and Finike-Kumluca Plains on the west and east, respectively are nested in tectonic collapse areas. Outside these plains, the elevation toward inland rises abruptly to about 1,000 m asl (Figure 2).

The present climate in the study area is Mediterranean type with hot dry summers and mild wet winters (Köppen climate type of Csa). Precipitation falls mainly between November and April. Rainfall is the common type of precipitation in the coastal zone whereas snowfall is dominant above 2,000 m asl. Source of moisture in the study area is mostly the Atlantic Ocean and the Mediterranean Sea. Both orographic and frontal precipitation occur. The mean annual precipitation reduces from around 850 mm/year along the coastal zone to about 500 mm/ year in the intra-mountainous plain of Elmali (Figure 2) located around 1,000 m asl. The precipitation over mountains is around 1,200 mm/year. The mean annual air temperatures in the coastal zone is 20°C but, reduces to 13°C at about 1,000 m asl elevation.

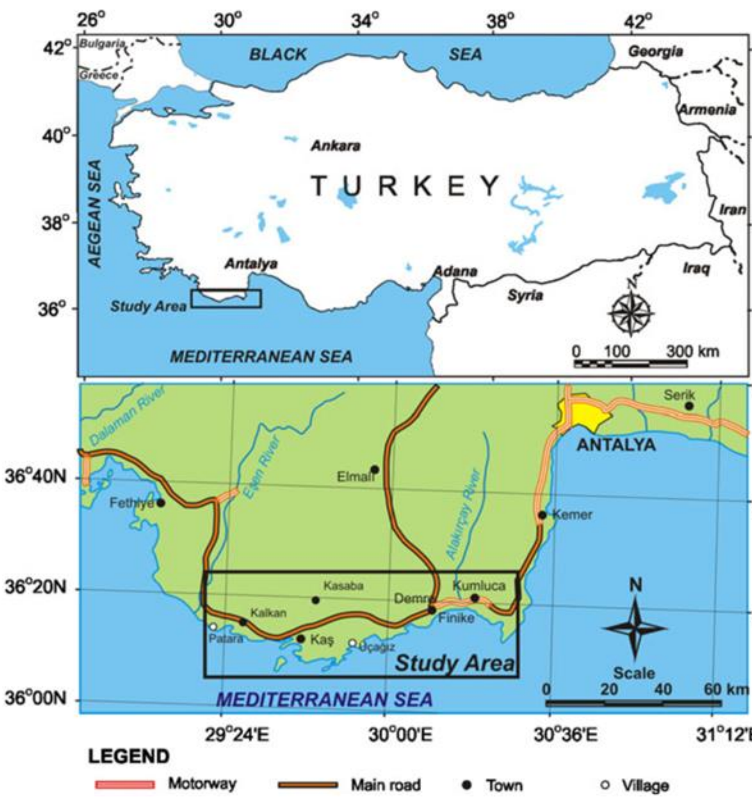

Figure 1. Location map of the study area (after Bayari *et al.* 2011)

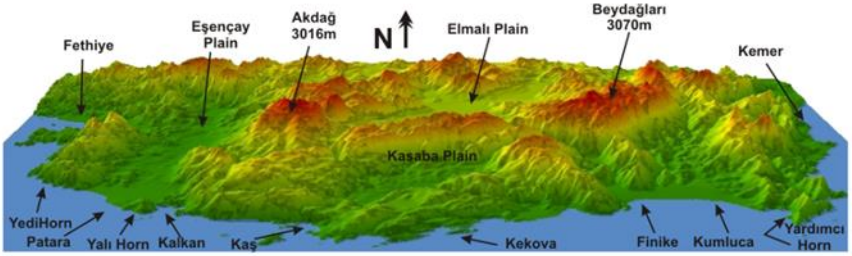

Figure 2. Digital elevation model showing the morphology beyond the coastal zone (after Bayari *et al.* 2011)

Geology

The geology of the study area comprises mainly of the Mesozoic-aged carbonate rocks with extensive karst development. The Taurus Mountains Belt is a part of the Alpine-Himalayan Orogeny, which is a result of the closure of the southern branch of the Neo-Tethys Ocean during the Miocene. The closure of the ocean has resulted in the over thrusting of several carbonate rock platforms onto each other which once nested side-by-side in the epicontinental ocean (Senel 1997a, b). Hence, the main components of the geological structure include a) Beydaglari Autochthonous, b) Western (Lycian) Nappes in the west and c) Eastern (Antalya) Nappes in the east. Both nappes thrusted over the Beydaglari Autochthonous by the end of the late Miocene. The autochthonous and allocthonous rock sequences comprise mainly of carbonate rocks (i.e. limestone and dolomite) with some intercalations of detritic and ophiolite rocks. The late Miocene-aged sandstone, claystone and siltstone is observed mainly in the center of the autochthonous. The intra-mountainous and coastal plains are covered by Plio-Quaternary deposits (Figure 3).

Hydrogeology

Two types of groundwater bearing media (i.e. aquifers) exist in the study area, the granular and the karst aquifers. Karst is a geomorphic term used for the distinctive surface and subsurface morphology of soluble rocks such as limestone and dolomite. The carbonate rocks of autochthonous and allocthonous sequences constitute prolific karst aquifers whereas the coarse-graded clastic rocks belonging to Miocene, Pliocene and Quaternary formations form the granular (non-karstic) aquifers. In the granular aquifers, the groundwater moves through the voids (pores) between the grains of rocks. The velocity of groundwater flow in granular aquifers is in the order of 1 m/year though, this value may vary within two orders of magnitude. In the case of karst aquifers, groundwater is transmitted mainly through dissolution channels, the diameters of which vary from a few mm to several tens of meters. Therefore, the velocity of groundwater flow in such large void systems (i.e. flow conduits) is much greater than it is in granular aquifers and may reach several kilometers per day.

Accordingly, karst aquifers feed the largest springs of the world. Fontaine de Vaucluse group of karst springs in southern France (Q= 21 m^3/sec), Kırkgöz karst springs in Antalya (Q= 18 m^3/sec) and Oymapınar spring under the reservoir of Oymapınar Dam in Manavgat (Q= 35 m^3/sec) are among the world-wide known major karst springs in the world.

Bayari *et al.* (2011) estimated that the mean annual karst groundwater discharge into the Mediterranean Sea is about 36 m^3/s. A considerable amount of this discharge is expected to occur through large karst conduits that eventually form coastal and submarine caves. More information on the hydrogeology of the study area and its vicinity can be obtained from Coskun (1978), DSI (1974), Elhatib and Günay (1998) and Elhatib (1992).

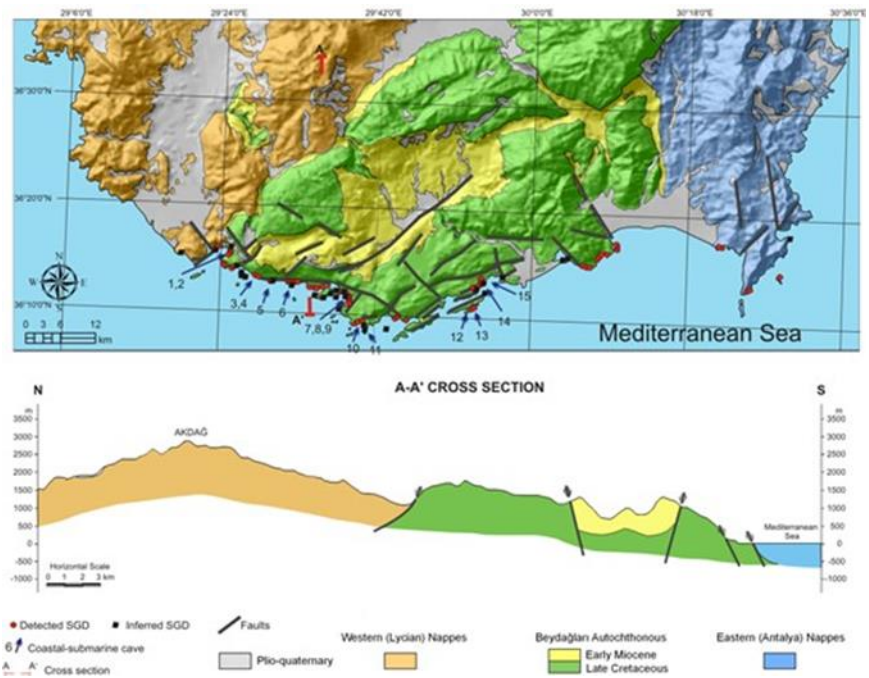

Figure 3. Outlines of the regional geology in the study area. The numbers indicate the discovered caves (after Bayari *et al.* 2011)

Data and methods

The potential locations of the previously unknown marine caves discharging groundwater in the study area have been explored based on the thermal anomaly between the temperatures of the groundwater and the seawater. Bayari *et al.* (2011) used the Landsat-TM satellite thermal images with 60 m spatial resolution (band 6) of the study area to determine the thermal anomaly sites along the coast line. Images taken on August were selected intentionally as the contrast between groundwater temperature (e.g. 15°C) and the seawater temperature (e.g. 25°C) is highest. Data obtained from satellite images used as a guide for surface explorations for which three diving teams of two to three members have been used to survey the 120-km long coastline for thermal (thermocline) and visual (halocline) evidence of submarine groundwater discharges coming out of the karst dissolution cavities. The diving teams explored different depth intervals of 0 to -10 m, -10 to -20 m, and - 20 to -30 m below sea surface. At each halocline and/or thermocline spot as sensed by diver synchronous water samples have been taken to determine the amount of karst groundwater in seawater. The coastal and submarine caves discovered have been explored in detail by later diving campaigns. The caves have been mapped according to the British Cave Research Association (BCRA) classification (Day 2002).

Factors affecting marine cave development

Dissolution mechanism

Dissolution of carbonate minerals leading to marine cave formation occurs through epigenetic (downward) or hypogenetic (upward) karst development processes. The epigenetic and hypogenetic karst systems are formed by carbonate-aggressive groundwater that flows downward and upward, respectively. Aggressively of groundwater is supplied mostly by dissolved carbon-dioxide which may be atmospheric, biogenic or geogenic. The hypogenetic karst development is, in general, associated with rising artesian groundwater (flowing upwards) systems which may or may not be linked to volcanism. The marine caves investigated in this paper are associated with epigenetic karst development.

Dissolution of calcite ($CaCO_3$), as an example of carbonate minerals, can be summarized by the following reaction.

$$CO_{2(g)} + H_2O + \quad aCO_3 \leftrightarrow Ca^{2+} + 2HCO_3^- \qquad (1)$$

As can be inferred from the equation, the amount of calcite dissolution depends mainly on the amount of carbon-dioxide (CO_2) supplied into the aqueous system. Typical dissolved carbon-dioxide partial pressure (P_{CO2}) of a solution in equilibrium with the atmosphere is about $10^{-3.5}$ atm. Biogenic P_{CO2} formed in the root zone of plants varies between $10^{-2.5}$ atm and $10^{-1.5}$ atm and the P_{CO2} formed by magmatogenic processes at depths of the earth's crust may exceed $10^{-0.5}$ atm. Eventually, the extent of carbonate mineral dissolution (and hence the karst development) is much greater in aqueous systems in equilibrium with geogenic CO_2 than those in equilibrium with biogenic CO_2 than those in equilibrium with atmospheric.

Regardless the source of CO_2 dissolved in water, a chemical equilibrium, s established between the P_{CO2} and the activity of the dissolved products of carbonate mineral (e.g. for calcite, calcium, Ca^{2+} and bicarbonate, HCO_3^- ions). At equilibrium, there will be no more carbonate mineral dissolution. However, if the conditions of the equilibrium are changed, the aqueous system seeks for a new equilibrium, which may require additional carbonate mineral dissolution or precipitation. Major conditions leading to a new chemical equilibrium include common ion effect, ionic enrichment effect and the temperature effect. Among them, ionic enrichment and temperature effects may force a solution which was previously in equilibrium with respect to a carbonate mineral, to dissolve more carbonate mineral. These effects are observed usually in mixing of two (or more) waters which are previously in equilibrium with the carbonate mineral. Because such a mixing results in a new dissolution (i.e. corrosion of carbonate mineral), it is called mixing corrosion (Wigley and Plummer 1976; Back *et al.* 1986).

Mixing corrosion is a common coastal and submarine geochemical process in the carbonate aquifers and occurs when waters (i.e. seawater and groundwater) with different P_{CO2} mix. Figure 4 shows the solubility of calcite in aqueous solution as a function of P_{CO2}. The line represents the equilibrium with calcite. Waters A and B are in equilibrium with calcite at their respective P_{CO2} values. Depending on the mixing rate, any mixture of these waters will be positioned somewhere on the dashed line which is under the equilibrium line. Hence, the mixture would dissolve the carbonate minerals with which it contacts. This process is the main reason of the conduit (eventually the cave) development in coastal zones.

Dissolution features in a coastal carbonate aquifer is depicted on Figure 5. The simple and biogenic corrosions occur on the rock surface and in the root zone due to the acidity provided by atmospheric and biogenic CO_2, respectively. Part of the biogenic CO_2 is transported to the water table by percolation and leads to horizontal dissolution along the water table due to the difference between the P_{CO2} of the groundwater and the percolating water from the surface/root zone (mixing corrosion). Seawater intrudes below the freshwater (groundwater, ρ= 1.000 kg/L) in the land because of its higher density (e.g. ρ= 1.022 kg/L). The interface between the fresh groundwater on the top and the seawater at the bottom is diffusive mixing zone where a new water with a salinity between those of fresh and salt water end members is formed. Under special circumstances controlled by the temperature, pH, salinity and the P_{CO2} of end members, the mixture water may regain aggressivity against carbonate minerals even though both members are in chemical equilibrium with respect to this mineral.

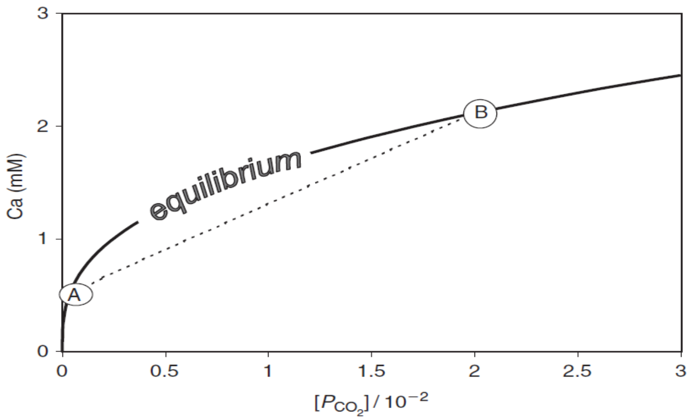

Figure 4. The “mixing corrosion curve” (after Appelo and Postma 2005)

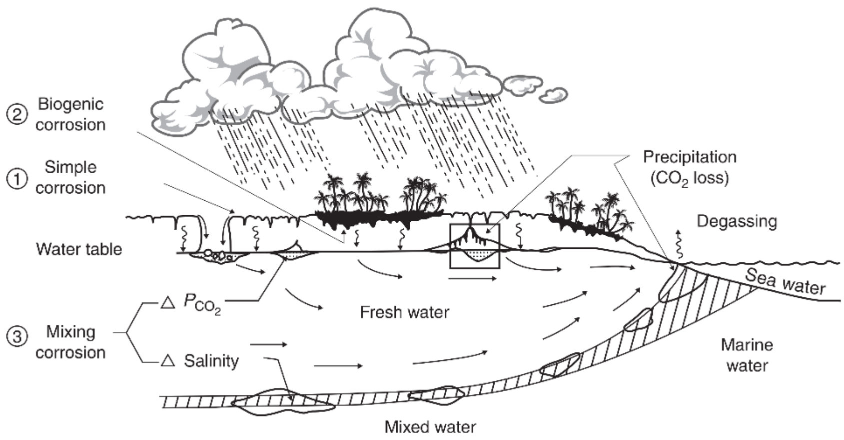

Figure 5. Dissolution features in a coastal carbonate aquifer (James and Choquette 1984; after Appelo and Postma 2005)

Sea level changes

The processes summarized above lead to the formation of karst conduits which may enlarge to become coastal and submarine caves. Unless high hydraulic conductivity zones do exist below the sea level, groundwater flows toward the sea between the water table and fresh water – salt water interface. Therefore, the sea level is the final elevation of the groundwater flowing into the sea. However, development of a cave from the beginning may take a period in the order of several tens of thousands years (Dreybrodt and Gabrovsek 2003; Kaufmann and Braun 2000). Sometimes, the evolution of the cave may take several million years. Yet, the global sea level has not been constant in geological time scale. Various geological processes such as glaciation and plate tectonics affect the global sea level. For example, Mediterranean Sea dried up completely for about 600,000 years during the “Messinian Salinity Crises” at about 5 million years ago (Hsü *et al*. 1977). The reason was the closure of Gibraltar between the Mediterranean Sea and Atlanic Ocean by the movements of the African and European tectonic plates. Furthermore, global sea level fluctuated substantially during the Quaternary glaciations that occurred during the last 2.8 million years. Present climate conditions and the global sea level was started to establish after the Last Glacial Maximum that occurred at about 20,000 years ago. Figure 6 shows that the global sea level declined many times up to 125 m below the present elevation during the last 800,000 years. In each glacial stage, the global sea level has declined because the moisture in atmosphere supplied from the oceans by evaporation has been locked in solid phase (i.e. the ice and snow) and has not returned to the ocean until a new inter-glacial stage started.

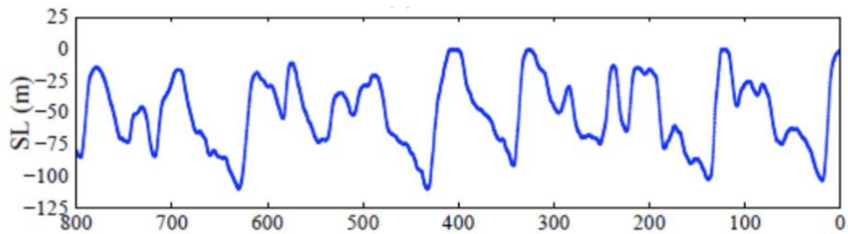

Figure 6. Global sea level change during the last 800 ka (after Bintanja *et al*. 2005). High sea level stands represent interglacial periods.

Marine caves in SW Turkey

Spatial distribution

Bayari *et al.* (2011) discovered, explored and mapped 14 caves between Kalkan town at the west and Kekova Island at the east of the surveyed coastal zone. Locations of these caves are shown on Figure 7 by a black dot with the letter M. The black dots without a letter indicate locations of karst conduits with sensible karst groundwater discharge. Currently, these conduits have not developed enough to allow for diver penetration. Moreover, the caves discovered may not be the all marine caves in the study area since the exploration depth has been limited to 30 m below the current sea level. Nevertheless, discovery of Gökhan Türe submarine cave in a depth of about 60 m below seat about 550 m offshore Kekova Island (Figure 8).

Locations of the discovered caves do not seem to be directly related to the lineaments detected from satellite images. About half of the caves discovered has not been associated with the known lineaments. The lineaments, most of which are fracture zones, may serve as high hydraulic conductivity zones along which the groundwater moves preferentially. However, the fractures with clay-rich fillings may serve also as impermeable boundaries against groundwater flow. Moreover, sensible groundwater discharges do not occur at all times of a year. Therefore, discovery of coastal and submarine caves in an area probably requires repeated surveys. Besides, discovery of caves located deeper than 30 m depths requires use of robotic submarine probes which can use salinity and temperature changes as the likely evidence of groundwater discharge coming out of a cave.

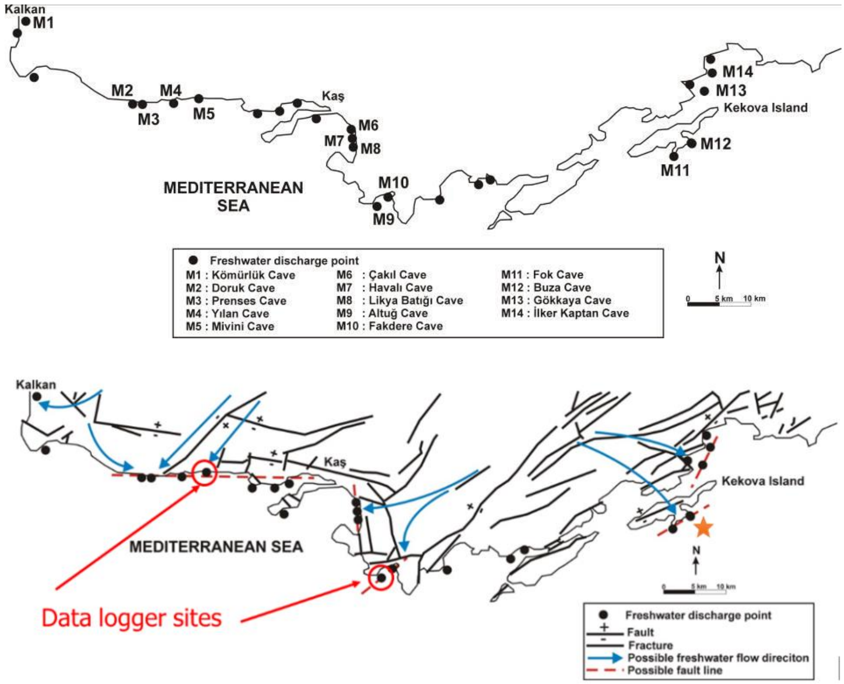

Figure 7. Locations of the marine caves between Kalkan town and Kekova island in SW Turkey. Star marks the location of Gökhan Türe Cave (modified after Bayarı and Özyurt 2008).

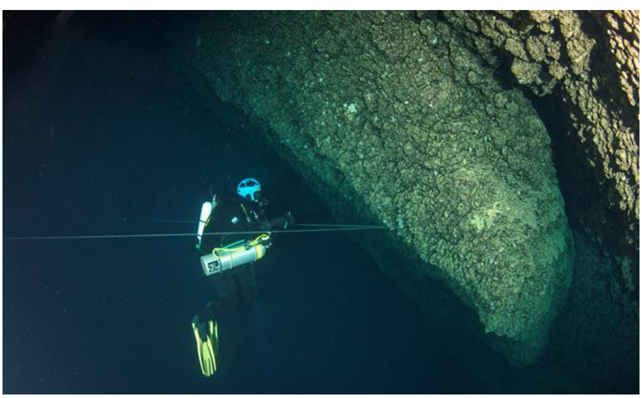

Figure 8. View of speleothems in Gökhan Türe Cave (photo courtesy of Ali Ethem Keskin)

Typical cave morphologies

The typical morphology of marine caves in the study area is explained by the selected cross-sections of Kömürlük (M1), Prenses (M3), Mivini (M5) and Altuğ (M9) caves (Figure 9). The morphology of each cave represent a different type of cave development. Kömürlük Cave (Figure 9a) is a typical water table cave which developed horizontally along the water table fluctuation zone (see Figure 5). Under proper conditions, mixing of seawater and fresh water (i.e. groundwater) results in a mixture which is aggressive with respect to carbonate minerals which dissolve eventually. Moreover, storm surges, changes in local and regional air pressures and the ebb-and-flow cause the sea level fluctuate. This fluctuation is transmitted accordingly to the water table elevation which change also due to recharge from ground surface (e.g. percolation from rainfall). Eventually, dissolution occurs within the entire zone of fluctuation. Dissolution zone serves as a high hydraulic conductivity zone that attract more recharge from the surface. Therefore, once an initial dissolution conduit develops, the later dissolution is more accelerated by the increasing amount of recharge from surface.

Prenses Cave (Figure 9b) seem to have developed by the so-called phreatic dissolution which occurs along the fractures in the saturated zone. The fracture zones serve as high-hydraulic conductivity conduits along which the groundwater moves faster that flow in the surrounding rock matrix. Groundwater’s physical and chemical properties (e.g. temperature, pH, saturation state with respect to carbonate minerals etc.) are affected by the velocity of flow. Therefore, mixing of groundwater flowing through the conduits and through the rock matrix may lead to the formation of a mixture which is aggressive with respect to the carbonate minerals surrounding the fractures. The 3-dimensional extent of the phreatic cave passages (i.e. conduits) depends on the geometry of fracture system. Such caves are characterized usually by the interconnection of the steeply-sloping (both upward and downward) passages.

Mivini Cave (Figure 9c, see mixing corrosion in Figure 5) represents a dissolution along the interface between the fresh water and the seawater. Such an interface extends typically toward the depths of inland. Mivini Cave, starting from about 10 m below sea level has been explored to a depth of – 80 m. Beyond this depth, the cave conduit narrows and do not allow for more penetration by divers.

Altuğ Cave (Figure 9d) has a typical morphology of caves developed inland. Currently, the entrance of the cave is located about 12 m below the present sea level. The deepest point reached in the cave is at about – 65 m. The upper 25 m of the cave is a chimney with a diameter of 1 m. Morphology of the caves is typical of caves developed in unsaturated zone by the aggressive percolation water coming from the root zone. The chimney may either be a result of roof collapse or be a sinkhole which used to receive surface runoff. The Taurus Mountains Range has been subject to since the start of neo-tectonic period at about 5 million years ago. Therefore, development of a land cave which is under present sea level today, the sea level at the time of cave formation must have been at least 70 m below the current sea level. This suggest that Altuğ Cave developed during one of the glacial periods of the Quaternary.

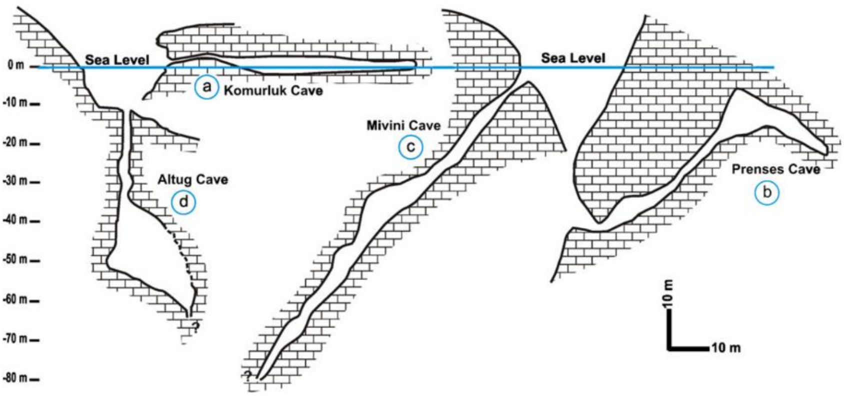

Figure 9. Cross-sections representing typical marine cave morphologies in SW Turkey (after Bayari *et al*. 2011)

Cave hydrogeology

Hydrogeochemistry

Bayari *et al.* (2011) measured the freshwater content in the seawater that is associated with the marine caves and karst conduits discharging cool groundwater. Specific conductance of seawater (55,000 microS/cm @ 25°C) and fresh groundwater (500 microS/cm @ 25°C). Fresh water content is calculated by the following equation,

%Fw Content=(Sample-Fresh water)/(Seawater-Sample)*100 (2)

where,

Sample, Fresh water and Seawater are the specific conductance measured in microS/cm @ 25°. Freshwater content of the seawater in the marine caves and associated karst conduits are spatio-temporally variable. In other words, the freshwater content does not vary only between the spots but also vary in time in a specific spot. In the Mediterranean climate zone of Turkey, August is the middle of the dry season and November is the beginning of wet season. Under usual circumstances the groundwater outflow into the sea should be at minimum in August and more groundwater outflow should occur in November compared to August. Figure 10 shows that, the fresh water content is greater in November or equal to August rate in many of the spots investigated. However, is a few spots, the freshwater content in August is greater than that in November. This is probably because the recharge from recent precipitation has not yet reached these spots. The freshwater contribution rates in these caves have not been extremely variable which is an indication of the discontinuity of large conduit systems towards inland.

Bayari *et al.* (2011) employed several geochemical modeling tests to better understand the nature of marine cave development in carbonate rock aquifers. In the models typical fresh water and seawater major ions compositions are used and 3 cases of different water temperatures have been tested. The seawater and groundwater temperatures during the spring have been assumed to be 25°C and 15°C, respectively. During the winter and summer water temperatures have been assumed to be 15°C for both type of waters. Models tests have been conducted for freshwater contribution rates varying between 10% and 90% with 10% increments. Results are shown on Figure 11 as "Saturation Index_Calcite" and as "pH of mixture". Saturation Index_Calcite (i.e. SI) indicates the tendency of the mixture with respect to calcite mineral. Positive and negative values show that the mixture would tend to precipitate or dissolve calcite, respectively. The dots on Figure 11 indicates that position of water samples collected from marine caves and conduits. Results of geochemical models indicate that the amount of fresh water contribution should be about 60% or higher in order for an effective dissolution of carbonate minerals so that the marine caves and karst conduits can develop effectively. The "pH of mixture" calculated by the models has also been in agreement with the field data that a pH of 7.6 or lower is required for effective conduit development that can lead to a cave formation.

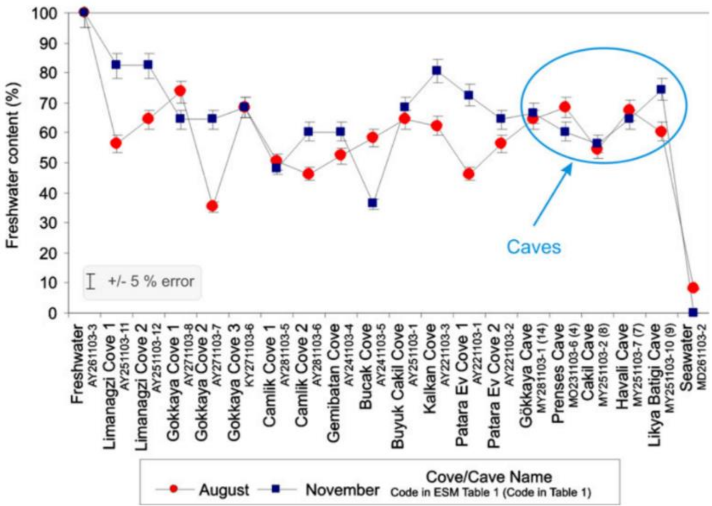

Figure 10. Fresh water content of the water samples collected from marine caves and karst conduits (after Bayari *et al*. 2011)

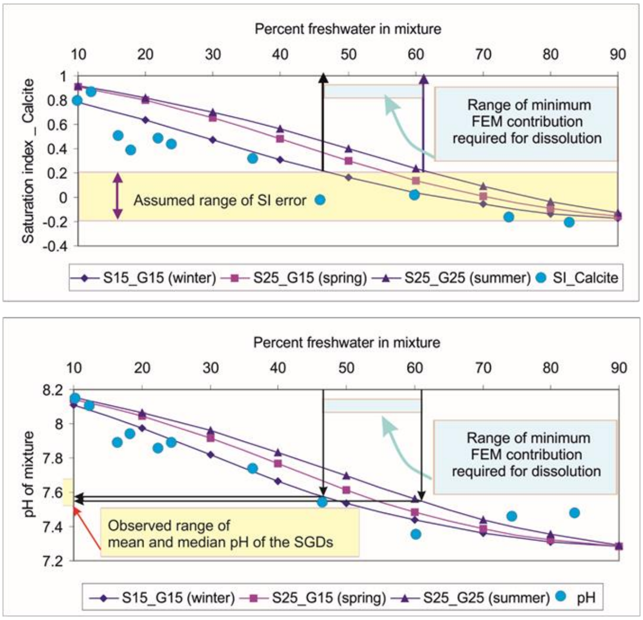

Figure 11. Effect of fresh water contribution rate on the marine cave/conduit development (after Bayari *et al.* 2011)

Hydrodynamics of groundwater outflow

Bayari *et al.* (2011) used submersible data loggers to monitor the hydrodynamics of groundwater outflow in two of the caves they explored. Data loggers were placed by divers in Altuğ and Mivini caves at depths of 28 m and 21 m below sea level, respectively. The loggers were set to collect specific conductance and temperature of seawater for every 15 minutes in the period of 14 November 2004 and 28 August 2005. The long term variation of specific conductance and temperature in these caves suggest clearly that the mixing dynamics of seawater and fresh groundwater in these caves differ remarkably (Figure 12). The specific conductance and temperature values in Altuğ Cave declined from November to late April and then started to rise toward August. This variation is in agreement with the recharge-discharge dynamics of the groundwater system in the study area where effective recharge of the aquifer is realized from mid-autumn to mid-spring. As more recharge from recent precipitation contributes to the mixed water in cave, the temperature and specific conductance values decrease accordingly because recent recharge has low temperature and specific conductance values. When the contribution from recent recharge declines, both the temperature and the specific conductance values of seawater in the cave start to rise after mid-spring.

The situation in Mivini Cave in terms of temporal temperature and specific conductance values differs substantially from that in Altuğ Cave. In this cave, both signals exhibit a periodic oscillation which becomes more evident after late April. Spectral analyses of the showed that these variations are governed by combined effect of the earth tides and the recharge over the aquifer (Bayari and Özyurt 2014). Earth tides, like sea tides (i.e. ebb and flow), are controlled by the gravitational attraction between the earth and, the sun and moon. Moon and sun are responsible for about 2/3 and 1/3 of this attraction, respectively.

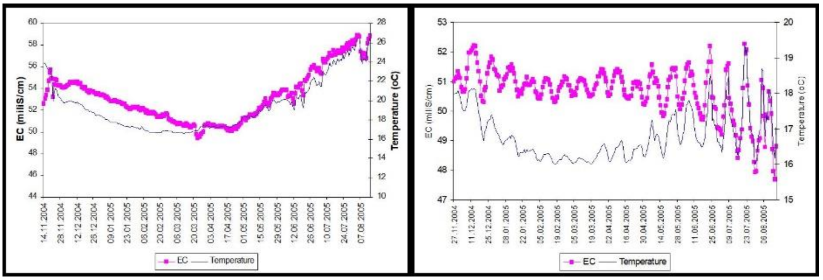

Figure 12. Temporal variation of specific conductance and temperature of the seawater in Altuğ (left) and Mivini (right) caves (after Bayari and Ozyurt 2008)

The horizontal component of the tide generating force (TDF) causes the deformation of earth's crust so that, as in the case of sea tides, the crust moves up and down. This movement results in hydrostatic pressure oscillations in large-scale confined groundwater systems in a manner that the aquifer behaves like a sponge which release water when squeezed and sucks water when released. Furthermore, the recharge (e.g. annual precipitation fallen on ground) over the aquifer forces the earth's crust to sink isostatically in astonosphere (i.e. the magma) as the total mass of crust is increased. The force generated by the recharge is named as recharge load (RL). The TDF and RL affects the aquifer in opposing ways so that a new variable called, aquifer deformation factor (ADF), can be described as follows.

$$ADF=TDF/RL \quad (3)$$

As seen from Figure 13 which shows the temporal variation of ADF and % freshwater in Mivini Cave, both variables are correlated perfectly well. This shows that there are other factors that control the temporal dynamics of fresh water content of seawater in the marine caves and conduit systems. Such processes may be important particularly deep sea caves where encountering with confined groundwater discharges are more likely.

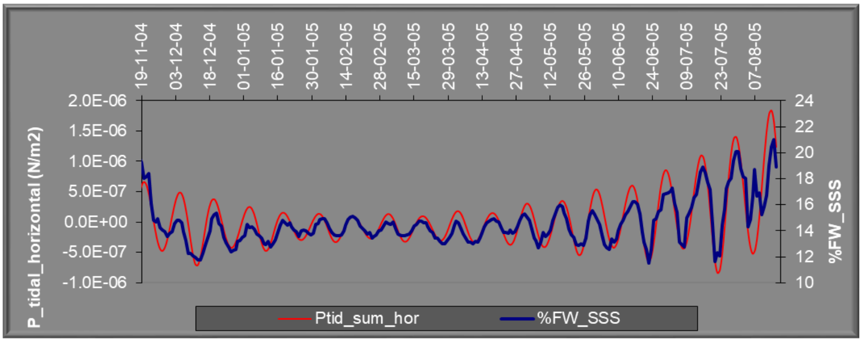

Figure 13. Correlation between the aquifer deformation factor and the fresh water content of seawater in Mivini Cave (modified after Bayari and Özyurt 2014)

Conclusions and Outlook

Little is known about the coastal and submarine caves which are important sites for marine ecosystems. This is mainly because of the difficulties and risks of underwater exploration. These caves may also serve as important elements of the coastal groundwater systems. Basic properties of marine karst caves along the SW coast of Turkey have been determined by means of systematic observations. It is understood that a) development of these caves require specific hydrogeochemical conditions, b) their location depends on the past sea level changes, c) their spatial distribution is controlled by numerous factors which are difficult to classify, d) different cave morphologies are associated with the different types of dissolution media, e) hydrodynamics of groundwater outflow in marine caves and karst conduits is controlled not only by the annual recharge distribution but also by the earth tides. Hydrogeochemical modeling tests showed that the pH of groundwater and seawater mixture should be below about 7.6 in order to initialize the carbonate rock dissolution that could lead to marine cave formation. Some of the marine caves are formed at the fresh groundwater and seawater interface and hence their locations have been determined by the past sea level which varied temporally due particularly to glacial climate conditions. Field observations suggest that the factors affecting the location of a cave are difficult to ascertain. The faults and joints that collect groundwater flow on themselves are known to ease cave formation. However, not all of the hydraulically more conductive faults and joints turn into dissolution conduits since many other factors affect the regional hydrogeological conditions. It has been revealed that the morphology of caves is associated certainly with the dissolution media. In general, horizontal caves are developed along the water table whereas those dipping towards land from the past/present coastline are developed along the interface between fresh groundwater and seawater. The hydrodynamics of groundwater flow leading to marine cave formation is complicated. Amount of the groundwater flow reaching marine caves is controlled generally by timing of the seasonal recharge from the precipitation. New observations reveal that periodic deformation of the confined aquifers by earth tides may cause a cyclic variation in the amount of groundwater reaching at marine caves.

Results of previous studies reveal that a systematic surveying of the coastline by snorkelers and divers is probably the best approach in precisely determining the locations of coastal and submarine caves and conduits. Such studies could be supported or enhanced by the remotely operated diving vehicles equipped with salinity, temperature or other types of sensors. Extensive use of data loggers seems to be an essential part of the future studies.

Acknowledgement

The findings and ideas presented in this paper are the results of long-lasting studies conducted with the support of many people and institutions. Authors thank to the Scientific and Technical Research Council of Turkey (Grant no. CAYDAG-103Y025), Hacettepe University Research Fund (Grant no: 01G013), International Atomic Energy Agency (Grant no: RC 12570.). Support of many divers from Underwater Research Society of Turkey, SAD) and Underwater Society of the Middle East Technical University, METU-SAT) to the field works are acknowledged.

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Macrophytobenthos of the Turkish marine caves

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Introduction

The European Union (EU) has identified and classified a number of different marine habitats types (sandbanks, *Posidonia oceanica* beds, estuaries, mudflats and sand-flats, coastal lagoons, bays, reefs, etc.) within the Habitats Directive (92/43/EEC; code 8330) (Giakoumi *et al.* 2013). Marine caves (submerged or partially submerged sea caves) are also a habitat type, listed in the EU Habitats Directive. Dark Habitats (underwater caves, canyons, aphotic hard beds and chemosynthetic phenomena) are acknowledged as delicate and sensitive environments requiring protection (Directive 92/43/EEC). Such habitats can be considered as full-fledged vessels for biodiversity, hence the need for further attention and for enhanced protection (UNEP RAC/SPA 2015).

Submarine caves are semi-closed subsystems within the marine littoral ecosystem (Gili *et al.* 1986). Marine caves are hosting different kinds of sciaphilic communities; coralligenous algae at the entrance of the caves, sessile filter-feeding invertebrates in semi-dark zone and dark zone with sponges, polychaetes and bryozoans (UNEP RAC/SPA 2017). Semi-sciaphilic and coralligenous algae are found abundantly in the semi-dark and dark assemblages (Riedl 1966). Two habitats (semi-dark cave and dark caves) are especially known in Mediterranean marine caves (MMC) (Pérès and Picard 1964; Pérès 1967).

About 4000 marine caves were previously reported in the Mediterranean Sea. To date, 738 marine caves have been recorded in the eastern Mediterranean (Giakoumi *et al.* 2013; Gerovasileiou *et al.* 2015). Aside from shallow caves, SCUBA diving is usually used for mapping and inventorying marine caves. Unlike the flora of Mediterranean marine caves (Alongi *et al.* 2012), the faunal composition was abundantly studied within MMC. Two macrophytobenthic communities (photophilic and sciaphilic communities) are defined according to the ambient luminance. Photophilic algae (i.e. brown alga *Cystoseira* spp., green alga *Ulva* spp., red alga *Porphyra*) are commonly found in well-illuminated habitats, whereas sciaphilic or semi-sciaphilic algae (i.e. brown alga *Lobophora* *variegata*, green alga *Flabellia petiolata*, and red alga *Peyssonnelia* spp.) are observed in less illuminated habitats (marine caves, canyons, deep sea, etc.).

Lazaridou and Charitonidis (1993; 68 taxa from Milos Island identified) have undertaken several studies on macrophytobenthic communities within marine caves in the Mediterranean Sea. Arko-Pijevac *et al.* (2001) studied a submarine cave at the Island of Krk in Croatia (North Adriatic Sea). As a result, 23 macro-flora taxa were described (10 red algae, 7 brown algae, and 6 green algae).

Marti *et al.* (2004) investigated the biodiversity of two marine caves in the north-western part of the Mediterranean Sea. As such, 50 taxa (13 Phaeophyceae, 26 Rhodophyta and 11 Chlorophyta) were recorded. Alongi *et al.* (2012) reported phytobenthic assemblages within submerged marine caves in Maddalena Peninsula and on Pelagean Islands in Italy. In total 95 taxa (14 Phaeophyceae, 71 Rhodophyta and 10 Chlorophyta) were inventoried in both Maddalena Peninsula and Pelagean Islands.

Gerovasileiou *et al.* (2016) reported 56 faunal and floral alien species from the Mediterranean marine caves, and then most alien species from Lebanese caves were recorded. Overall Gerovasileiou *et al.* (2015) recently described 520 taxa belonging to 34 groups in the eastern Mediterranean marine caves. Gerovasileiou *et al.* (2015) reported that 78 macro-algal taxa (18 Phaeophyceae, 53 Rhodophyta and 7 Chlorophyta) inhabited the eastern Mediterranean marine caves. 46 taxa belonging to 9 higher taxonomic groups were recorded in a semi-submerged marine cave located in the eastern part of the Mediterranean Sea (North Aegean Sea) by Dimarchopoulou *et al.* (2018). Consequently, 9 marine algal taxa were identified (2 Chlorophyta, 2 Ochrophyta, 5 Rhodophyta) within the research area.

Macrobenthic flora in the Turkish marine caves

Macrophytobenthic communities (marine algae and angiosperms) were mostly investigated in the mediolittoral and infralittoral areas of Turkish coasts, they are known for their photophilic algae's biocoenosis. In contrast, the benthic flora of marine caves in Turkey were less studied (statement also valid for dark habitats). Sea Caves, Flank Margin Caves and Tufa Caves of Antalya (Mediterranean coasts of Turkey) were studied by Dipova and Okudan (2011). Sea caves from the coast of Antalya are depicted in Figure 1a-b, with its hemi-sciaphilic macroalgal vegetation, predominantly composed by the coralline red (Rhodophyta) *Jania rubens, Phymatolithon lenormandii*, *Corallina officinalis*, *Ellisolandia elongata,* and others. *Peyssonnelia* spp. are common in sea caves from Foça and Aliağa, along with sponge communities (Figure 1c-d). Coralligenous habitats are ubiquitous in the Mediterranean Sea, highly productive and rich in terms of biodiversity. Sciaphilous coralline algae are abundant in these coralligenous habitats (Taşkın 2015). Sciaphilous coralline red algae *Lithophyllum stictaeforme*, *Mesophyllum alternans*, *M. expansum*, and *Peyssonnelia polymorpha* were reported in the Aegean coasts by Taşkın (2015).

In the present study, 79 taxa of marine benthic macroalgae in Turkish marine caves are reported, at specific and infraspecific level. Among them, 9 are brown algae (Phaeophyceae) (11%), 58 belong to red algae (Rhodophyta) (74%) and 12 are affiliated to green algae (Chlorophyta) (15%) (Table 1, Figure 2). In total 668 marine benthic macroalgae [165 Phaeophyceae (brown algae), 378 Rhodophyta (red algae) and 125 Chlorophyta (green algae)] were reported in Turkey (Taşkın *et al.* 2019). Subsequently, the present study underlines the fact that 11.83% of the Turkish macrophytobenthos is contained in Turkish marine caves.

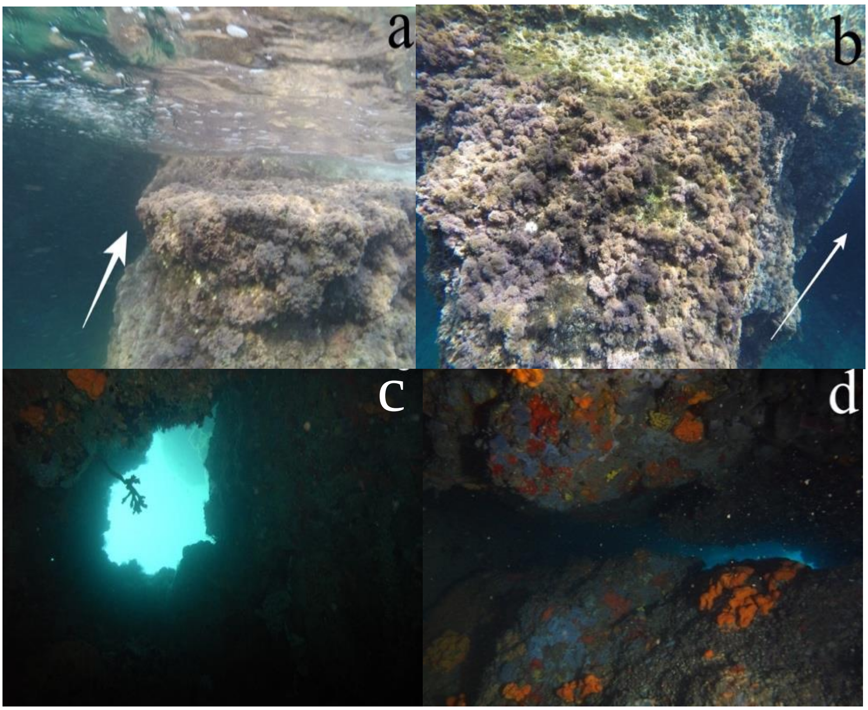

Figure 1. Hemi-sciaphilic red alga *Corallina officinalis* **(a)**, and *Jania rubens* **(b)** in marine caves from Antalya's coasts (Turkey). Sciaphilic communities in marine caves from Foça **(c)** and Aliağa **(d)** coasts in Izmir (Turkey).

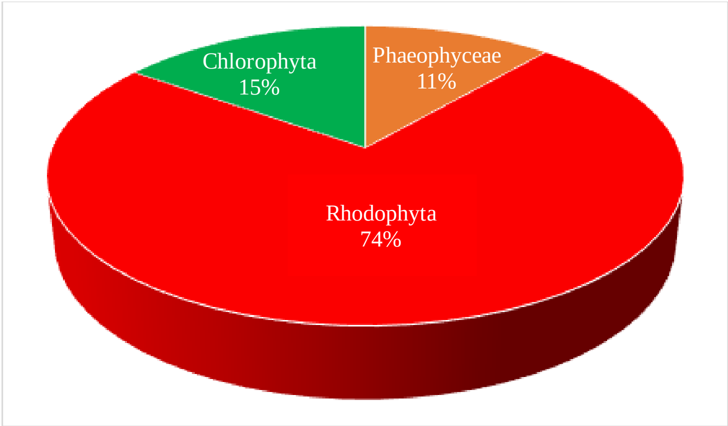

Figure 2. Percentage (%) of marine caves' macrobenthic algal flora in Turkey

Table 1. Inventory of macrophytobenthos taxa in Turkish marine caves

PHAEOPHYCEAE (BROWN ALGAE)
Dictyotales
Dictyotaceae
Dictyota dichotoma (Hudson) J.V.Lamouroux
Lobophora variegata (J.V.Lamouroux) Womersley ex E.C.Oliveira
Padina pavonica (Linnaeus) Thivy
Stypopodium schimperi (Kützing) M.Verlaque & Boudourosque*
Discosporangiales
Discosporangiaceae
Discosporangium mesarthrocarpum (Meneghini) Hauck
Sphacelariales
Sphacelariaceae
Sphacelaria cirrosa (Roth) C.Agardh
Stypocaulaceae
Halopteris filicina (Grateloup) Kützing
Tilopteridales
Cutleriaceae
Cutleria chilosa (Falkenberg) P.C.Silva
Zanardinia typus (Nardo) P.C.Silva
RHODOPHYTA (RED ALGAE)
Bonnemaisoniales
Bonnemaisoniaceae
Asparagopsis armata Harvey*
Ceramiales
Callithamniaceae
Aglaothamnion tenuissimum (Bonnemaison) Feldmann-Mazoyer
Callithamnion corymbosum (J.E.Smith) Lyngbye
Crouania attenuata (C.Agardh) J.Agardh
Ceramiaceae
Antithamnion cruciatum (C.Agardh) Nägeli

Table 1. Continued

Ceramium codii (H.Richards) G.Mazoyer
Spyridia filamentosa (Wulfen) Harvey
Dasyaceae
Dasya rigidula (Kützing) Ardissone
Eupogodon planus (C.Agardh) Kützing
Heterosiphonia crispella (C.Agardh) M.J.Wynne
Delesseriaceae
Acrosorium ciliolatum (Harvey) Kylin
Hypoglossum hypoglossoides (Stackhouse) F.Collins & Hervey
Myriogramme minuta Kylin
Rhodomelaceae
Herposiphonia secunda (C. Agardh) Ambronn f. *secunda*
Herposiphonia secunda f. *tenella* (C.Agardh) M.J.Wynne
Lophosiphonia obscura (C.Agardh) Falkenberg
Polysiphonia atra Zanardini
Polysiphonia scopulorum Harvey
Wrangeliaceae
Anotrichium tenue (C.Agardh) Nägeli
Lejolisia mediterranea Bornet
Monosporus pedicellatus (J.E.Smith) Solier
Ptilothamnion pluma (Dillwyn) Thuret
Corallinales
Corallinaceae
Amphiroa rigida J.V.Lamouroux
Corallina officinalis Linnaeus
Ellisolandia elongata (J.Ellis & Solander) K.R.Hind & G.W.Saunders
Hydrolithon farinosum (J.V. Lamour.) D. Penrose & Y.M. Chamberlain
Jania adhaerens J.V.Lamouroux
Jania rubens (Linnaeus) J.V.Lamouroux
Lithophyllum stictiforme (Areschoug) Hauck
Pneophyllum confervicola (Kützing) Y.M.Chamberlain
Pneophyllum fragile Kützing
Erythropeltales
Erythrotrichiaceae
Erythrotrichia carnea (Dillwyn) J.Agardh
Gelidiales
Gelidiaceae
Gelidium serra (S.G.Gmelin) E.Taşkın & M.J.Wynne
Gigartinales
Kallymeniaceae
Kallymenia requienii (J.Agardh) J.Agardh
Meredithia microphylla (J.Agardh) J.Agardh
Halymeniales
Halymeniaceae
Acrodiscus vidovichii (Meneghini) Zanardini
Hapalidiales
Mesophyllaceae
Mesophyllum alternans (Foslie) Cabioch & M.L.Mendoza
Mesophyllum expansum (Philippi) Cabioch & M.L.Mendoza

Table 1. Continued

Mesophyllum lichenoides (J.Ellis) Me.Lemoine
Nemaliales
Galaxauraceae
Tricleocarpa cylindrica (J.Ellis & Sol.) Huisman & Borowitzka
Tricleocarpa fragilis (Linnaeus) Huisman & R.A.Townsend
Peyssonneliales
Peyssonneliaceae
Metapeyssonnelia feldmannii Boudouresque, Coppejans & Marcot
Peyssonnelia armorica (P.Crouan & H.Crouan) Weber Bosse
Peyssonnelia bornetii Boudouresque & Denizot
Peyssonnelia coriacea Feldmann
Peyssonnelia crispata Boudouresque & Denizot
Peyssonnelia dubyi P.Crouan & H.Crouan
Peyssonnelia harveyana P.Crouan & H.Crouan ex J.Agardh
Peyssonnelia heteromorpha (Zanardini) Athanasiadis
Peyssonnelia orientalis (Weber Bosse) Cormaci & G.Furnari
Peyssonnelia rosa-marina Boudouresque & Denizot
Peyssonnelia rubra (Greville) J.Agardh
Peyssonnelia squamaria (S.G.Gmelin) Decaisne
Rhodymeniales
Rhodymeniaceae
Botryocladia chiajeana (Meneghini) Kylin
Irvinea boergesenii (Feldmann) R.J.Wilkes, L.M.McIvor & Guiry
Rhodymenia ardissonei (Kuntze) G.Feldmann
Stylonematales
Stylonemataceae
Chroodactylon ornatum (C.Agardh) Basson
Stylonema alsidii (Zanardini) K.M.Drew
CHLOROPHYTA (GREEN ALGAE)
Bryopsidales
Caulerpaceae
Caulerpa cylindracea Sonder*
Codiaceae
Codium bursa (Olivi) C.Agardh
Derbesiaceae
Derbesia tenuissima (Moris & De Notaris.) P.L.Crouan
Pedobesia simplex (Meneghini *ex* Kützing) M.J.Wynne & F.Leliaert
Halimedaceae
Halimeda tuna (J.Ellis & Solander) J.V.Lamouroux
Udoteaceae
Flabellia petiolata (Turra) Nizam.
Pseudochlorodesmis furcellata (Zanardini) Børgesen
Cladophorales
Anadyomenaceae
Anadyomene stellata (Wulfen) C.Agardh
Cladophoraceae
Cladophora prolifera (Roth) Kützing
Lychaete pellucida (Hudson) M.J.Wynne
Valoniaceae

Table 1. Continued

Valonia utriculosa (Roth) C.Agardh
Palmophyllales
Palmophyllaceae
Palmophyllum crassum (Naccari) Rabenh.

*Alien species

Alien species classified as Phaeophyceae, such as *Stypopodium schimperi,* the red alga *Asparagopsis taxiformis*, and the Chlorophyta *Caulerpa cylindracea* were found in marine located alongside Aegean and Mediterranean coasts in Turkish waters. These species are found in both the illuminated and the less illuminated habitats. *C. cylindracea* was found with the sciaphilic brown alga *Lobophora varigeata* on the red calcareous alga *Mesophyllum alternans* (Figure 3a). *S. schimperi, A. taxiformis*, and *C. cylindracea* are widespread alongside Aegean coasts in Turkey and display in fact invasive behaviours (Taşkın 2015). Marine macroalgae are common in semi-dark caves and around their entrances in Turkey.

Sciaphilic brown macroalgal vegetation in Turkish marine caves are well represented by the following families; Dictyotaceae (*Dictyota dichotoma*, *Padina pavonica*, etc.), Discosporangiaceae (*Discosporangium mesarthrocarpum*), Sphacelariaceae (*Sphacelaria cirrosa*), Stypocaulaceae (*Halopteris filicina*), and Cutleriaceae (*Cutleria chilosa*, *Zanardinia typus*). In opposition, two species were found scarcely in Turkish marine coasts. ***Lobophora varigeata***; thalli decumbent to erect, arising from a matted rhizoidal holdfast, up to 20 cm long, with broadly flabellate to irregularly laterally branched fronds. Growth is initiated via apical cells, organised in complete row. This species was found on the red calcareous alga *Mesophyllum alternans* (Figure 3a). ***Zanardinia typus***; thallus flat, membranous, transparent, margins entire but with slippery hairs, olive brown to dark brown, 5-10 cm in diameter (Figure 3b).

Sciaphilic green macroalgal vegetation in Turkish marine caves are represented by the order of Bryopsidales (*Caulerpa cylindraceae*, *Derbesia tenuissima, Pedobesia simplex,* etc.), Cladophorales (*Anadyomene stellata*, *Cladophora prolifera*, *Lychaete pellucida*), and Palmophyllales (*Palmophyllum crassum*). The green algae *Flabellia petiolata* (Figure 4a), *Halimeda tuna* (Figure 4b), and *Codium bursa* (Figure 4c) are found in the less illuminated habitats. ***Derbesia tenuissima***; thallus heteromorphic; sporophyte (erect, filamentous, 1-4 cm long) and gametophyte (*Halicyctis parvula*: globosus, or oval, to 5mm in diameter, fixed by a short stalk that penetrates the calcified thallus crusty Corallinales). ***Palmophyllum crassum***; prostrate crustose thalli, fully adhered to the substrate or free, rounded or lobed margins, up to 20 cm in diameter. Macroalgae of Turkish marine caves are mostly represented by red algae (Rhodophyta) in terms of species richness and abundance. Sciaphilic red macroalgal vegetation in

Turkish marine caves are represented by the order of Bonnemaisoniales, Ceramiales (*Callithamnion corymbosum, Crouania attenuata, Ceramium codii, Eupogodon planus, Acrosorium ciliolatum, Lophosiphonia obscura, Monosporus pedicellatus,* etc.), Corallinales (*Amphiroa rigida*, *Corallina officinalis*, *Jania* spp., etc.), Erythropeltales (*Erythrotrichia carnea*), Gelidiales (*Gelidium serra*), Gigartinales (i.e. *Kallymenia requienii*), Halymeniales (*Acrodiscus vidovichii*), Hapalidiales (*Mesophyllum* spp.), Nemaliales (*Tricleocarpa* spp.), Peyssonneliales (*Peyssonnelia* spp.), Rhodymeniales (i.e. *Botryocladia chiajeana*), and Stylonematales (*Chroodactylon ornatum, Stylonema alsidii*). Red coralligenous algae such as *Peyssonnelia* spp. (Figure 4d) and *Mesophyllum* spp. (Figures 3a, 4f) are predominant in marine caves. Two species are also common in the semi-dark habitats: *Acrodiscus vidovichii* and *Meredithia microphylla*. ***Acrodiscus vidovichii***; thallus sporophyte erect, band-like, gregarious, rigid, 10 cm long, dark red, cartilaginosus, irregularly dichotomous branching, structure pseudoparenchimotous multiaxial. ***Meredithia microphylla***; thallus gametophyte erect, laminar, to 20 cm long, dark red, pink or brown, lobe to 5 cm large, 2 cm in diametre, structure pseudoparenchimotous multiaxial (Figure 4e).

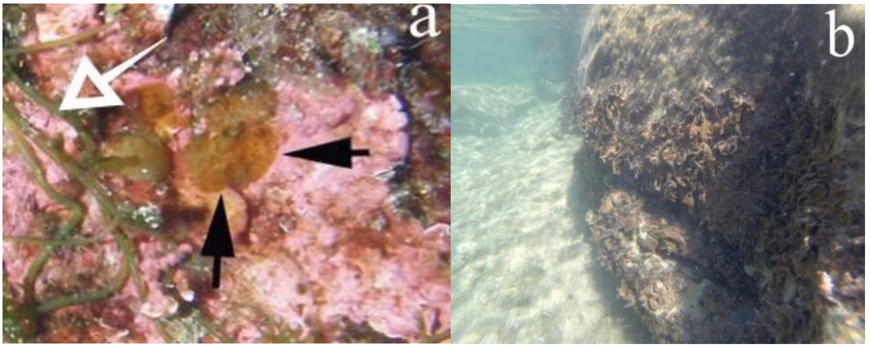

Figure 3. Sciaphilic brown alga *Lobophora varigeata* shown in black arrows, green alga *Caulerpa cylindracea* indicated with an empty arrow, and red alga *Mesophyllum alternans* **(a)** in the background. *Sciaphilic* brown alga *Zanardinia typus* **(b)**.

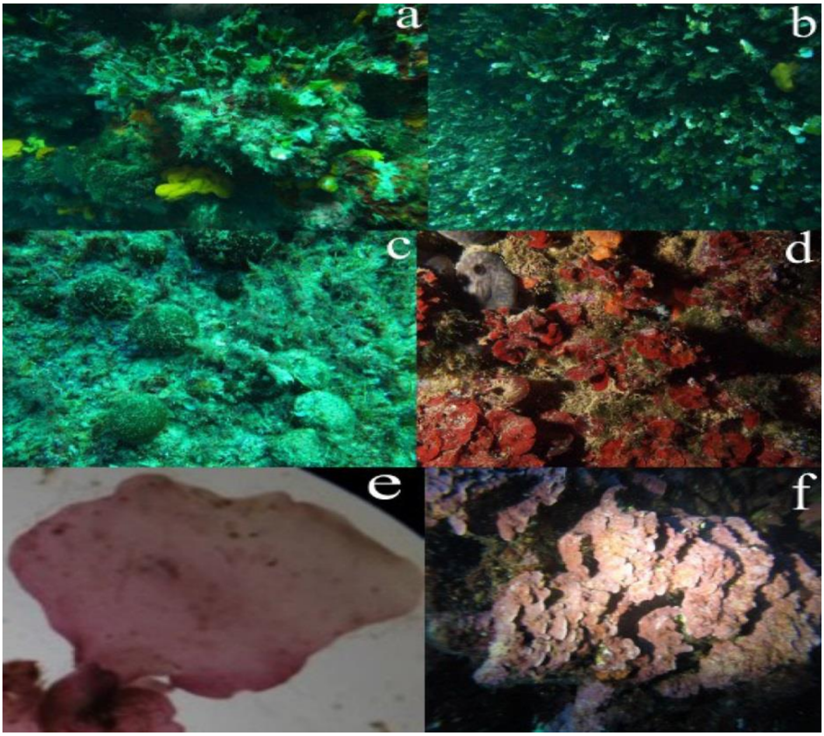

Figure 4. Sciaphilic green algae *Flabellia petiolata* **(a)**, *Halimeda tuna* **(b)**, and *Codium bursa* **(c)**. Sciaphilic red algae *Peyssonnelia rubra* **(d)**, *Meredithia microphylla* **(e)**, and *Mesophyllum expansum* **(f)**.

Conclusion

The macroalgal diversity of Turkish marine caves have been less studied in comparison with marine caves from other Mediterranean coastal areas, thus a greater endeavour is required to study this dark habitat in more details. Marine caves and dark habitats have important ecosystemical functions as they have a fragile, special and sensitive structure. Therefore, their distribution should be mapped, inventory studies should be performed and monitoring programs should be established. Necessary measures and programs should be secured for the protection of these structures. Due to their importance, "The Action Plan for the conservation of habitats and species associated with seamounts, underwater caves and canyons, aphotic hard beds and chemosynthetic phenomena in the Mediterranean Sea" was adopted in the Eighteenth Ordinary Meeting of the Contracting Parties to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its Protocols (UNEP MAP 2013). According to this protocol, developing conservation plans for these habitats, building appropriate legislative measures, establishing scientific databases and maintaining public awareness have to be achieved at a national level.

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Macrozoobenthic invertebrates in three submarine caves of the Aegean Sea: Preliminary results

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Introduction

Submarine caves represent a set of habitats of specific species assemblages and thus are considered as priority habitats by the EU Habitats Directive and/or the Barcelona Convention (Giakoumi *et al*. 2013). The exposure of light through the exterior-interior axis of marine caves leads to the creation of special ecological conditions that allow different marine species to settle down (Harmelin 1985). Pérès & Picard (1964) classified cave benthos as “semi-obscure” (=semi-dark) and “obscure” (=dark) communities, in relation with the light penetration into the horizontal axis of caves. Nowadays, submarine caves can be mainly categorized into three zones, gate (entrance) zone, semi-dark zone and dark zone (Martí *et al*. 2004). In each zone, different species assemblages are formed by prevailing biotic and abiotic factors. Species richness and coverages represent a decreasing gradient along the outside-inside axis of caves (Harmelin *et al*. 1985; Gili *et al*. 1986; Gerovasileiou *et al*. 2014). The species richness near the cave entrances is similar to that of cliffs and overhangs, and often decreasing even to zero in long caves (Harmelin *et al*. 1985).

Submarine caves are wide-spread across the Mediterranean Sea, but have been poorly studied when compared to other shallow-water formations. However, biota compositions of marine caves in the western Mediterranean Sea are relatively well known. Some sporadic attempts were performed to elucidate macro-benthic species diversity of marine caves in the eastern Mediterranean Sea (e.g. Laborel, 1961; Ben-Eliahu and ten Hove 1992). However, in recent years, some promising initiatives have been implemented to shed light on benthic community structures of marine caves in the region, especially in the Aegean Sea (Gerovasileiou and Voultsiadou 2012; Gerovasileiou *et al*. 2014, 2015, 2017).

Along the coasts of Turkey, only Topaloğlu (2019) carried out a study on macro-benthic assemblages of a submarine cave in the Marine Part of Gökçeada Island (north Aegean Sea). He gave the relative importance of coverages of main taxonomic groups along the light-dark axis of the tunnel-like cave. Apart from this study, Yokes and Galil (2006) reported the alien decapod species *Carupa tenuipes* Dana, 1851 from a cave (8 m depth) near Dalyan (Aegean Sea). Rastorgueff *et al*. (2014) and Chevaldonné *et al*. (2015) found two mysid species (*Hemimysis margalefi* Alcaraz, Riera and Gili, 1986 and *Harmelinella mariannae* Ledoyer 1989) in the Kanyon Cave (17 m depth) located off Kaş (Levantine Sea).

The present paper aimed to determine macro-benthic invertebrates occurring in different light zones of three submarine caves along the Aegean coast of Turkey.

Material and methods

The distribution of macro-invertebrates was investigated in three submarine caves in the east Aegean Sea. The caves have almost a similar morphology structure; simple horizontal tunnel with a blind end. Marine caves are located on the coasts of Aydın [Kuşadası (Banko)] and İzmir [Sığacık (Kanyon), Çeşme (Yatak Odası)] cities (Figure 1).

Figure 1. Map of the investigated area with the locations of the submarine caves studied

The Banko Cave (Kuşadası) is located at 15 m depth; it is a horizontal, small blind cave, approximately 10-15 m long, 2-3 m height; its bottom is mainly covered by rocks, partly by sand. The Kanyon Cave (Sığacık) is located at 24 m depth; it is a horizontal, small blind cave, 15-20 m length, 1-4 m high; its bottom is mainly covered by fine sand. The Yatak Odası Cave (Çeşme, Ildır Bay) is located at 10 m depth; it is a small horizontal blind cave, 15-20 m long, 3-4 m high; its bottom is covered by fine sands.

The caves were visited in summer 2016, but the Kanyon Cave was also visited in fall 2019. In each cave, random photographic samples were taken on rocky walls in the semi-dark and dark zones of the caves using a Nikon D7000 camera with close-up and wide-angle lens, and 2 electronic strobes. In addition, small pieces from encrusting sponges, and a few numbers of cnidarian and polychaete individuals were taken from hard substrata of the caves in order to be sure the taxonomic identity of the specimens.

Results

Examination of a number of photographs taken and the material collected from three caves in the Aegean Sea revealed 104 species belonging to 10 taxonomic groups (Porifera, Cnidaria, Sipuncula, Polychaeta, Crustacea, Mollusca, Brachiopoda, Bryozoa, Echinodermata and Tunicata) (Table 1). However, the number of species living in the caves is much more than we actually estimated, as many sponge and bryozoan specimens could not be identified from photographs, so they were lumped into one category under their group or genera names.

Table 1. Species found in three caves along the east coast of the Aegean Sea with their total number of individuals observed.

Species	Caves		
	Yatak Odası	**Kanyon**	**Banko**
PORIFERA			
Acanthella acuta Schmidt, 1862	<10	<50	<10
Agelas oroides (Schmidt, 1864)	>100	>100	>100
Aplysilla sulfurea Schulze, 1878	>100	>100	>100
Aplysina aerophoba (Nardo, 1833)	-	<10	-
Aplysina cavernicola (Vacelet, 1959)	-	<10	-
Axinella cannabina (Esper, 1794)	-	<10	-
Axinella damicornis (Esper, 1794)	<10	<10	<10
Axinella polypoides Schmidt, 1862	<50	<50	<100
Axinella verrucosa (Esper, 1794)	<10	<10	-
Chondrilla nucula Schmidt, 1862	-	<10	-
Chondrosia reniformis Nardo, 1847	<50	<10	<10
Clathrina clathrus (Schmidt, 1864)	<10	<10	<10
Clathrina coriacea (Montagu, 1814)	<10	<10	<10
Cliona celata Grant, 1826	-	<10	-
Cliona schmidtii (Ridley, 1881)	<10	<10	<10
Corticium candelabrum Schmidt, 1862	<10	-	-
Crambe crambe (Schmidt, 1862)	<50	<50	<50
Dendroxea lenis (Topsent, 1892)	<10	<50	<10
Dysidea avara (Schmidt, 1862)	<10	<50	<50
Dysidea fragilis (Montagu, 1818)	<10	<10	<10
Dysidea sp.	<10	-	-
Erylus discophorus (Schmidt, 1862)	-	-	<10

Table 1. Continued

Fasciospongia cavernosa (Schmidt, 1862)	<50	<50	<50
Haliclona (*Halichoclona*) *fulva* (Topsent, 1893)	-	<10	<10
Haliclona (*Rhizoniera*) *sarai* (Pulitzer-Finali, 1969)	<10	-	-
Haliclona (*Soestella*) *mucosa* (Griessinger, 1971)	<50	<50	<50
Haliclona spp.	<50	<50	<50
Hexadella pruvoti Topsent, 1896	-	<10	-
Hexadella racovitzai Topsent, 1896	<10	<50	>100
Ircinia oros (Schmidt, 1864)	-	<10	<10
Ircinia sp.	-	-	<10
Ircinia variabilis (Schmidt, 1862)	-	<10	-
Mycale (*Mycale*) *massa* (Schmidt, 1862)	<10	<10	<50
Myxilla (*Myxilla*) *incrustans* (Johnston, 1842)	<10	<10	-
Oscarella sp.	-	<10	-
Penares helleri (Schmidt, 1864)	<10	<50	<50
Petrosia (*Petrosia*) *ficiformis* (Poiret, 1789)	<50	<10	<10
Phorbas fictitius (Bowerbank, 1866)	<10	<10	<10
Phorbas sp.	<10	-	-
Phorbas tenacior (Topsent, 1925)	>100	>100	>100
Plakina bowerbanki (Sarà, 1960)	-	>100	-
Pleraplysilla spinifera (Schulze, 1879)	>100	>100	>100
Protosuberites sp.	-	<50	-
Sarcotragus foetidus (Schmidt, 1862)	<10	<10	-
Spirastrella cunctatrix Schmidt, 1868	>100	>100	>100
Terpios gelatinosa (Bowerbank, 1866)	<10	<10	<50
Timea sp.	-	<10	-
Porifera (spp.)	>100	>100	>100
CNIDARIA			
Hydrozoa			
Aglaophenia pluma (Linnaeus, 1758)	-	<10	-
Eudendrium merulum Watson, 1985	-	<10	-
Obelia bidentata Clark, 1875	-	<10	-
Scyphozoa			
Nausithoe punctata Kölliker, 1853	<10	-	-
Anthozoa			
Caryophyllia inornata (Duncan, 1878)	<10	<10	<10
Cerianthus membranaceus (Spallanzani, 1784)	-	<10	-
Cornularia sp.	>100	>100	-
Hoplangia durotrix Gosse, 1860	<100	-	-
Leptopsammia pruvoti Lacaze-Duthiers, 1897	>100	>100	>100
Madracis pharensis (Heller, 1868)	>100	>100	>100
Parazoanthus axinellae (Schmidt, 1862)	-	<10	-
Polycyathus muellerae (Abel, 1959)	-	-	>100
SIPUNCULA			
Phascolosoma stephensoni (Stephen, 1942)	<10	<10	<10
Aspidosiphon muelleri Diesing, 1851	<10	-	-
POLYCHAETA			
Filograna/*Salmacina* sp.	>100	>100	>100
Hermodice carunculata (Pallas, 1766)	-	-	<10

Table 1. Continued

Janita (*Omphalopoma*) *fimbriata* (Delle Chiaje, 1822)	<10	-	-
Janua heterostropha (Montagu, 1803)	>100	>100	-
Josephella marenzelleri Caullery & Mesnil, 1896	>100	<50	<50
Metavermilia multicristata (Philippi, 1844)	<100	<100	<100
Myxicola aesthetica (Claparède, 1870)	-	<10	<10
Pileolaria militaris Claparède, 1870	>100	-	-
Protula tubularia (Montagu, 1803)	>100	>100	>100
Sabella spallanzani (Gmelin, 1791)	-	<10	-
Semivermilia crenata (O. G. Costa, 1861)	<50	-	-
Serpula vermicularis Linnaeus, 1767	<10	<10	<10
Spirobranchus polytrema (Philippi, 1844)	<10		
Terebellidae (sp.)	<10	<10	<10
CRUSTACEA			
Galathea strigosa (Linnaeus, 1761)	-	<10	-
Palinurus elephas (Fabricius, 1787)	-	<10	-
Scyllarides latus (Latreille, 1803)	-	<10	-
Stenopus spinosus Risso, 1827	<10	<10	-
Mysida (sp.)	<10	<10	-
MOLLUSCA			
Bivalvia			
Lithophaga lithophaga (Linnaeus, 1758)	<10	<50	<10
Rocellaria dubia (Pennant, 1777)	-	<50	-
Gastropoda			
Felimare picta (Philippi, 1836)	-	<10	-
Muricopsis cristata (Brocchi, 1814)	-	<10	-
Peltodoris atromaculata Bergh, 1880	-	<10	-
Thylacodes arenarius (Linnaeus, 1758)	-	<10	<50
Trapania lineata Haefelfinger, 1960	-	<10	-
BRACHIOPODA			
Argyrotheca cuneata (Risso, 1826)	>100	>100	<100
Joania cordata (Risso, 1826)	<50	-	-
BRYOZOA			
Reteporella sp.	<10	-	-
Adeonella pallasi (Heller, 1867)	-	<10	-
Bryozoa (spp.)	>100	>100	>100
ECHINODERMATA			
Asteroidea			
Hacelia attenuata Gray, 1840	<10	-	-
Ophidiaster ophidianus (Lamarck, 1816)	-	<10	-
Crinoidea			
Antedon mediterranea (Lamarck, 1816)	-	<10	-
Holothuroidea			
Holothuria sanctori Delle Chiaje, 1823	-	<10	-
Ophiuroidea			
Ophiothrix fragilis (Abildgaard in O.F. Müller, 1789)	<10	<10	-
Ophiuroidea (sp.)	<10	<10	<10
Echinoidea			
Arbacia lixula (Linnaeus, 1758)	-	<10	-

Table 1. Continued

Centrostephanus longispinus (Philippi, 1845)	-	<10	<10
Sphaerechinus granularis (de Lamarck, 1816)	-	<10	<10
TUNICATA			
Halocynthia papillosa (Linnaeus, 1767)	<10	<10	<10
Aplidium tabarquense Ramos-Espla, 1991	-	<10	-

Apart from the invertebrates presented here, the pink, branched foraminiferan *Miniacina miniacea* (Pallas 1766) dominated walls of the semi-dark and dark zones of the caves. The distribution of algal groups represented a distinct zonation along the caves. Depending on the depth and habitats where the entrance of caves opened to, different algal species dominated the gate zone of the caves. For example, photophilic algae such as *Caulerpa cylindracea* Sonder, *Padina pavonica* Linnaeus (Thivy) and *Stypopodium schimperi* (Kützing) Verlaque and Boudouresque were abundantly present around the entrance of the Yatak Odası Cave, whereas coralligenous species (coralline red algae) were covered the entrance of the Kanyon and Banko Caves. Moving from light to dark, the red algae (*Mesophyllum*/*Lithophyllum*/*Peyssonnelia* spp.) and the green alga *Palmophyllum crassum* (Naccari) Rabenhorst occurred more frequently and abundantly in the species assemblages. In the dark zone, no algal canopy was observed.

Among macro-invertebrates, sponges were the most dominant and frequent group both in terms of the number of species and individuals (or colonies) in the caves studied. Nearly half of the species number (48 species) found in the caves belonged to the group Porifera, which was followed by Polychaeta with 14 species (Figure 2). The importance of sponges in the species assemblages did not change among the caves, comprising 49% (Kanyon Cave)-59% (Banko Cave) of the total number of species (Figure 3). Mollusca and Echinodermata had the highest percentages in the Kanyon Cave, Polychaeta in the Yatak Odası and Banko Caves. The encrusting and erect bryozoans had low percentages (2%-3%) in the caves. However, the percentages estimated do not reflect the reality; they were indeed highly diversified and widespread in the caves. The low number of species of this group in the list was just because of the fact that bryozoan specimens could not be identified at the species level from photographs.

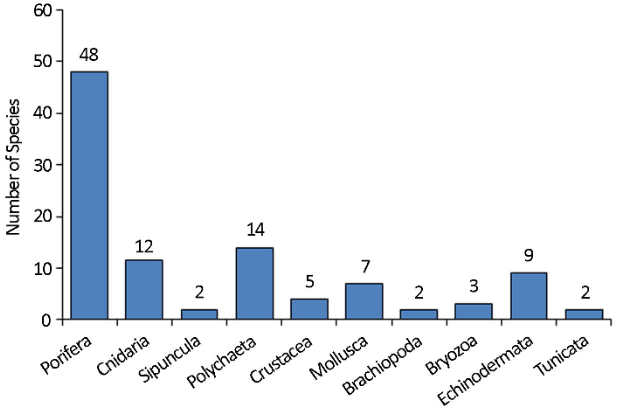

Figure 2. Number of species in each taxonomic group

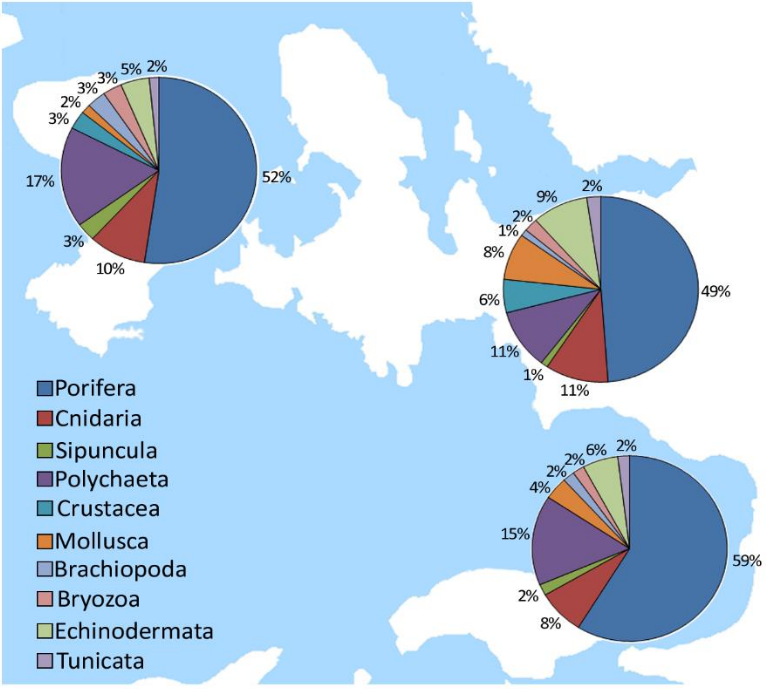

Figure 3. Percentages of taxonomic groups in terms of the number of species in the submarine caves

Among the caves, the Kanyon Cave had the highest number of species (86 species), followed by Yatak Odası (63 species) (Figure 4). A total of 41 species were found to be common in all caves. Among these species, *Agelas oroides*, *Aplysilla sulfurea*, *Phorbas tenacior*, *Pleraplysilla spinifera*, *Spirastrella cunctatrix*, *Leptopsammia pruvoti*, *Madracis pharensis*, *Filograna*/*Salmacina* sp. and *Protula tubularia* had the highest number of species/colonies in the caves. In addition, the brachiopod *Argyrotheca cuneata* and the serpulid polychaete *Metavermilia multicristata* were also abundant in the caves. However, some species occurred solely in one cave. For example, 31 species were only found in the Kanyon Cave, which was visited twice.

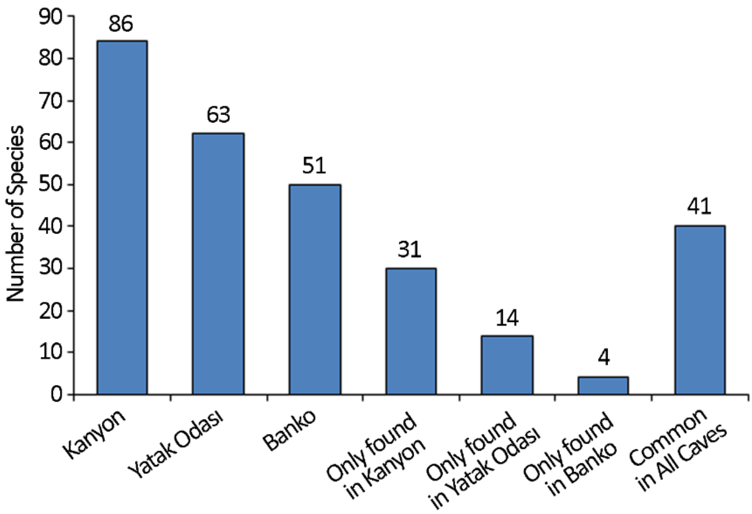

Figure 4. Number of species in the submarine caves studied

The abundances and diversity of species decreased when the darkness increased. For example, walls in the semi-dark zone of the Kanyon Cave were densely covered by a variety of species, with *Madracis pharensis*, *Agelas oroides* and *Protula tubularia* being the most abundant, but walls in the dark zone of the cave were patchily covered by a few number of serpulid and sponge species (Figure 5). The high coverage of the sponge *Hexadella racovitzai* was noteworthy in the semi-dark zone of the Banko Cave (Figure 6). The semi-dark and dark zones of the Yatak Odası Cave were mainly covered by *A. oroides*, *Spirastrella cunctatrix*, *M. pharensis* and serpulids (Figure 7).

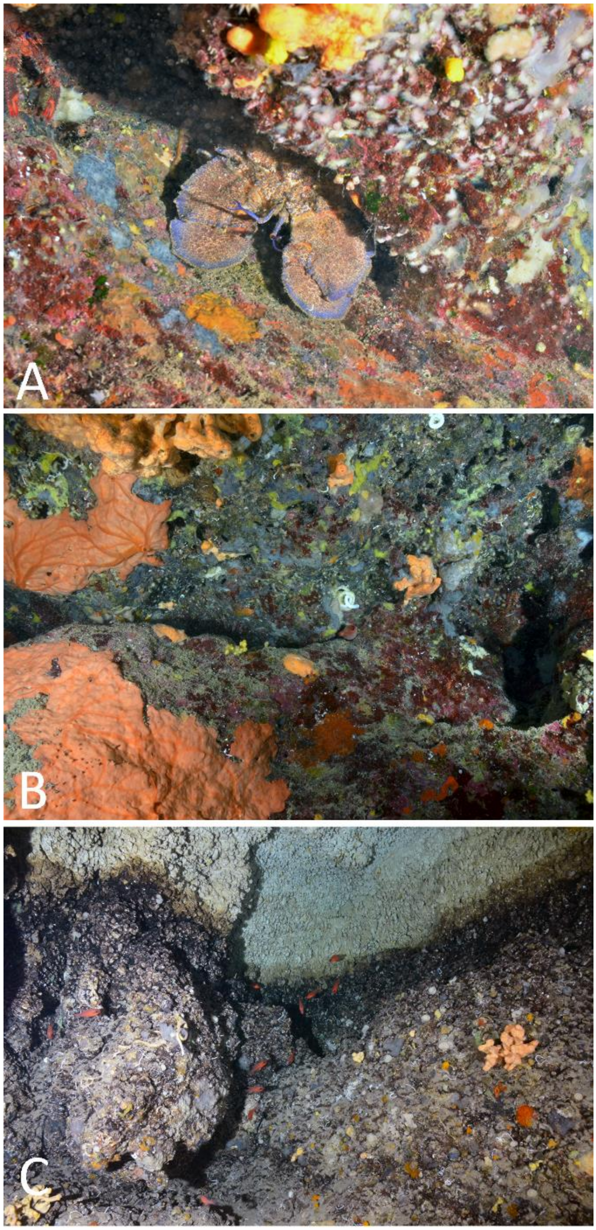

Figure 5. General pictures from the Kanyon Cave. **A-B.** Semi-dark Zone, distinguishable invertebrates: *Madracis pharensis*, *Agelas oroides*, *Scyllarides latus*, *Galathea strigosa*, *Spirastrella cunctatrix* and *Protula tubularia*; **C.** Dark Zone, distinguishable invertebrates: *Protula tubularia* and *Agelas oroides* (photographed by Melih Ertan ÇINAR).

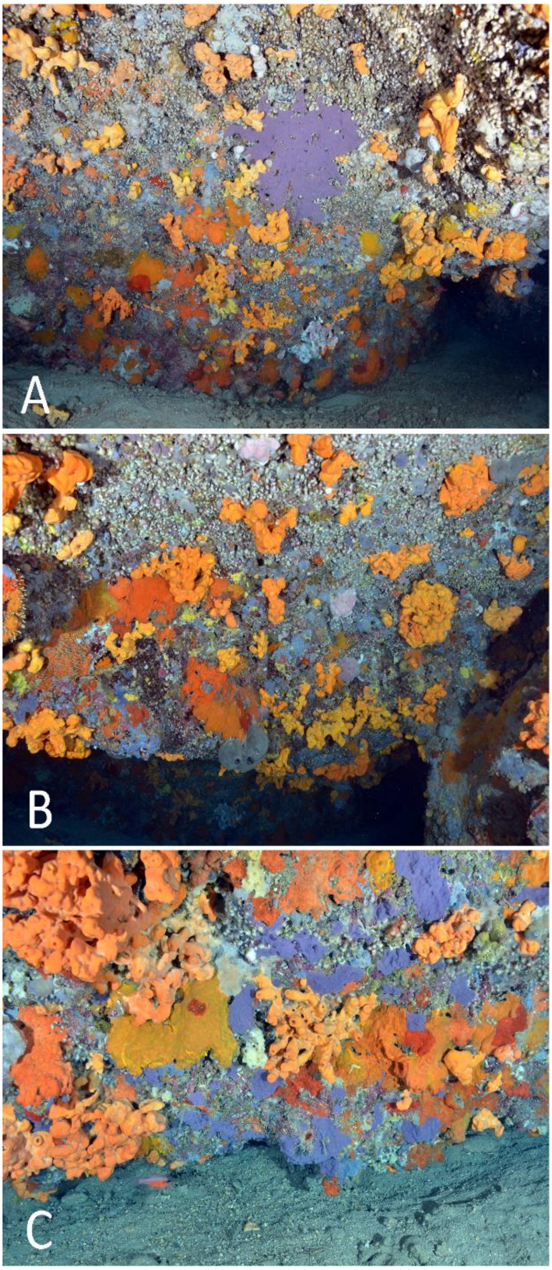

Figure 6. General pictures from the Banko Cave. **A-C.** Semi-dark Zone, distinguishable invertebrates: *Agelas oroides*, *Madracis pharensis*, *Hexadella racovitzai* and *Petrosia ficiformis* (photographed by Melih Ertan ÇINAR).

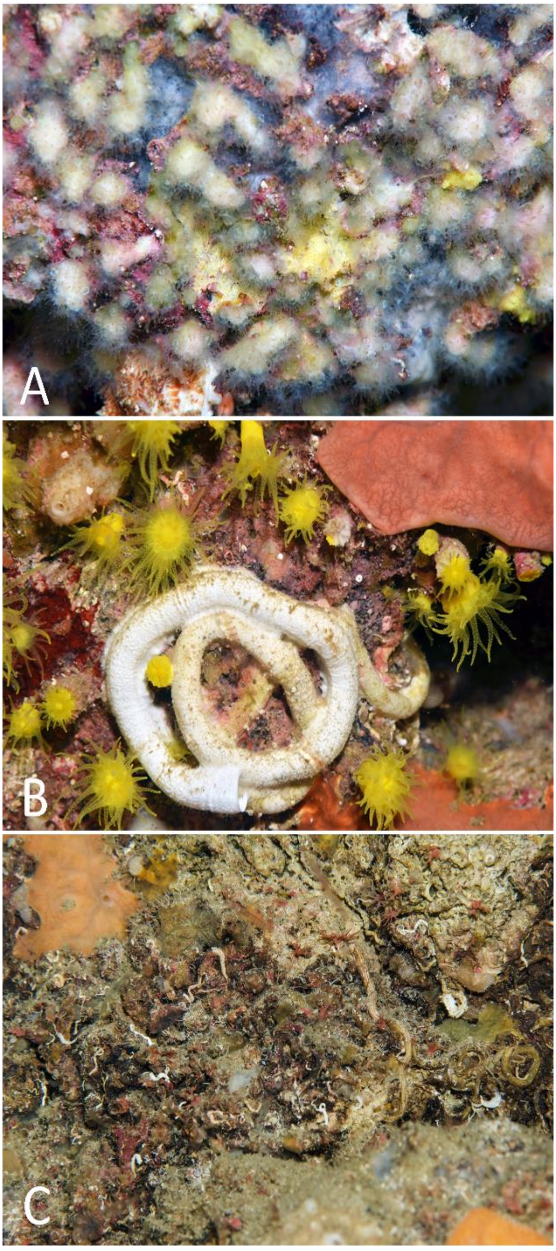

Figure 7. General pictures from the Yatak Odası Cave. **A-B.** Semi-dark Zone, distinguishable invertebrates: *Madracis pharensis*, *Leptopsammia pruvoti*, *Protula tubularia* and *Spirastrella cunctatrix*; **C.** Dark Zone, mainly dominated by serpulid polychaetes (e.g. *Metavermilia multicristata*) (photographed by Melih Ertan ÇINAR).

The caves harbored ten species, which are protected under the Bern and/or Barcelona Conventions: the sponges *Axinella cannabiana*, *A. polyphoides*, *Aplysina aerophoba*, *A. cavernicola*, *Sarcotragus foetidus*, the crustaceans *Palinurus elephas* and *Scyllarides latus*, the mollusk *Lithophaga lithophaga*, and the echinoderms *Centrostephanus longispinus* and *Ophidiaster ophidianus*. They are rarely found in the caves, except for *A. polyphoides*, which were abundant and common.

Discussion

Even at this preliminary stage, the present study indicated that the east Aegean Sea's marine caves studied were diversified and colonized by different animal groups in accordance with the intensity of light. The number of species reported here did not reflect the real diversity of the caves, as 1) cryptic species were not taken into account in the present study and 2) many sessile species (e.g. sponges and bryozoans) could not be identified from the photographs taken. In a revisionary work, Gerovasileiou *et al*. (2015) listed a total of 520 species from the eastern Mediterranean's marine caves, of which 400 species belonged to invertebrates. The species listed in the present study were also reported in the checklist, but 21 species (*Aplysilla sulfurea, Aplysina cavernicola, Chondrilla nucula, Corticium candelabrum, Haliclona sarai, Myxilla incrustans, Mycale massa, Aglaophenia pluma, Obelia bidentata, Nausithoe punctata, Phascolosoma stephensoni, Janita fimbriata, Janua heterostropha, Pileolaria militaris, Josephella marenzelleri, Semivermilia crenata, Myxicola aesthetica, Trapania lineata, Thylacodes arenarius, Muricopsis cristata*, *Aplidium tabarquense*), which were found in the present study, were not included in the checklist. However, except for *J. heterostropha*, Sanfilippo *et al*. (2017) also found the serpulid species (*J. fimbriata, P. militaris, J. marenzelleri* and *S. crenata*) in the marine caves' communities of the Lesvos Island.

Among the caves studied, the Kanyon Cave had the richest faunal components. The reality lying behind this fact might be complicated, but this cave was more studied than others (visited twice), which indicate the role of scientific efforts in the adequate assessment of the inventory of biodiversity. Although the morphology of the caves is more or less similar, the depths of the caves are different; the Kanyon Cave is located in deeper water. Therefore, the habitats outside the caves were different; photophilic algal assemblages at the depth of the Yatak Odası Cave, coralligenous at the depth of the Kanyon and Banko Caves. The high coverages of some coralligenous species (e.g. *Agelas oroides*) in the semi-dark zone of the Kanyon Cave might be explained by the interaction between the cave's and coralligenous species assemblages. However, the main bio-constructions of the caves were similar among the caves. *Madracis pharensis* preferred to settle on the ceiling of the caves, whereas the massive and encrusting sponges (e.g. *Agelas oroides*, *Spirastrella cunctatrix*) preferred horizontal surfaces.

The species assemblages in the caves studied changed when moving along the horizontal axis of the caves, from light to dark, in well accordance with the findings of previous studied performed in the western (e.g. Gili *et al*. 1986; Martí *et al*. 2004) and eastern (e.g. Gerovasileiou *et al*. 2014) Mediterranean Seas. Depending on the environmental conditions (e.g. depth), the gate's species assemblages of the caves were more or less affected from surrounding habitats and were more diversified, but the species composition started to change when the shadow fell on the walls, which were mainly dominated by three major groups; red coralline algae, sponges and scleractinians. In the semi-dark zone, red algae still existed, but their coverage tended to decrease towards the dark side of the caves, and sponges overwhelmingly dominated the assemblages. Interestingly, in the small scale, the species compositions in the caves can change and have specific characters. For example, in the semi-dark zone of the Banko Cave, the encrusting sponge *Hexadella racovitzai* were among the dominant species in the assemblage, whereas it rarely occurred in the Yatak Odası and Kanyon Caves. Galani *et al*. (2019) also postulated that different geomorphological types of cave possessed distinct benthic communities, showing a high level of individuality. It has been proved that animal assemblages in caves are influenced by multiple factors, such as water movement, light penetration and nutrient availability (Harmelin 1985; Balduzzi *et al*. 1989; Martí *et al*. 2004).

The present study gives a first detailed list of macro-invertebrates living in the submarine caves located at the Aegean coast of Turkey, establishing a background database for further studies. Although data presented here were not collected within the framework of a pre-defined, adequate sampling design, the cave's communities were proved to be diversified and highly specified. It was also found that the caves are home to many protected invertebrate species, so even this finding should encourage authorities to take measures to prioritize and conserve these unique habitats. The results obtained in the present study also point out the necessity of implementing comprehensive investigations to determine the spatio-temporal variations and functional characteristics of benthic species assemblages in marine caves. Cryptic and soft bottom habitats of caves should be considered and studied within this broad scope.

Acknowledgments

We would like to thank Dr. Bilal Öztürk (Ege University, İzmir) for identifying the gastropod *Muricopsis cristata*; Dr. Baki Yokeş (AMBRD Laboratories, İstanbul) for identifying the sea-slug *Trapania lineata*; and Drs. Antonietta Rosso (Universita di Catania, Italy) and Alfonso Ramos (Universidad de Alicante, Spain) for confirming the identifications of the bryozoan *Adeonella pallasi* and the ascidian *Aplidium tabarquense*, respectively. The present study was supported by the Ege University Research Project (number: 16/SUF/003).

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Diversity of cavern fishes at the Eastern Aegean Sea coasts (Turkey): Preliminary observation

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Introduction

The rocky coasts of the Mediterranean Sea include over 3000 submerged caves, hosting variety of unique taxa including rare, endemic, protected and commercially important species (Giakoumi *et al*. 2013). These fragile ecosystems of high conservation importance are designated as priority habitats by EU Habitats Directive (92/43/EEC), Barcelona Convention and related action plans (UNEP-MAP-RAC/SPA 2015). Biota of submerged marine caves of the Mediterranean remained unexplored until the mid 20th century, but conspicuous progress was achieved especially during the last few decades, representing a clear increasing trend (Gerovasileiou and Voultsiadou 2014). The number of taxa identified so far are typically higher in the western and central Mediterranean basins (for example 822 and 700 species were reported from Tyrrhenian and Ionian Seas, respectively), when compared to the eastern basin (324 sp. in Aegean and 157 sp. in Levantine Seas) (Gerovasileiou *et al*. 2015a; Aguilar *et al*. 2017). Scientific efforts spent per taxonomical group appear to be uneven, in which particular taxa such as anthozoans, polychaetes and bryozoans were much more effectively studied (Gerovasileiou and Voultsiadou 2014). Obtained results clearly point out the urge of conducting more detailed research in cave ecosystems, since there is lack of knowledge for several taxonomic groups and cavern biodiversity data is lacking in several countries (Gerovasileiou *et al*. 2015a).

Considering the cave associated fish fauna, notable information is available from Croatia (Arko-Pijevac *et al*. 2001), Italy (Bussotti and Guidetti 2009; Bussotti *et al*. 2002, 2015), Malta (Knittweis *et al*. 2015), Montenegro (Mačić *et al*. 2019) and Greece (Gerovasileiou *et al*. 2015 a,b). According to the comprehensive review of Gerovasileiou & Voultsiadou (2014), only 40 studies have been carried out so far at 13 different areas of the Mediterranean, indicating the presence of 96 fish species (14.8% of the ichthyofauna). Relevant inventory is currently lacking in Turkey, where only few occasional case reports including *Pempheris vanicolensis*, *Corcyrogobius liechtensteini*, *Didogobius splechtnai*, *Gammogobius steinitzi*, *Thorogobius epphiphiatus* and *Thorogobius* *macrolepis* were presented from Aegean and Levant coasts until now (Bilecenoglu and Taskavak 1999; Francour *et al*. 2007; Bilecenoglu and Yokeş 2016; Engin *et al*. 2018). In this study, a preliminary inventory of fishes is given based on underwater observations carried out at the eastern Aegean Sea (Turkey). Despite few caves were investigated through a limited number of dives, the results presented would probably form a baseline for further research.

Material and methods

Underwater observations were carried out between 2013 and 2019 during scuba divings at six different caves located at the Aegean Sea coasts of Turkey (Figure 1). A total of 16 divings were made at Yeni Foça (2 dives in an unnamed cave), Karaburun (3 dives in an unnamed cave), Çeşme (3 dives in "Yatak Odası" cave), Sığacık (4 dives in "Şömine" cave and 3 dives in an unnamed cave) and Kuşadası (1 dive at "Ada Banko" cave). All of the caves had wide openings enabling easy access to scuba divers (Figure 2).

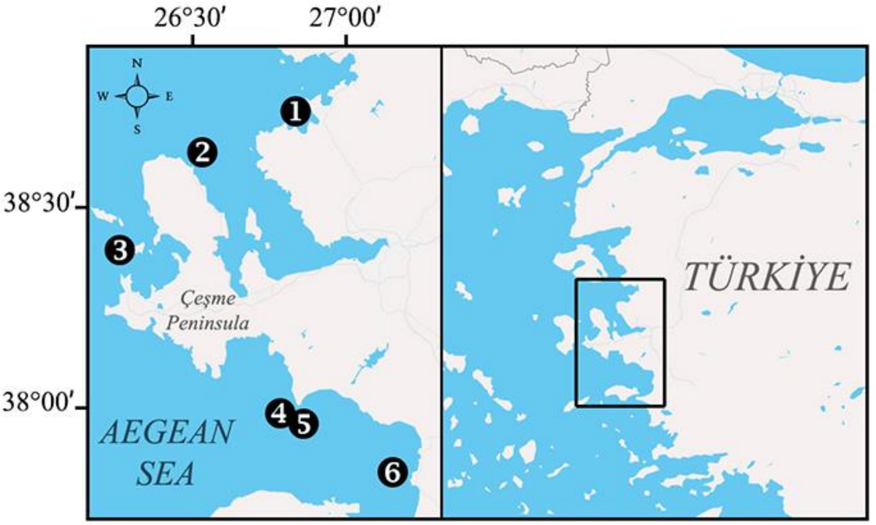

Figure 1. Map showing the approximate localities of underwater caves.
1- Yeni Foça, 2- Karaburun, 3- Çeşme, 4/5- Sığacık, 6- Kuşadası

Since emphasize was given to determine the fish biodiversity, physical features of the caves (size, structure, etc.) were not determined in detail. Fish counts were made following a predetermined scale as follows: +: 1 individual, ++: 2-10 individuals, +++: > 10 individuals. According to their positions within the cave, species those observed at the entrance or inside (semi dark and dark zones) of the caves were noted.

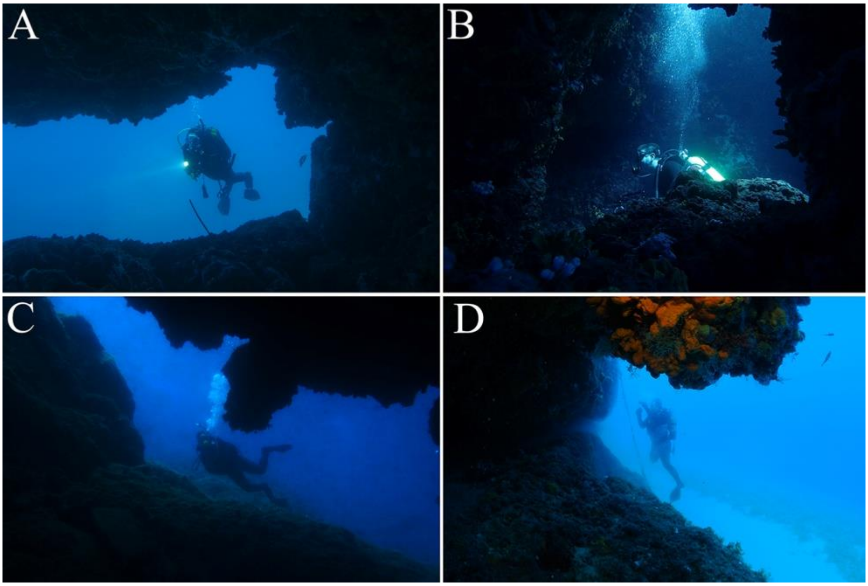

Figure 2. General views of selected cave entrances; **A/B:** Sığacık, **C:** Yeni Foça, **D:** Karaburun
(Photographs: A, C and D by Murat Bilecenoğlu, B by Duygu Kaya Bilecenoğlu)

Results and discussion

A total of 32 species belonging to 11 families were observed (Table 1), which is comparable to previous studies (Bussotti *et al*. 2015, Gerovasileiou *et al*. 2015a). Gobiidae was the most species rich family (8 sp.), followed by Serranidae (6 sp.), Blenniidae (3sp.), Scorpaenidae (3 sp.), Sparidae (3 sp.) and Tripterygiidae (3 sp.). Except for two triplefin blennies endemic to the Mediterranean Sea (*Tripterygion melanurum* and *T. tripteronotum*), all identified fish are Atlanto-Mediterranean originated and no any alien/invasive species was encountered. Caves of Sığacık and Çeşme region had the richest fauna (18 and 13 sp., respectively), while only 4 species were found in Ada Banko cave (Kuşadası), most likely as a result of the limited diving effort.

Table 1. List of fish species identified (Cave localities as follows: 1- Yeni Foça, 2- Karaburun, 3- Çeşme, 4/5- Sığacık, 6- Kuşadası). * denotes new records for the Aegean Sea cave ichthyofauna. Cave zone: e - entrance of the cave, i - inside of the cave.

Family/Species	**Cave Zone**	**Caves**				
		1	**2**	**3**	**4**	**5**
Apogonidae						
Apogon imberbis	e, i		++	++	++	++
Blenniidae						
Parablennius gattorugine	e	+				
Parablennius rouxi	e		+		++	+
*Parablennius zvonimiri**	e			+		
Gobiidae						
Corcyrogobius liechtensteini	e					+
Gobius auratus	e	++				
*Gobius bucchichi**	e					+
*Gobius cruentatus**	e				+	
*Gobius geniporus**	e	+		+		
*Gobius vittatus**	e, i				++	
Thorogobius epphiphiatus	i	+			+++	++
Thorogobius macrolepis	i		+		++	+
Labridae						
Symphodus mediterraneus	e, i			+	+	
*Symphodus rostratus**	e				+	
Muraenidae						
Muraena helena	e		++		++	+
Pomacentridae						
Chromis chromis	e, i	++	++	++	+++	++
Sciaenidae						
Sciaena umbra	i				++	
Scorpaenidae						
Scorpaena maderensis	i	+		+		++
Scorpaena porcus	i		+	+		
Scorpaena scrofa	e			+	++	+
Serranidae						
Anthias anthias	e				++	+
*Epinephelus caninus**	i				+	
Epinephelus costae	e					+
Epinephelus marginatus	e, i		+	+		
Serranus cabrilla	e, i				+	+
Serranus scriba	e			+	++	
Sparidae						
Diplodus annularis	e				++	
*Diplodus puntazzo**	i					+
Diplodus vulgaris	e, i		++	++	+++	++
Tripterygiidae						
Tripterygion delaisi	e, i	+		+		
*Tripterygion melanurum**	e		+			
*Tripterygion tripteronotum**	e			+		
Total number of species		7	9	13	18	15

Fish schools of more than 10 individuals within a single cave were observed only for *Apogon imberbis*, *Chromis chromis* (mostly juveniles), *Diplodus vulgaris* and *Thorogobius epphiphiatus*; these species are also among the most frequent fish within caves of the central Mediterranean (Bussotti *et al*. 2015). Half of the species (16 sp.) were encountered at the entrance of the caves and 8 species were found only in semi dark and dark zones, while the remaining 8 species were observed in both cave zones.

The first inventory of the Aegean Sea cave fishes was given by Gerovasileiou *et al*. (2015a), who listed 36 species in total (33 from northern and 5 from southern Aegean basin). Recently, three species were reported from Crete and Lesvos islands (*Grammonus ater*, *Corcyrogobius liechtensteini* and *Thorogobius ephippiatus*) (Gerovasileiou *et al*. 2015b), while another species (*Gammogobius steinitzi*) from Sığacık Bay (Engin *et al*. 2018). In this study, 10 previously unobserved fish species from Aegean Sea caves are being presented, which increases the diversity to 50 species, comprising almost half of those known from the entire Mediterranean Sea (96 sp., Gerovasileiou and Voultsiadou, 2014). All newly reported species have quite abundant populations along the coastal waters of the Aegean Sea, except for the dogtooth grouper (*Epinephelus caninus*, Figure 3). This species is the rarest of the subfamily Epinephelinae in Turkey, whose population clearly declined in the last couple of decades primarily as a result of spear fishing activities. It is worth to mention that caves are not among the documented habitat types for *E. caninus* (Heemstra and Randall 1993).

Although this study does not constitute an in depth survey, it presents simply a snapshot of the cavern fish fauna, which can be considered as a prelude to further studies. It is obvious that significant results can be achieved even by moderate research efforts, but rather than concentrating on a single group of organism, a holistic approach must be exercised and analysis of the entire cavern biota should be taken into consideration.

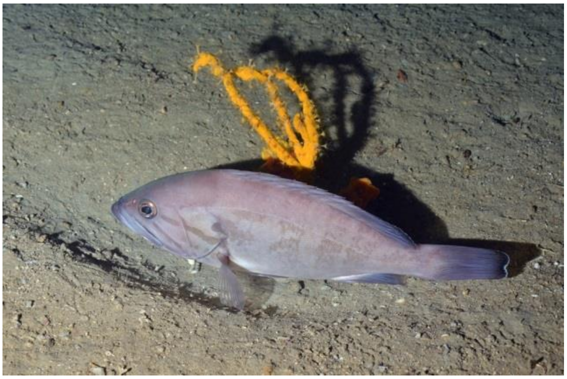

Figure 3. The dogtooth grouper (*Epinephelus caninus*) observed in a cave at Kanyon region, Sığacık Bay (Photograph by Melih Ertan Çınar)

Acknowledgements

Sincere thanks to Dr. Melih Ertan Çınar (Ege University), Bülent Şelli (İmbat Underwater Imaging Centre) and Dr. Duygu Kaya Bilecenoğlu (Aydın Adnan Menderes University) for their participation during the scuba dives. Dr. Vasilis Gerovasileiou (Hellenic Centre for Marine Research) kindly shared papers and information. This paper is dedicated to the memory of the late Dr. Patrice Francour, in recognition of his valuable and inspiring contributions to the conservation of biodiversity, in depth examination of ecosystem functioning in marine protected areas, and monitoring of Mediterranean Sea native and alien fish populations.

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Biodiversity, Threats and Conservation. Turkish Marine Research Foundation (TUDAV)
Publication no: 53, Istanbul, Turkey.

A dream within a dream: Kakoskali Cave, a unique marine ecosystem in Cyprus (Levantine Sea)

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Introduction

According to recent estimates, the global marine environment has been modified by human activities over almost 90% of the ocean (Jones *et al*. 2018). Not surprisingly, the deterioration is higher, more evident in coastal areas. Biological and chemical pollution, habitat destruction, over-exploitation, biological invasions and the global threat of climate change and ocean acidification are among the most well documented stressors affecting these areas (Jackson 2008; Rilov 2016; Dailianis *et al*. 2018).

In the Mediterranean Sea, there is a remarkable coastal marine habitat: submarine caves, the subject of this chapter. Due to its geological history, the Mediterranean coastal margins have an impressive abundance of marine caves (Giakoumi *et al*. 2013). Many were used by humans during the last sea-level low stand and the fascination they exerted on the archaic mind can be recognized in the wall paintings of one of such caves (e.g. Collina-Girard 2004). Submerged marine caves are particular environments that are considered refugia or reservoirs of biodiversity in the Mediterranean Sea (Gerovasileiou and Voultsiadou 2012, 2014). Still, the majority has no data on basic aspects such as species composition, structure of communities, function, and response to disturbances (Gerovasileiou *et al*. 2016, 2017b; SPA/RAC–UN

Environment/MAP and OCEANA 2017).

In this chapter, we give an overview of the remarkable characteristics of the Kakoskali Cave, a submerged marine cave in north-western Cyprus, the first of its kind to be discovered on the island. Inside the cave, there are bioconstructions that only recently have been explored and studied.

Kakoskali

Kakoskali Cave is located in the Marine Protected Area of Kakoskali (hereafter MPA Kakoskali) on the north-western coast of Cyprus (Figure 1a). The MPA Kakoskali includes a small islet with the same name, which is also known as Agios Georgios Island (lat: 35.074767, long: 32.333254), with steep, rocky flanks that reach depths of about -50m (Figıre 1b). Kakoskali Cave (17m max length) is a shallow blind cave (i.e. a *cul-de-sac*) (Figure 1c) with a small entrance (-9m depth) encircled by patches of the seagrass *Posidonia oceanica* (Figure 1d). Due to the shape (Figure 1c) and orientation of the cave, light penetration is limited and restricted to the first 3-4m from the entrance.

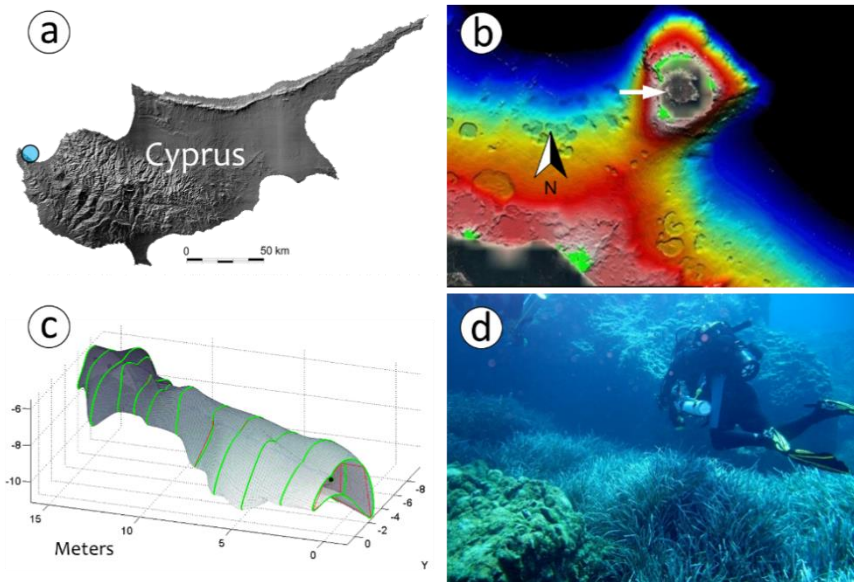

Figure 1. **(a)** Kakoskali Cave location (dot) on the north-western coast of Cyprus. **(b)** Multi Beam bathymetric model of the area around Kakoskali islet where the cave is located (arrow); colour scale from light green (-5m) to blue (-50m); courtesy of Department of Fisheries and Marine Research. **(c)** 3D model of the cave (max 17m length); the model was built using "cavetopo" software (Gerovasileiou *et al*. 2013). **(d)** Entrance of the cave (-9m) encircled by the seagrass *Posidonia oceanica*; photo by ENALIA.

Since the first descriptions of the cave and of some of its epibenthic species in the 1990s (Ten Hove and Van den Hurk 1993; Muricy *et al*. 1998), the presence of bioconstructions can be considered among the most significant findings of the incipient cave research in Cyprus. The shape of these bioconstructions resembles stalactites, hence the term of "biostalactites" (pseudo stalactites) that is adopted here in this chapter. The nature of these biostalactites in Kakoskali was recently studied and described in detail by Guido *et al*. (2017). Here we succinctly mention some of the results of that study but also provide more detailed information on the characteristics and distribution of the biostalactites in the cave.

Sections of the cave are covered by these biostalactites (Figure 2), which are built by skeletal organisms and microbialites. The macro-organisms responsible for these build-ups are serpulid polychaetes (i.e. bioconstructers), mainly *Protula* sp. and on a lesser extent *Josephella marenzelleri*, that form a meshwork of tubes providing thus a substrate to other epibionts (i.e. encrusters). Among the epibionts there are other serpulids (e.g. *Semivermilia crenata*, *Pileolaria militaris*), sponges (*Agelas oroides*, *Diplastrella bistellata*, *Spirastrella cunctatrix*, *Merlia* spp., *Phorbas tenacior*, *Plakina weinbergi*, boring clionaids and several undetermined species), foraminifers (e.g. *Miniacina miniacea*), bryozoans (e.g. *Monoporella bouchardii*, *Glabrilaria pedunculata*, *Onychocella* cf. *vibraculifera*), bivalves (*Spondylus gaederopus*, *Chama gryphoides*), brachiopods (*Argyrotheca cuneata*, *Argyrotheca cordata*, *Gwynia capsula*), and scleractinian corals (depending on the position in the cave: *Madracis pharensis*, *Polycyathus muellerae*, *Guynia annulata*, *Caryophyllia inornata*) (Jimenez *et al*. in prep.). The framework of the Kakoskali biostalactites is strengthened by microbial derived micrite that, similarly to other biostalactites in Sicily and Belize caves, contribute to cement together the skeletons. Sulfate reducing bacteria are the main microbes involved in this process (Guido *et al*. 2013, 2017; Gischler *et al*. 2017).

It is hard not to notice the high abundance of the pendant sponge *P. weinbergi* (Figure 2b), known exclusively from Eastern Mediterranean caves (Lage *et al*. 2019 and references therein), which contributes to the eeriness of the cave environment. In general, the composition of the epibenthic communities on the biostalactites varies according to the position in the cave and on the walls. A description and evaluation of the sessile epibenthic communities as well as mobile organisms (e.g. fish, crustaceans) in all sections of the cave is in progress.

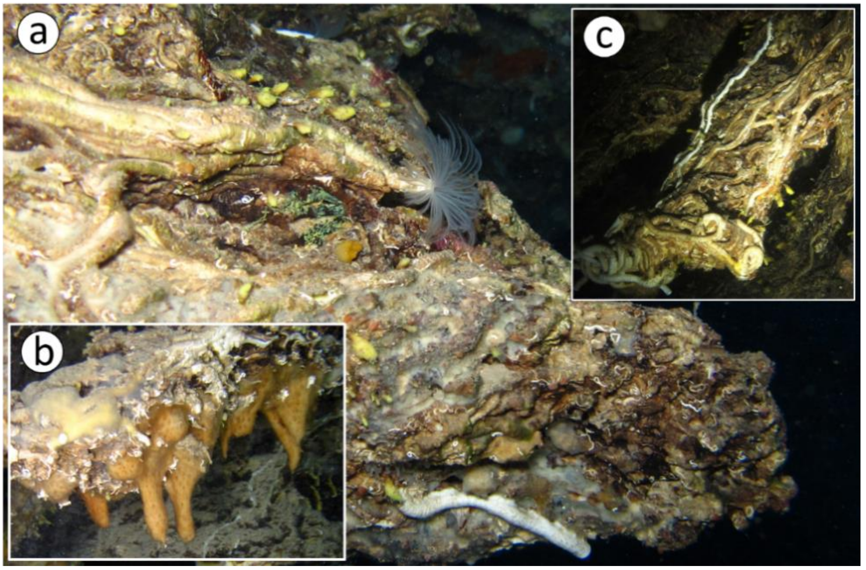

Figure 2. **(a)** Biostalactite with a high diversity of species including non-identified yet sponges. Recognisable in the photo: serpulid (e.g. *Protula* sp.) and spirorbid (*Pileolaria militaris*) polychaetes; middle section of the cave. **(b)** Biostalactite with a sponge-dominated assemblage (e.g. *Plakina weinbergi*); middle section. **(c)** Biostalactite with the characteristic meshwork of serpulid tubes and low-diversity community (mostly sponges, bryozoans and brachiopods); between middle and narrowest sections. Scale in all photos varies due to the perspective. Photos by ENALIA.

The morphology of Kakoskali Cave (e.g. blind end, narrow tunnel section; Figure 1c) generates high spatial heterogeneity of environmental conditions (e.g. gradients of light and water circulation) that, by turn, affect the distribution of organic matter, elements and regulate temperature inside the cave's sections (discussed more in the next section). This diverse physical-chemical environment inside the cave is complemented by the high structural heterogeneity provided by the biostalactites. These bioconstructions are deflected from the walls and towards the cave's entrance. With the exception of two meters at the narrow passage, biostalactites grow on most of the sections of the cave, from the first meters after the entrance until the blind end of the inner chamber (Figure 3). As a consequence, the epibiont communities are benefited by a constellation of micro-habitats in an already heterogenous environment.

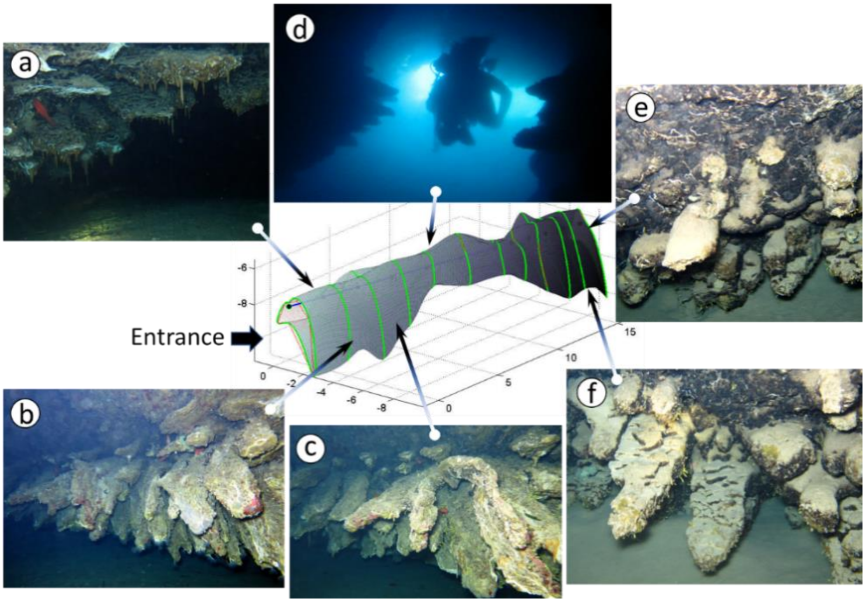

Figure 3. **(a, b)** Biostalactites from walls near the cave's entrance. **(c)** Larger and thicker biostalactites found between 8 and 10m from the entrance. **(d)** Diver exiting the cave cross the middle section where is narrowest, with biostalactites jutting out from the sides. **(e, f)** Sediment covered biostalactites at both flanks of the inner chamber (blind end). Cave 3D model visualised with "cavetopo" software (Gerovasileiou *et al*. 2013). Scale varies in all photos due to the perspective. Photos by ENALIA.

The distribution and size of 41 haphazardly selected biostalactites in different sections of the cave are shown in Figure 4. They differ in length, width and abundance. Mean length (±SD) is 55.5 ± 30.1cm (range = 14.4-129cm); mean width is 33.4 ± 16.8cm (range = 10-92cm). At 9-10m from the entrance, where the cave is narrowest and higher (Figure 4a), the largest (but not the thickest) biostalactite is located on the right (South) flank (Figure 4b). This side of the cave exhibits in general the most developed biostalactites that fan out from the walls and follow the orientation towards the entrance of the cave that was mentioned before. However, a few instances of changes in the axis of growth can be observed. One example is of a lateral fusion along the axis of growth in the middle part of two neighbouring biostalactites, leaving the distal end of the two biostructures separated. Another rare example of deviation of the general direction of growth can be seen in Figure 3c. The biostalactite in the middle of the panel seems to have deflected the axis away from the closest neighbouring biostructure.

There are fewer biostalactites in the inner chamber and one of those, found attached a few centimetres above the floor, is the largest biostalactite measured in the cave (>150cm length; not shown in Figure 4b). It was not possible to measure its circumference because the encroachment at that particular corner of the chamber restricts significantly divers' mobility, increasing the risk of damaging the bioconstructions.

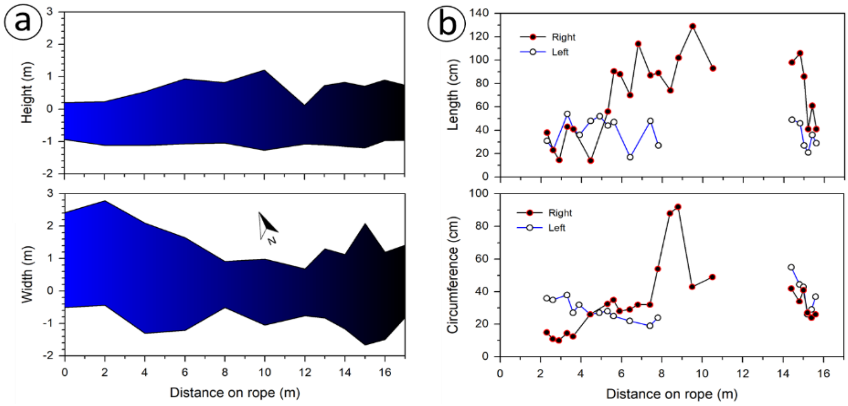

Figure 4. **(a)** Longitudinal section and plan view of Kakoskali Cave. Height and width measured following Gerovasileiou *et al*. (2013) methodology; a fix and marked rope was laid 115° relative to the north. **(b)** Length and circumference of randomly selected biostalactites from both right/South (red circle) and left/North (open circle) flanks of the cave from the rope axis. There is an interruption in biostalactites formation between 11 and 13m from the entrance.

This information, together with monitoring of environmental variables (e.g. seawater temperature), is used in the study of the factors influencing the distribution and composition of the epibenthic communities associated to the biostalactites. These communities seem to be strongly influenced by the position of the biostalactites in the cave, the gradients mentioned before (e.g. exposure to light), the heterogeneity of the bioconstruction itself (rough/smooth and upper/lower surface), and exposure to sediment loads (Figure 3f) (Gerovasileiou *et al*. 2013; Guido *et al*. 2017; Montefalcone *et al*. 2018). Ongoing research shows that the epibenthic communities are most diverse close to the entrance and until the middle section of the cave (Figures 1c, 3a-f). Mobile species can be found in abundance that varies seasonally and according to the section of the cave. For example, echinoderms (sea urchins, starfish, holothurians), crustaceans (mysids, crabs) are found in all sections. Fish in Kakoskali include speleophilic species (see Gerovasileiou *et al*. 2017b) as well as habitat generalists that utilize the cave as diurnal refuge (see next section).

Kakoskali's ecosystemic and trophic connectivity

The cave communities develop in a dark, nutrient-poor environment where low water circulation restricts dispersion over prolonged periods of time. The absence or scarcity of primary producers in the dark confines of the cave result in a nutrient-depleted environment. However, several nutrient pathways have been suggested to be operational in Kakoskali Islet (Figure 5). This trophic connectivity involves resident and transient fish, crustaceans (mysids and crabs), and the arrival of significant loads of organic matter due to water circulation (e.g. during stormy weather) from the adjacent *P. oceanica* patches. The crepuscular and nocturnal movements (e.g. horizontal transport) of fish and crustaceans outside of the cave to feed in the external habitats – seagrass patches, rocky-coralligenous areas – are important pathways of nutrients when they get back into the cave (e.g. Coma *et al*. 1997; Rastorgueff *et al*. 2011, 2015; Bussotti *et al*. 2018). These nutrients are made accessible to other components of the ecosystem by the release and deposition of faecal pellets and carcasses, but also by predation of the mobile organisms (mysids and crabs) by other cave-dwelling species such as fish (Rastorgueff *et al*. 2011, 2015).

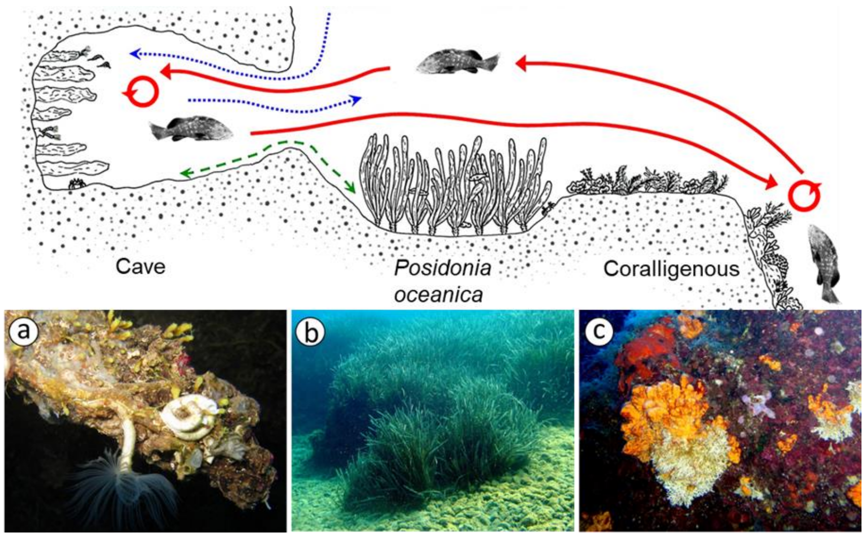

Figure 5. Schematic representation of the general and simplified connectivity pathways between cave, seagrass patches and rocky reef (coralligenous) habitats at the Kakoskali Islet. Dashed blue arrows: transport of dissolved and suspended organic matter by water circulation. Red arrows: active transport by swimming organisms. Green arrow: transport by benthic motile organisms and swells. Circular arrows: generation of organic matter that remains in the same place. **(a)** Biostalactite, cave's middle section. **(b)** *Posidonia oceanica* patches between the cave entrance and the drop-off margin of the islet (-9 to -12m). **(c)** Coralligenous communities along the rocky walls of the drop-off (-15 to -40m). Diagram K. Achilleos. Photos by ENALIA.

Cave-welling fish in Kakoskali include sciaphilous as well as speleophilic species (Gerovasileiou *et al*. 2017b; Hadjioannou *et al*. in prep.). An example of the former is *Apogon imberbis*, which can be seen in almost all sections of the cave and is known to effectively trophic-connect other Mediterranean caves with external habitats (Bussotti *et al*. 2018). Other fish species seem to use Kakoskali as a diurnal refuge; this is the case of groupers (*Epinephelus* spp.) that maintain shelters or lairs (floor-level burrows at the base of the walls) in the middle and inner sections of the cave (Hadjioannou *et al*. in prep.). Even though it is not known how often are these lairs occupied by the groupers, whenever they are there, there will be a horizontal movement of groupers inside and outside of the cave to the other habitats. Observations by divers confirm these movements of groupers (in this case *Epinephelus marginatus*) from the coralligenous areas to the *Posidonia* meadows in Kakoskali Islet and around the entrance of the cave. The infamous lionfish *Pterois miles*, a Lessepsian species introduced through the Suez Canal, is occasionally found inside the cave as far in as the middle section. The cave is used by *P. miles* as a diurnal refuge and in consequence, the fish could also transport organic matter into the cave (faecal pellets) as well as consume crustaceans and other fish there.

Water movement also transports organic matter into the cave, particularly during rough sea conditions that increase turbulence in the shallow entrance of the cave and where the seagrass patches are located. On several occasions, after heavy swells related to transient wind storms, organic debris (mostly *Posidonia* blades) were found inside the cave as far as the end of the middle section. Seagrass remains were deposited on the upper surface of a few biostalactites and also trapped between them.

Human footprint in the cave

Similar to other cave habitats in the Mediterranean region, Kakoskali is affected by human activities (e.g. Montefalcone *et al*. 2018). Recreational scuba diving, snorkeling and spearfishing are popular activities in the area of Kakoskali Islet; these activities inside the cave are discussed in Guido *et al*. (2017). Even though there are professional, highly trained divers that often penetrate the cave following the proper protocols for these constricted environments, other divers without proper skills often visit it too. Unfortunately, inexperienced divers leave more than only bubbles in the cave. The majority do not follow dive ethical standards and, in consequence, leave a trail of evidence of their poor performance that is hard to dismiss (Figure 6). Litter, like for example discharged accessories, and physical damage to the biostalactites (fragmentation or detachment of complete biostructures) and to the epibenthic communities (abrasion or detachment of organisms like sponges), and piles of sediment on the biostalactites are among the observed impacts. Physical damage by recreational divers in other Mediterranean caves is an aspect of concern for managers (Lloret *et al*. 2006; Di Franco *et al*. 2009, SPA/RAC–UN Environment/MAP and OCEANA 2017).

The resettlement of loads of resuspend, fine sediments on the upper surfaces of biostalactites have been related to differences in the distribution and composition of epibenthic communities in caves elsewhere (e.g. Sanfilippo *et al*.

2015). Impacts by divers resuspending sediments could be episodic and no less than catastrophic to the centimeter or millimeter-scale and in the long-term, it could turn chronic (Sempere-Valverde *et al*. 2019). In this special environment, the effects of such local impacts may surpass those of climate (Montefalcone *et al*. 2018). If sedimentation is low, it may interfere with biological functions such as larval settlement, but if it is extreme, then it will conduce burial and death of individuals or the entire community. In the sections near the cave entrance, sediments accumulated on top of biostalactites might be removed by water circulation. However, in the inner chamber it is much less likely because water circulation is very low and the sediments are very fine (Di Franco *et al*. in prep.). Indeed, the observed sediment build-ups on the biostalactites from the inner chamber (Figure 5d) remained for months. At this point, it is not possible to discern resuspended sediments by divers from the natural sedimentation inside the cave, task that has proven to be elusive in other studies (Di Franco *et al*. 2010). Neither is possible at the moment to hypothesize on the effect of resuspension of sediments due to biological agents (bioturbation). Some fish in the cave, while burrowing or maintaining their lairs in the sandy bottom (see previous section), produce sediment loads that might settle on the biostalactites at the base of the walls. One final comment on the impacts of diving in the cave is that scuba divers also leave pockets of air trapped on the ceiling (e.g. Lloret *et al*. 2006), with unknown effects on the encrusting communities.

Research activities that utilize invasive of destructive methods might also pose a serious threat to Kakoskali Cave biodiversity. Given the uniqueness of the epibenthic community of each biostalactite (see below) and their low recovery potential, research in the cave must follow a strict protocol in order to minimize possible impacts that could compromise the integrity of the biostalactites or the epibenthic communities on the walls and ceiling. Collection of samples is an activity that needs to be carefully planned and evaluated as well as other research activities. To the best of our knowledge, a reduced number of biostalactites in Kakoskali cave have been collected only by us for research purposes and, with a single exception, all of them were found already detached on the cave floor (Figure 5b). Only one biostalactite was detached from the wall, collected “live” for biogeochemical analyses (Guido *et al*. 2017). The on-going study of the collected biostalactites as well as many “live” ones (still attached to the walls) by non-invasive methods such as macrophotography, has confirmed that no two biostalactites share the same epibenthic communities. For example, on one biostalactite (30cm length), 551 individuals of the rare scleractinian coral *Guynia annulata* were stablished on the rough, lower surface (360cm^2 approx.) of the biostructure. Up to now, no other *G. annulata* has been found in the other inspected material from Kakoskali (Jimenez *et al*. in prep.). This coral species is known to occur in two other eastern Mediterranean caves (Zibrowius 1971; Gerovasileiou *et al*. 2015) but not in the abundance observed in Kakoskali.

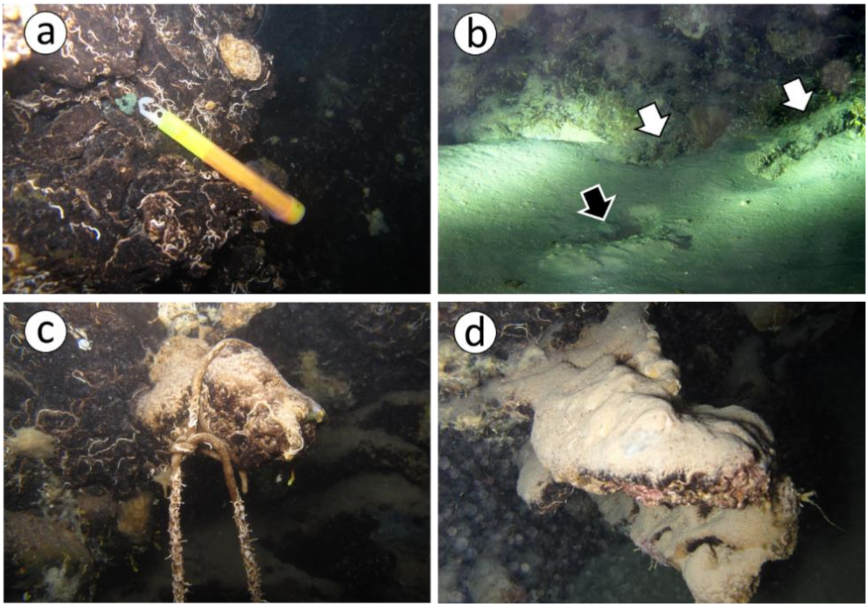

Figure 6. Human footprint inside Kakoskali Cave. **(a)** Light stick; ceiling of middle chamber. **(b)** Detached biostalactites (white arrows) and imprint (black arrow) from a fallen piece, which was collected and is currently under investigation; floor middle chamber. **(c)** rope left attached to biostalactite; wall inner chamber. **(d)** heaps of fine sediment deposited on biostalactites; wall inner chamber. Photos by ENALIA.

Other threats

Episodic changes in water temperature (e.g. heatwaves), non-indigenous species and, on a lesser degree, marine pollution are among other threats for Kakoskali Cave. Impacts of heatwaves on marine caves are documented in the Mediterranean (Chevaldonné and Lejeusne 2003; Parravicini *et al*. 2010; Montefalcone *et al*. 2018) and the effects comprised mortality of organisms, such as sponges, and changes in the cave epibenthic community (e.g. growth forms and feeding guilds). Cyprus underwent a heat-wave in 2012 and again in 2016 with extensive mortality of corals and other epibenthic species (Jimenez *et al*. 2016; Hadjioannou *et al*. in prep). More recently, seawater temperature in Cyprus during 2018 was above the average and mortality of organisms was recorded to a depth of 30m in several areas (Jimenez *et al*. in prep.). How the epibenthic community of Kakoskali Cave fared during 2018 is currently being evaluated.

Changes in water temperature and consequently changes in the epibenthic communities can also facilitate the spread of invasive non-indigenous species which are also considered a threat to cave habitats (Gerovasileiou *et al*. 2016).

As we write this chapter, a general evaluation of calcifying organisms in the sedimentary record of Kakoskali Cave is underway (Di Franco *et al*. in prep.). This effort, complemented with surveys of the biostructures and walls' epibenthic communities, will contribute to establish the historical presence and abundance of non-indigenous species in the cave. At the current state of the study a total of four species of non-indigenous molluscs were recorded in two different sections of the cave (middle section and entrance). They include representatives of two different classes: *Septifer cumingii* and *Pinctada imbricata radiata* (Bivalvia), *Cerithium scabridum* and *Conomurex persicus* (Gastropoda). Most likely, *Septifer* and *Pinctada* do occur at the entrance, but not in the middle section were specimens may have been washed in by currents and storms. Noteworthy is also the observations of the Lessepsian lionfish *P. miles* inside the cave. As mentioned before, individuals of *P. miles* have been recorded around the cave entrance as well as in the middle section. Individuals tend to hover between the biostalactites and on the ceiling of the cave, the latter posing a risk of accidental injuries to divers entering the cave. In fact, it is the risk of accidental envenomation that was the main reason why divers started calling to our attention to the lionfish inside the cave. Since *P. miles* diet in Cyprus includes a wide spectrum of macroinvertebrates and other fish species (Savva *et al*. submitted, D'Agostino *et al*. submitted), this new predator in Kakoskali could have a dramatic effect on the communities in the cave, particularly on rare and cryptic species such as the speleophilic fish *Grammonus ater*, a Mediterranean endemic species that has been found in Cyprus only in Kakoskali Cave (Gerovasileiou *et al*. 2017a).

Marine protected area Kakoskali

The process to create the MPA Kakoskali started in 2012 with the research NGO Enalia Physis Environmental Research Centre (ENALIA) organising research expeditions and exploring the islet and cave in order to gain further knowledge in the habitats and biodiversity of the area. Soon after the initial surveys, it became apparent that the structural complexity, rich biodiversity, unique habitat structure, the substantial biomass and diversity of ichthyofauna, and the presence of various protected species and habitats in the area of the islet, made it an ideal candidate for protection and the creation of an MPA. Given the small area of Kakoskali Islet (Figure 1b), it is remarkable that important habitats – such as the submarine cave, rocky reefs (including the coralligenous), and seagrass patches– are found there. These three ecosystems are protected by the European Union (Habitat Directive 92/43 EEC) and the Barcelona Convention (UNEP-MAP-RAC/SPA 2008, 2015).

Preliminary discussions were held with local small-scale fishermen in order to understand the importance of the area as a fishing target. It became immediately clear that due to its complex nature, the islet was not an easy target for professional fishing activities mainly due to the complex structure of the rocky bottom and the significant changes in depth within short distances from the islet. The complex rocky bottom did not allow for the safe recovery and damage-free retrieval of nets of the fishermen, who avoid the area for most of the year rather than risking to lose nets and longlines. Furthermore, the islet being on the north-eastern coast is only a small area in the greater Nature 2000 area of the Akamas National Park, which is extensively fished. It was made clear, however, that the area was used by recreational fisherman, rod and line fisherman and spearfisherman extensively.

During the meetings and informal talks with the fishermen, they were asked how they would feel if the area was closed to all commercial and sport fish activities. The response was immediate, especially from the older more experienced fishers. "Create the MPA today if you can, we will benefit since the place is a 'fishfarm'." With this it was clear that a potential and major obstacle to the creation of an MPA, did not exist. Furthermore, the closing of the area would benefit the fishermen directly since they utilise the nearby areas only in the winter/spring seasons for the fishing of picarel (*Spicara smaris*), which locally is considered an important species, and the creation of an MPA with a buffer zone, would give them sole access to the fishing grounds for this species.

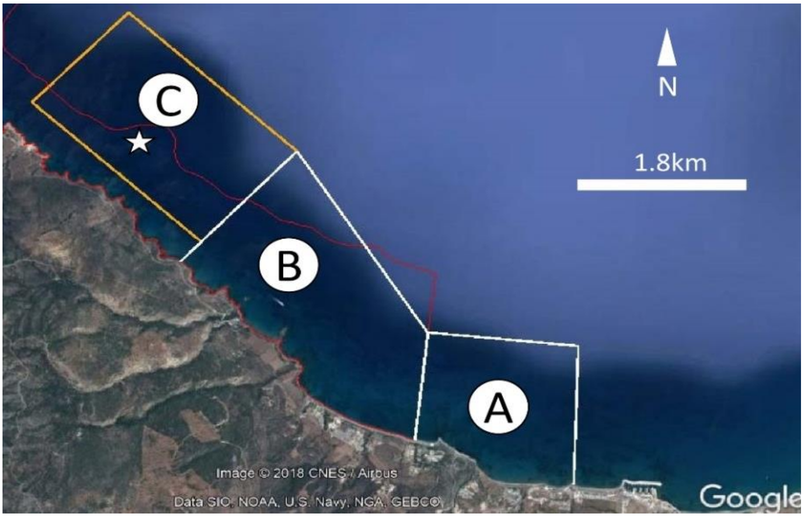

Figure 7. Proposal in 2016 for MPA Kakoskali. A and C= No-Take zones; B= buffer area. Star indicates location of Kakoskali Islet.

An initial proposal was created by the NGO ENALIA, discussed and agreed with the fishermen but also with recreational divers and boat charters owners, and proposed in a formal document to the relevant governmental department, the Department of Fisheries and Marine Research (DFMR). The initial proposal consisted of three areas (core, buffer and peripheral) which allowed varying degrees of fishing to take place, from no fishing of any kind in the core area to limited fishing gears in the buffer and peripheral (all small scale). The first amendment to the plan was made by the DFMR and created two instead of three areas in order to create less complexity and for easier policing and control in the area. The second change to the original plan was due to a local land owner who did not want the MPA to reach too close to the shore, and therefore the MPA shallow end was restricted to approximately 5m depth. In 2016 the DFMR proposed a new plan that would create a much larger MPA (Figure 7), which would include Kakoskali Islet as a No-Takezone, a buffer area joining towards the east and a third area which would also be a No-Take Zone in order to protect a monk seal breeding cave and create an area for an artificial reef site.

The local fishermen initially accepted this proposal but later rejected the plan and informed the government that they did no longer accept any form of MPA in the area with the exception of the original proposal made in collaboration with ENALIA. This situation led to a stand-off of the initiative to protect Kakoskali Islet and its important ecosystems. With the support of several other stakeholders including a marine consultant office, and external funding (MedPAN Small Projects), a series of meetings, proposals and counter proposals were elaborated by ENALIA with both the fishermen and the DFMR. In 2019 ENALIA finally got both sides to agree on the boundaries of the MPA.

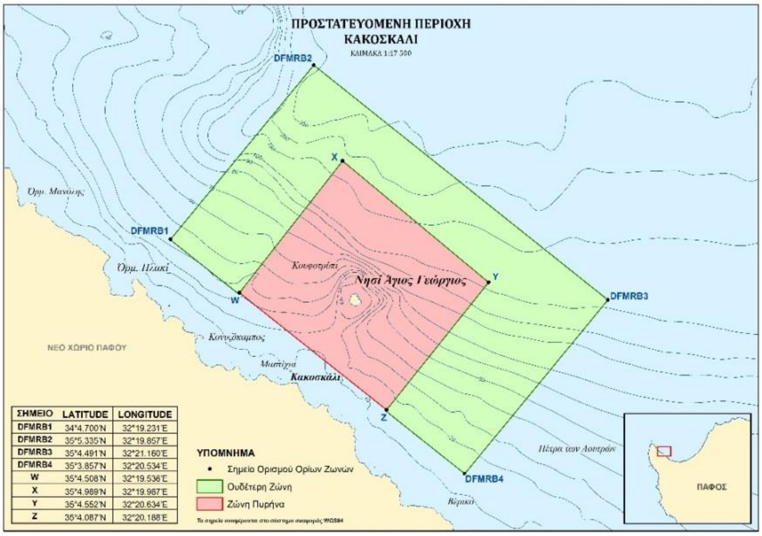

Figure 8. Official map of boundaries of MPA Kakoskali. The pink area is the core were fishing is totally prohibited and Kakoskali islet is located. The green area is the area where fishing activities are allowed only to professional fishermen. Map available at http://www.cylaw.org/KDP/data/2019_1_258.pdf (official document in Greek).

In a final meeting held with the fishermen's association in June 2019, an overwhelming majority of the fisherman agreed to the creation of the MPA with a few voices of rejection. This was proposed once again to the DFMR for final approval and in August 2019 a ministerial decree was issued creating the MPA Kakoskali (Figure 8).

Challenges to research and management

Kakoskali is the most recent MPA established in Cyprus and is protecting from fishing pressure three important habitats: the submarine cave, seagrass meadows and rocky-coralligenous reefs. Not often are such important habitats found together and in such a small area like Kakoskali Islet. Consider the following reflection: the biostalactites and their epibionts form a very complex micro-habitat within another singular habitat (the cave), and both are interconnected in subtle but dynamic ways with the two other external habitats. This ecosystem-within-ecosystem situation (borrowing from Edgar A. Poe "A Dream within a Dream" is unavoidable), the connectivity between the three habitats, and the uniqueness of the cave habitats (see Bussotti *et al*. 2006; Gerovasileiou and Voultsiadou 2012) is what offers an unusual opportunity for research but also poses great challenges to conservation and management.

For an adequate management of MPA Kakoskali habitats, it is necessary to establish reference conditions from which change (improvement or deterioration) can be identified and measured. It is crucial to study and understand the capacity of Kakoskali Cave's ecosystem to recover from the impacts of disturbances, such as the ones mentioned earlier, given the low resilience typical of this kind of complex ecosystems (Harmelin *et al*. 1985; Rastorgueff *et al*. 2015). Information on the cave's resilience processes and mechanisms must be integrated and used in any conservation and management activities (Parravicini *et al*. 2010). However, pre-impact data, the one that will be considered to define the baseline or reference conditions for the Kakoskali Cave communities, is difficult to almost impossible to find. Could sections of the cave or biostalactites be used as reference? Such an attempt to consider the visually most "healthy" or biodiverse biostalactites as "reference biostalactites" will be an entirely wrong approach, a futile effort that will bring erroneous results. Given the strong gradients influencing the communities of the cave and, in consequence, the extreme variability of the epibionts and associated organisms of neighbouring biostalactites (example of the coral *G. annulata* discussed earlier), it is almost certain that no two biostalactites host the same communities. In addition, several sessile encrusters (e.g. sponges and bryozoans) which developed on different biostalactites remained undetermined. Focused taxonomic studies are required for their identification, potentially shedding light on new undescribed species. Each biostalactite is different and all must be treated as unique, with biostalactite-specific communities, meaning as well that generalizations can't be lightly or easily made when observations are made from a few biostalactites. The fact that small-scale variability in epibiotic communities between biostalactites and between sectors within the same cave is remarkable should not surprise. This variability is reflected in the skeletal framework composition of the bioconstructions (Guido *et al*. 2019). It is common that this variability is even larger than the one between “similar” caves (Gerovasileiou *et al*. 2017; Montefalcone *et al*. 2018), asserting thus the uniqueness, cave-specific and cave-sector features. Therefore, achieving replicability in sampling designs for statistical comparison and generalization of conclusions is a major challenge; this limitation has been mentioned often in cave research (e.g. Montefalcone *et al*. 2018). If other caves are found in Cyprus with similar well-developed biostalactites, the environmental and ecological conditions will differ precluding also their use as “reference caves”.

An effort is being made to identify changes in the biostalactites and hopefully, in the most conspicuous members of the epibiotic community in Kakoskali Cave is by comparing historical photographs taken at different time periods. The oldest photographic material that we are aware of the biostalactites in the cave comes from the 1980s (Figure 9). A passionate diver and photographer used to visit the islet and made several incursions into the cave at least until the middle section. Assembling a time-series of photos from selected sectors or features (e.g. biostalactites) in the cave may provide a rough estimation of the rate of morphological/structural changes.

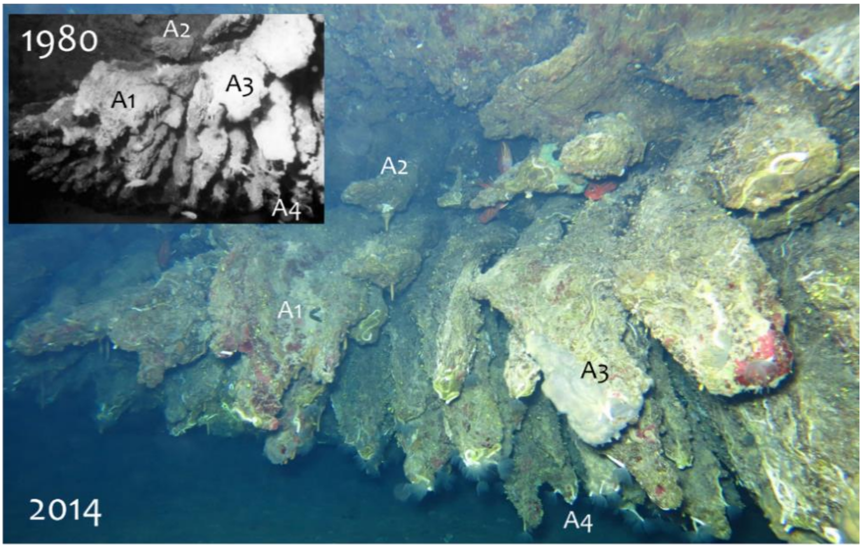

Figure 9. Comparison of a small area between the entrance and the middle section of the cave by using two photographs taken 34yrs apart; 1980 photo by using a wide-angle lens. A1-A4 are points of reference to illustrate the changes. Scale varies in this perspective. Photos by A. Tsirides (1980) and ENALIA (2014).

For some invertebrate groups, the lack of reference data may be overcome studying the death assemblages, that is, the accumulations of skeletal parts (e.g. molluscan or brachiopod shells, foraminiferal tests, coral skeletons) in the sediments. Such death assemblages proved to show high fidelity to their corresponding living assemblages in the absence of major human impact (Kidwell 2013). Although never tested in caves, this high fidelity held in similarly complex habitats such as *Posidonia* meadows and coralligenous substrates (Albano and Sabelli 2011). Because of skeletal durability, death assemblages usually capture a long-time interval which can be even centuries or millennia (Flessa and Kowalewski 1994; Ritter *et al*. 2017) and are thus dominated by the input of assemblages predating modern human impacts. Consequently, they can provide the baseline information on taxonomic and functional composition that we miss due to the lack of direct monitoring.

In conclusion, there are major challenges to the research, protection and management of MPA Kakoskali and in particular of the cave habitat. The successful first step in protecting the area from fishing pressure should be followed by other management activities, such as the regulation and monitoring of recreational activities. Recreational diving inside the cave by non-experienced divers is already leaving a footprint with serious consequences to the habitat (broken biostalactites and loads of sediments). There is a societal responsibility to protect and understand this unique ecosystem with its rare biostalactite communities. With the support of important sectors of the local community, the national authorities, and the multiple users of the MPA, a research program with a properly designed mid to long-term monitoring activities can be initiated. The results will provide information on the natural processes that link the cave communities with the outside ecosystems and its responses to disturbances at the local and larger scales.

Acknowledgements

This research was partially supported by ENALIA's research program, Nephila Works Ltd., AP Marine Environmental Consultancy Ltd., Mr Nick Galea, Stelios Foundation, grants MIUR, MedPAN Small Projects program. Our particular thanks to Mr Angelos Tsirides and Mr Stephen Weinberg for sharing their initial observations and photographic material from 1980 and 1990 on Kakoskali's ecology; to Helmut Zibrowius for guidance in all aspects of the study; to the fishermen of Latchi-Polis Chrysochou Bay for encouraging and supporting the creation of the MPA and to the Department of Fisheries and Marine Research for their support to the initial idea to protect Kakoskali's remarkable habitats.

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Publication no: 53, Istanbul, Turkey.

Marine caves alongside Fethiye/Turkey coasts

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Introduction

Marine caves are important components of the ecosystem and essential for ecotourism. In Fethiye region, several caves deserve protection, scientific discovery and conservation of biodiversity. For divers caves are always attractive but also need good diving practices. To minimize the risk of a diving incident or even a fatal accident by an unqualified diver, divers should be careful not to disturb marine life while visiting the caves. Below, most interesting diving caves are listed and a short description of caves is given around Fethiye region.

Yellowstone drop-off, cave and tunnels, Fethiye, Mugla

Yellowstone is a large bay with yellow slopes, alongside a beach at the end of the bay (Figure 1). This diving point is for experienced divers. It is recommended to jump from the boat at the entrance of the bay and to swim alongside the coastline to visit the magnificent cave and tunnels. From the 1990s up to the mid-2000s, it was a place where sea horses were commonly seen. As of now, one can only be encountered by chance.

The cave's entrance is 20 m downward and is large enough for only one person at a time (Figure 2). It is a single entry cave. The maximal height of the cave is 2 m and the width is around 5 m (Figure 3). Horizontal depth is 10-12 m deep. However, it becomes narrower once the depth threshold of 6-7 m is reached. The cave is large enough to fit 3-4 people at the start. It is in semi-darkness in terms of brightness. Within the distance of 3 m, away from the entrance, there are several openings on the cave's ceiling which can not be usable as routes due to their narrowness, while sunbeams illuminate the cave. There are unicorn shrimps (*Plesionica narval*) (Figure 4) in the narrow path. Pink cave sponge (*Petrosia ficiformis*), pixilated blenny (*Parablennius pilicornis)* (Figure 5), stoneweed (*Lithophyllum lichonoides*), squirrel-fish (*Sargocentron rubrum*) (Figure 6), lionfishes, long-spined urchin *(Centrostephanus longispinus)* are among the species that can be encountered in the cave and its tunnels.

The rest of the diving location includes over 10 short tunnels and passages between large rocks (Figure 7). The swimming troughs' lengths are at least 3 m and at best 10 m long. All of them are included in the depth interval of 2 m to 12 m. This cave diving profile is quite similar to a yoyo dive.

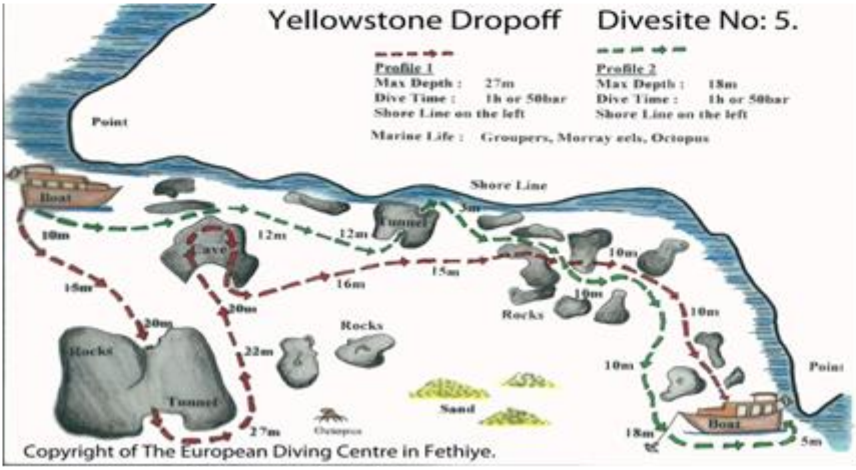

Figure 1. Yellowstone Bay's cave dive site (European Diving Centre 2019)

Figure 2. Cave entrance at a depth of 20 m in Yellowstone Bay (Çelikok 2007-2019)

Figure 3. Interior of the cave nearby the entrance at Yellowstone Bay (Çelikok 2007-2019)

Figure 4. Unicorn shrimps (*Plesionica narval*) in the cave of Yellowstone Bay (Çelikok 2007-2019)

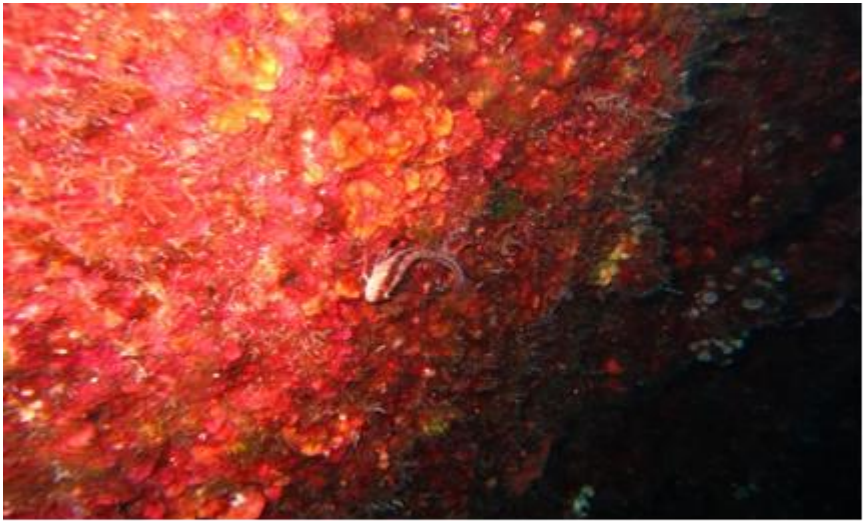

Figure 5. Pink cave sponge (*Petrosia ficiformis*) and pixelated blenny (*Parablennius pilicornis)* in the cave of Yellowstone Bay (Çelikok 2007-2019)

Figure 6. Stone weed (*Lithophyllum lichonoides*) and squirrel-fish (*Sargocentron rubrum*) in the cave of Yellowstone Bay (Çelikok 2007-2019)

Figure 7. Short tunnels and passages between large rocks in the cave of Yellowstone Bay (Çelikok 2007-2019)

Three Tunnels, Fethiye, Mugla

Tunnels were created by large cracks in a rocky structure. These tunnels are large enough for divers to pass through in single file (Figure 8). The deepest tunnel's entrance is 30 m deep and slowly ascends up to 26 m (Figure 9). Tunnel n°2 provides a good buoyancy test as there is a dog leg in the tunnel requiring divers to ascend slightly to maintain forwards motion. Tunnel n°2 exits at a depth of 22 m.

The shallowest tunnel is a relatively short one with a length of 5 m, exiting at the right angles into the blue water on the left of the tunnels at approximately 18 m.

The wildlife is essentially represented by squirrelfish (*Sargocentron rubrum*), tubeworms (*Protula tubularia), (Serpula vermicularis*), lionfishes, potato sponge (C*handrilla nucula*), yellow branching sponge, orange sponge (*Spirastrella cunctatrix*). Tunnels have a wide variety of colourful sponges (yellow, orange, red and brown).

Figure 8. Three Tunnel dive site (European Diving Centre 2019)

Figure 9. Three Tunnel cave's entrance (Çelikok 2007-2019)

Figure 10. Orange sponge (*Agelas oroides*) at Three Tunnels dive site (Çelikok 2007-2019)

Afkule, Fethiye, Mugla

The site is reachable via boat, one hour away from Fethiye harbour. The location is frequented by snorkellers as well as by divers. Although it is called Afkule, it is made up of 2 parts. The first part is the cave itself (Aladin`s Cavern) and the second part is "The Hamam" (Turkish Bath). This site was recently ranked in the top 10 dive sites in Turkey.

The entrance of the cave can be seen above the water (Figure 11). The view of the entrance is dome-shaped, 6 m wide and 3-4 m high. Descending to 29 m the cavern consists of 2 kidney-shaped areas allowing divers to observe the delicate Neptune Lace (*Sertella septentrionalis)* (Figure 12) and colourful formations like yellow cup corals (*Letosammia pruvoti*). The second part has a small overhang and sandy bottom with a resident large grouper. This is not a site for the beginner as the sandy bottom of the cave is 45 m deep and the vertical wall followed by divers is 65 m deep. Other species in the cave are *Anthias anthias, Epinephelus marginatus* and *Spirographis spallanzani.*

After swimming for 6-10 minutes, divers exit and ascend to a depth of 12-15 m for a 100 m travel to the Hamam. Entry is through a large opening (10-12 m deep and 3-5 m wide) leading to an enclosed room (Figures 13 and 14). The shallowest depth is 4 m on the other side of the room. Natural sunlight streams through 2 windows in the ceiling, creating fantastic light shows for photographers and divers alike (Figure 15). The opening patch at the ceiling is around 8-9 m high from the surface.

A spectacular wall awaits divers as they descend within the cave. Numerous varieties of anemones, lettuce coral, yellow cup coral, sea aubergine and many forms of lace coral, cleaner shrimp (*Plesionika narval*), pempheris fish (*Pempheris rhomboidea*) can be observed (Figure 16). After leaving the cave and following the wall, where groupers are often seen resting upon the large sponges, divers reach the Turkish bath. It is an open cavern, where a beautiful scenery above and below the sea awaits divers.

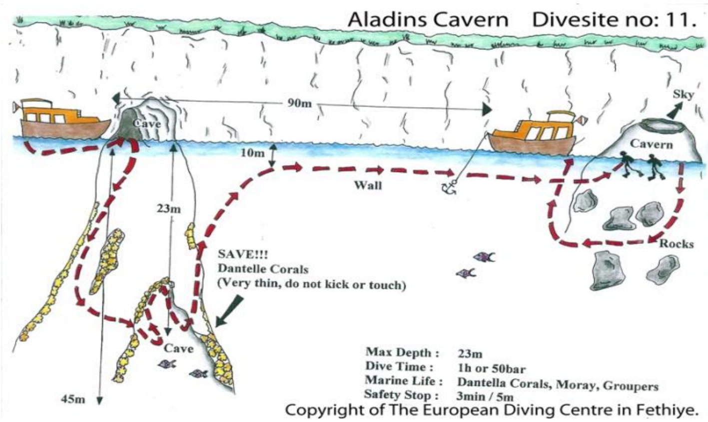

Figure 11. Afkule or Aladins Cave dive site (European Diving Centre 2019)

Figure 12. Neptune Lace (*Sertella septentrionalis*) in Afkule Cave (Çelikok 2007-2019)

Figure 13. Entrance of the Hamam Cave (Çelikok 2007-2019)

Figure 14. Entrance of the Hamam Cave (Çelikok 2007-2019)

Figure 15. Light show in the Hamam Cave
(Çelikok 2007-2019)

Figure 16. Yellow cup corals (*Letosammia pruvoti*) in Aladins Cave
(Çelikok 2007-2019).

Mexican Hat, Fethiye, Mugla

This dive site is also composed of two components with a single entry cave and tunnel (Figure 17). The first part requires divers to drop down to 25 m where the cave's entrance (Figure 18a) starts with dome-shaped form. The sandy bottom is 29 m deep alongside a sloppy-rocky bottom down goes deeper. The cave gets shallower and at last at a depth of 18 m one diver at a time may pass to visit the shrimp room (Figure 19). Under the light of a torch, thousands of shrimps can be seen living in their natural environment. Good buoyancy control is essential here for divers in order to have a chance to experience this event.

When all divers have left the shrimp room, they swim alongside a wall for 100 m at a depth of 30-35 m in order to gain access to the spring water tunnel which is second part of the dive site (Figure 18b). The second part of the dive involves swimming into a large tunnel, whose opening is 8 m wide at a depth of 10 m. The tunnel narrows down and becomes shallower for 90 m, hence the need of a torch. Halfway up the tunnel a mixture of salty and fresh water occurs while the water temperature drops quite significantly. The minimum depth at the end of the tunnel is 3 m. Safety stops are carried out from there before surfacing in a closed room. It gives the opportunity to rest whilst discussing about the low temperature. After a couple of minutes divers re-descend to a maximum depth of 5-6 m for the short return to the dive boat waiting outside.

The first part of this dive is restricted to advanced open water divers and above, however the second part is quite within the reach of open water divers. There are squirrel fishes, sea potatoes, starfishes, cleaner shrimps and Mediterranean seals in tunnels with fresh water.

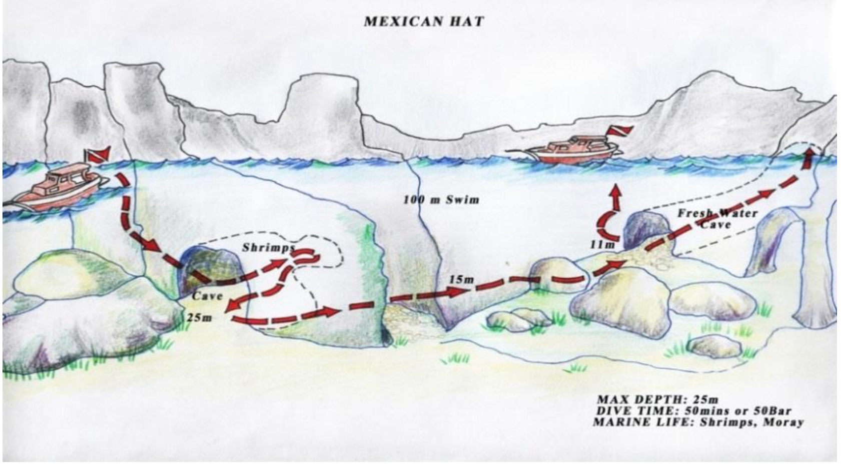

Figure 17. Mexican Hat Cave dive site map (European Diving Centre 2019)

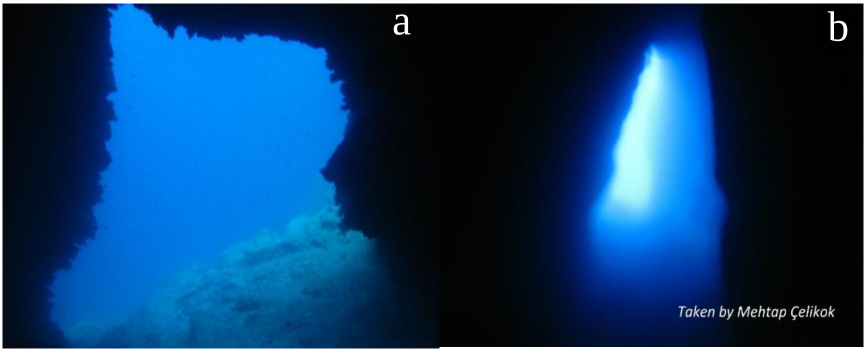

Figure 18. (a) Entrance and interior of Mexican Hat Cave, **(b)** spring water tunnel, second part of Mexican Hat dive site (Çelikok 2007-2019)

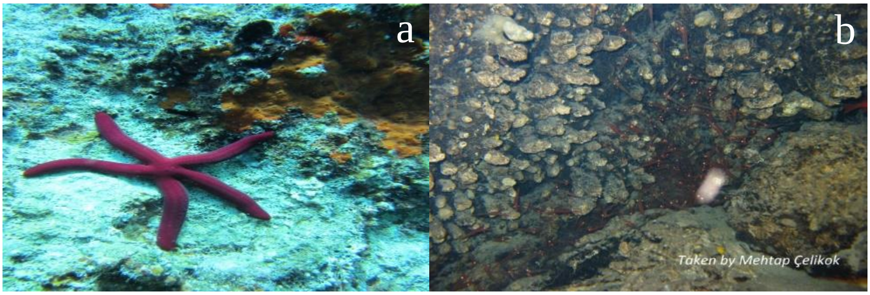

Figure 19. (a) Starfish at Mexican Hat Cave along the wall, **(b)** shrimp room of Mexican Hat Cave (Çelikok 2007-2019)

Figure 20. Tubeworm (*Serpula vermicularis*) at the entrance of Mexican Hat Cave (Çelikok 2007-2019)

Marcus`s Cave and Chimney

The cave (Figure 21) is similar to a tunnel and entrance is 20-21 m deep, it is also large enough to allow only one diver at a time. It is a single entry cave. The entrance is at best 3 m high and around 5 m wide. It is dark at the beginning and it gets darker as divers progress inside. There is a dog leg in the cave requiring divers to ascend slightly in order to maintain a forward motion. It does reach up to 14 m on a big rock then the tunnel is shaped like a chimney. Its width is 2 m wide and the chimney ascends up to 3 m. Unicorn shrimps (*Plesionica narval*) are encountered depending on the season where the chimney part starts. The squirrel-fish (*Sargocentron rubrum*) is another species inhabiting the cave.

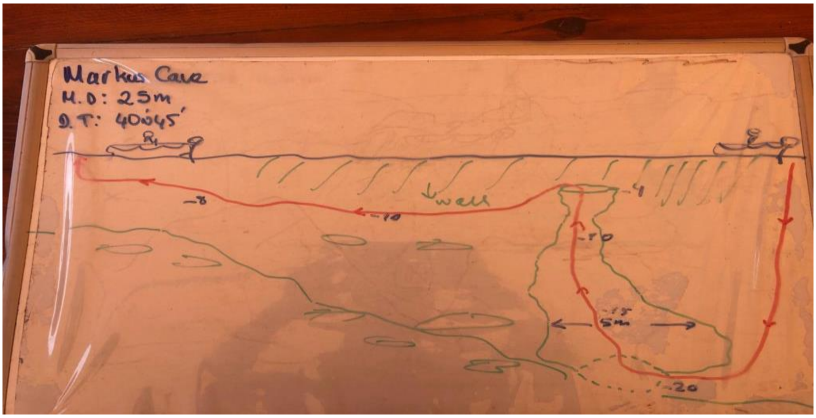

Figure 21. Sketch of Marcus Cave and Chimney dive site by Mehmet Avcu (Seahorse Diving Centre 2019)

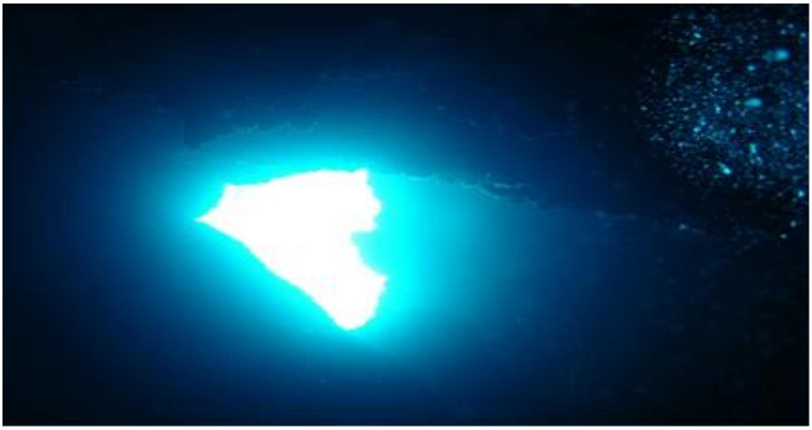

Figure 22. Exit of Marcus Cave and Chimney (Çelikok 2007-2019)

Secret Garden, Oludeniz, Fethiye, Mugla

Divers have to descend down to 25 m in order to find the first small cavern's exit (Figure 23). Afterwards they advance up to the point they come across a large cavern with a ceiling at 6 m and floor at 27 m. Cavern penetrate into the cliff for approximately 20 m. Divers need a torch to see the amazing rich colours of the sponges and soft corals. Then they can exit the cavern and swim through the arch at depth of 24 m. Finally, they start a gradual ascent with intriguing rock formations and schools of fish in their sights.

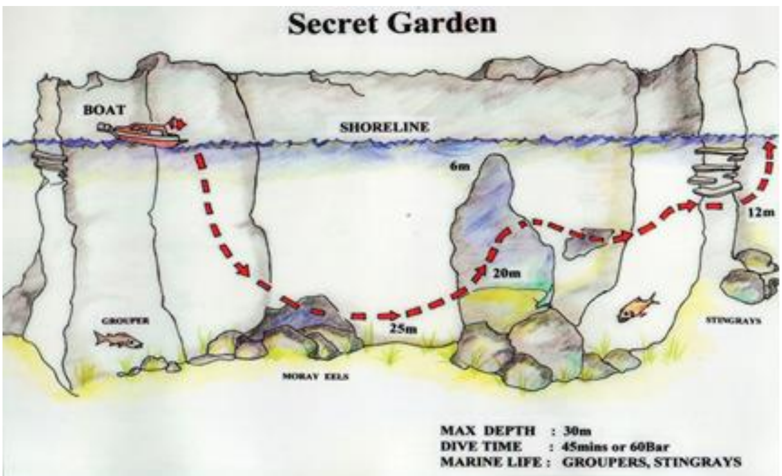

Figure 23. Secret Garden Cave dive site map (European Diving Centre 2019)

Chambers Cave, Oludeniz, Fethiye, Mugla

Divers have to keep the wall on the right during the descent in order to discover large boulders at a depth of 22 m. These boulders possess interesting holes and ledges which can be peaked underneath. The cavern's entrance starts from 22 m and descends down to 24 m. (Figure 24) The chamber on the left side descends to 28 m and the chamber on the right side goes down to 24 m. Divers must not forget their torches. After leaving the cavern, divers must keep the wall on their right side and the boat will pick them up on their ascent. They must be aware that only a handful of divers can fit in chambers.

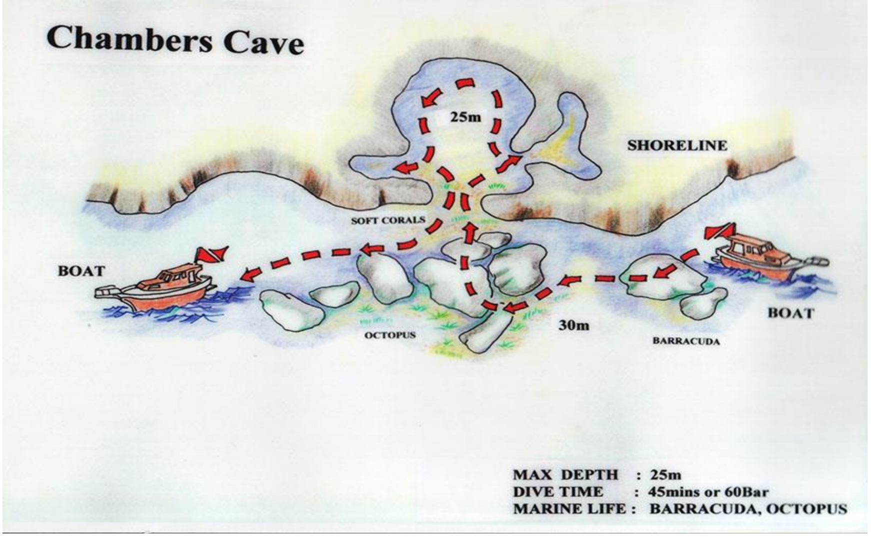

Figure 24. Chambers Cave dive site map (European Diving Centre 2019)

Acknowledgment

I am very grateful for the cave sketches produced by the European Diving Centre and for their kind permission.

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Mediterranean monk seal caves in the Turkish Aegean Sea and their conservation

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Introduction

The Mediterranean monk seal (*Monachus monachus* Hermann, 1779) is one of the largest and endangered species of the Phocidae family. The monk seal colonies used to be found throughout the Mediterranean, Marmara, Black Sea and the Atlantic coast of the northwestern African continent, including the Azores, Madeira and the Canary Islands. Today the world population is separated in reduced isolated subpopulations (Gonzalez 2015). In the eastern Mediterranean, a subpopulation composed of 250 – 300 individuals in small scattered groups are distributed among the Turkish Aegean and Mediterranean coasts and islands, Greek coasts and islands (Güçlüsoy *et al*. 2004, Gücü *et al*. 2004, MOm 2015). According to Güçlüsoy *et al*. (2004), the latest estimation on the Turkish coasts was given as 104.

Mediterranean monk seals, which are listed as Endangered by the IUCN Red List, once hauled out on open beaches but nowadays they use marine caves with sea entries for hauling out, resting and pupping (Karamanlidis and Dendrinos 2015). Therefore, all the appropriate marine caves are important for the survival of the species.

Along the coasts of Turkey, there are thousands of sea caves with very diverse geological forms. Some of those caves are suitable as sheltering and breeding areas for the monk seals. Öztürk *et al*. (1991) indicated 16 out of 70 investigated caves convenient for breeding. Up to now, 51 caves which have been used by monk seals on the Black Sea coasts and 39 on the Aegean and Western Mediterranean coasts of Turkey have been reported (Anonymous 2007; 2019). In this study, the caves (haul-out sites, coves, shelters) detected in the Mediterranean monk seal habitat researches in the Aegean Sea coasts of Turkey are reviewed.

Aegean Sea Caves

The Aegean Sea is the most important monk seal habitat in the Turkish waters, with quiet and isolated islets and islands, calm inlets, beaches and underwater caves, despite the fact that they are under the pressure of anthropogenic disturbance today (Dede *et al*. 2015).

Mursaloğlu (1991) mentioned 22 different regions where seals were sighted in the Turkish coasts, which also includes "Ayıdeliği" cave where lactation monitoring was conducted (Mursaloğlu 1986) (Figure 1). Öztürk (1994) identified 15 caves only in a short coastline between Çeşme and Sığacık (Figure 2). Öztürk and Dede (1995) stated potential seal habitats; seven caves and seven shelters in Foça. Güçlüsoy and Savaş (2003; 2004) mentioned that there were 11 caves that could be potential seal habitats in Foça. On the north shore of Gökçeada island, 5 caves were found to be suitable for seals (Dede 1998). There were 13 caves and shelters in Karaburun Penisula (Kıraç and Veryeri 2009), 15 around Bodrum Peninsula (Öztürk 2007), 13 caves and shelter in Aliağa, Çandarlı Bay (Ceyhuni-Szabo and Güçlüsoy 2016), one cave in Dipburun (Dilek Peninsula) (Öztürk 2007) and four caves in Gökova Bay (Saydam and Güçlüsoy 2019).

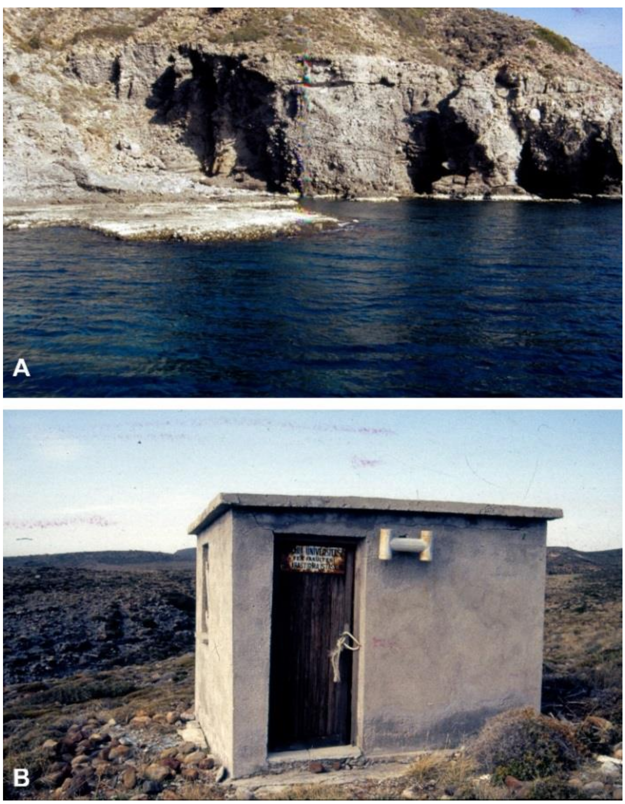

Figure 1. Ayıdeliği cave **(A)** and the observation hut of Musalıoğlu on the cave **(B)** in Sığacık

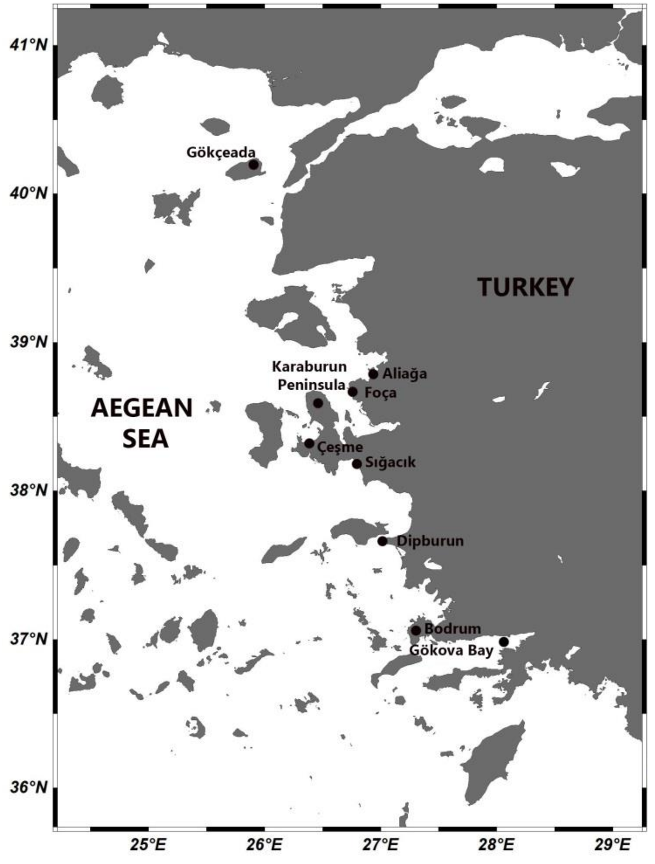

Figure 2. The regions where Mediterranean monk seal caves are found in the Turkish Aegean Sea coast

Conservation

The main factors that threaten the population are deliberate killings, entanglement to fishing gear, loss of habitat because of human activities (daily tours to seal habitats, recreational or cave diving, *etc.*) construction, overurbanisation, marine pollution, lack of prey as a result of overfishing and illegal fishing, and diseases (Dede *et al*. 2015). In addition, marine traffic is a considerable issue: In 1997, a ship accident occurred near Çavuş Island on the Bodrum Peninsula and a heavy oil spill was observed on the rocky cliffs and the region in and around the seal caves (Figure 3A, B). After the clean-up, navigation was prohibited between the nearby islands and Bodrum Peninsula for cargo vessels larger than 300 GRT and vessels carrying dangerous substances (Öztürk 1998a; ONHO 2002; Kıraç and Güçlüsoy 2007).

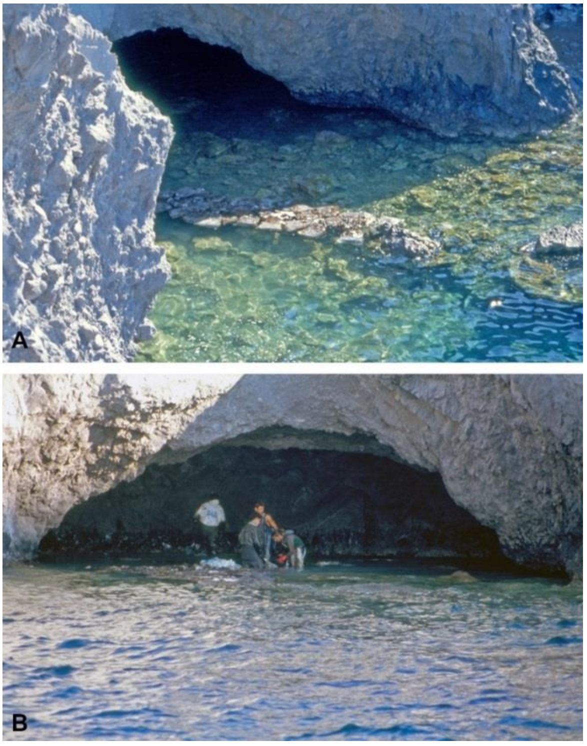

Figure 3. The affected monk seal habitat **(A)** by the oil spill in Çavuş Island in 1997 during the clean-up process **(B)**

Coastal cave habitats are vital for Mediterranean monk seals because they use these special habitats for lactating their pups for more than 14 weeks (Mursaloğlu 1986, Aguilar *et al*. 2007). Juvenile mortality has increased due to loss of favored habitat and, thus, pupping in inappropriate locations. Aborted pups or foetuses were reported with evidence of sensitive mother seals abandoning caves under human disturbance (Bareham and Fureddu 1975). Near big coastal settlements and new constructions, habitat loss is the main threat for the decline in the numbers of monk seals. Due to fast development and extensive urbanisation, suitable habitats for the monk seals are being destroyed or remain under the pressure of anthropogenic stress. There are many cases where formerly seal caves have been abandoned due to fast coastal excavation and settlement (Öztürk 1992, 1998b; Yediler and Gücü 1996).

As for the activities around the caves, according to Anonymous (2016a, b), it is forbidden to use light, diving, swimming or entering by any vehicle, waiting and anchoring at the entrance of the sea caves where Mediterranean monk seals live in Turkey. Fishery activities, especially around active caves, are important and should be limited or prohibited.

Every single Mediterranean monk seal individual is very important for such an endangered population. Therefore, every suitable cave and habitat of the Monk Seal should be protected. The survival chance of the monk seal in the Turkish Aegean Sea and Mediterranean Sea depends on the effective conservation measures. Establishment and management of operational protected areas, restrictions and inspection on recreational and fishery activities, especially around active caves, are crucial.

Acknowledgement

We would like to thank Prof. Bayram Öztürk to encourage us to publish this review.

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The Mediterranean monk seal caves in Northeastern Mediterranean Sea, current threats and their protection

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Introduction

Marine cave habitats are one of the important component of the coastal ecosystems and they are considered as biodiversity hotspots and high priority areas according to the EU Habitats Directive (92/43/EEC). They are even reservoirs of bulk of well-preserved fossil records of various marine organism including marine mammals (Sasowsky and Mylroie 2004; Springer *et al*. 2008).

Marine caves are also unique and crucial habitats for the survival of the Mediterranean monk seals, one of the rarest marine mammal on earth. Although formerly the Mediterranean monk seals used to be observed to haul out on open beaches and its nearest surviving congeneric, the Hawaiian monk seal still breeds mainly on open beaches (Lowry *et al.* 2011), haul out in the Mediterranean monk seal usually occurs in caves in recent decades due to persecution of the species and the destruction and disturbance of its habitats (Rejinders *et al*. 1997; Johnson and Lavigne 1999). The Mediterranean monk seals use marine caves for resting, breeding and nursing. These caves are usually located in rural/isolated areas characterized by a steep or sub-vertical coastal cliffs which is one of the prominent characteristics of the Mediterranean environment.

Although there is another seal species (Guadalupe fur seals) among the 33 pinniped species that reported to “prefer” volcanic caves and grottoes for breeding (Hubbs 1956), the Mediterranean monk seal is the only seal species that known to use exclusively marine cave habitats rather than open beaches.

As stated by Johnson and Lavigne (1998), the scientific research and monitoring should be conducted with minimum disturbance to individuals and populations. Therefore, priority should be given to the non-invasive methods such as land-based direct observation and use of suitable technology such as camera-traps or video surveillance system where suitable and applicable. Such methods give the researcher an information about the cave use pattern, the cave use frequency, number of individuals that use the same cave, individual identification and comparison of different individuals that are photographed. On the other hand, structure of the cave, the cave and sea condition and the period of the year have direct effect on the success of both installation and operation of the camera-trap systems hence receiving the monk seal photographs.

The Middle East Technical University (METU), Institute of Marine Sciences (IMS) has been studying the Mediterranean monk seal population inhabiting the northeastern Mediterranean since 1994. During various studies conducted in order to better understand monk seal populations in the northeastern Mediterranean, marine caves located along the coastline were explored and they were classified according to their suitability for Mediterranean monk seal use. These studies targeted the coasts of Mersin between 1994-2003, Adana-Hatay between 2003-2006, North Cyprus between 2006-2007, and Antalya between 2007-2012 and since then important caves have been observed with photo-traps. Result of these studies showed that there are four different monk seal populations the northeastern Mediterranean and these are dispersed along the coast of Mersin (Gücü *et al*. 2004), Hatay (Gücü and Ok 2006; Ok 2006), North Cyprus (Gücü *et al*. 2009a) and Antalya (Gücü *et al*. 2009b). The cave surveys and subsequent monitoring activities also showed that the region hosts one of the last and continuously breeding populations of the Mediterranean monk seal in the Mediterranean Sea.

During the routine habitat surveys for the Mediterranean monk seal, when a marine cave is explored, as much characteristics of the marine cave as possible are recorded. These characteristics can be listed as number of entrances, type of entrances, type of direction of the entrances, presence of long corridor and pool, number of platforms, type of the platforms, the geographic coordinates and other important remarks (Figure 1).

Marine caves that are used by the Mediterranean monk seal is classified according to the four categories described by Gücü *et al*. (2004);

- *Active:* caves in which one or more seals were sighted or there was evidence of seal use (e.g., seal tracks, body depressions, smell or faeces)
- *Breeding:* caves in which whelping occurred
- *Abandoned:* caves in which seals were historically observed, but were no longer in use,
- *Potential:* caves, which met the requirements and descriptions of a monk seal cave (IUCN/UNEP 1988), but lacked any sign of use.

Figure 1. Different marine caves used by the Mediterranean monk seals.

Along the coastline from Antalya to Syrian border, around 130 marine caves are discovered over 25 years of research efforts of METU-IMS and around 25 of these marine caves have been monitored by camera traps for the monk seal use (Figure 2). However only very few of them are suitable for breeding. Whelping did not occur in caves used for resting i.e. active caves. It is possibly because they lacked beach and/or a pool inside and protection against storm sand strong waves is absent or very weak. In active caves, seals only haul-out and sleep on the narrow and flat rock platforms. In addition, the presence of a protected pool which is almost a common feature inside all the breeding caves provided a safe area for newborns to get used to the water and practice how to swim when they are strong enough.

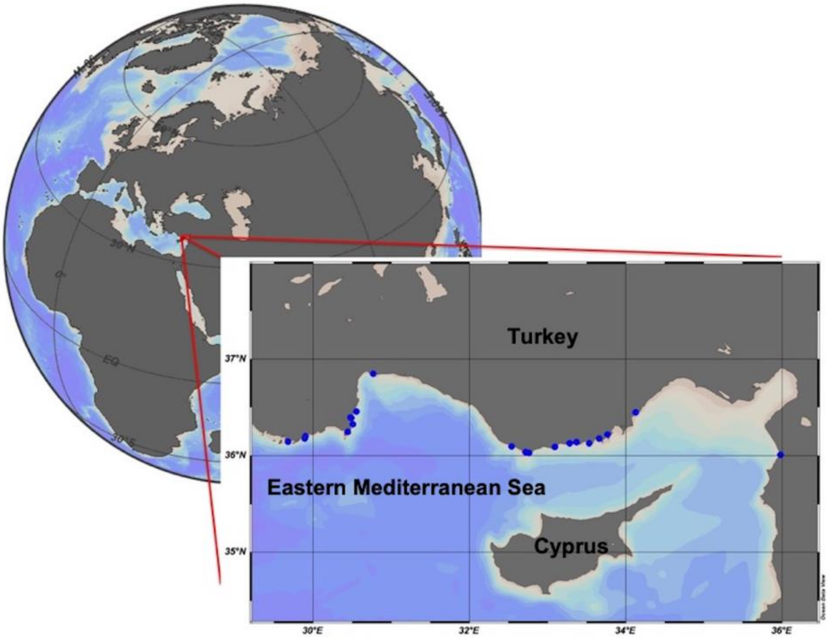

Figure 2. Marine caves that have been used for resting and breeding by the Mediterranean monk seal in the Northeastern Mediterranean and monitored by METU-IMS

All of the factors that can be listed as threats to Mediterranean monk seal caves are of human origin. Marine cave habitat disturbance, destruction or functionality loss are mainly due to road, industrial, touristic, agricultural and secondary house constructions along the coastal habitats. Furthermore, road construction in rural or forested areas has an additional indirect impact as it may potentially lead to deforestation and urbanization around marine cave habitats. In addition, in some areas of high human activity, anthropogenic pollution carried and accumulated by the waves into seal caves is becoming more frequent and is therefore considered as a growing problem.

The human entrance to the monk seal caves is prohibited in Turkey by Water Products Law Numbered as 1380. However, especially during the tourist season, these unique and pristine places may have considered as one of the touristic attraction of some boat tour activities. Therefore, boat tour companies and divers in such areas were visited and informed about the presence and importance of seals populations during the field surveys. Despite all these efforts, there are still some of the tour boat companies that bring many tourists to the monk seal cave habitats, stay long hours and these tourists are usually being encouraged and guided to enter monk seal cave (Figure 3).

Figure 3. Tour boats were anchored right in front of the monk seal cave and create high disturbance for long hours.

Tourists brought to the monk seal caves by boat tours were even recorded inside of the monk seal caves by camera traps of METU-IMS (Figure 4). Most of these caves are well-known by local people.

Figure 4. Human use (lower panel) of the Mediterranean monk seal caves (upper panel)

In the following parts below, two case studies about monk seal caves are given. These caves have crucial importance as they are located almost in the middle of the two fragmented populations and have role to facilitate connectivity between the populations.

Case study I: Akkum (parti) Cave in Akkum

The cave is located in Akkum area of Mersin and it was once known as the seal cave by the local people. However especially after the summer house site built near this cave, there were no longer use of the cave by seals. Since evidence of seals use were also not recorded during the studies conducted by METU-IMS in the 1990s, this cave was listed as “abandoned” and not monitored at that time anymore.

Upon the observation of the seal around the Kızkalesi area in 2005, this cave was checked again by METU-IMS and seal use were recorded during the investigations. The cave has relatively a large single air chamber inside where seals are haul out and it has two wide and open entrances opening to this air chamber via wide corridors. These features made the cave more exposed to human access and use for different purposes such as camping, drinking, spear fishing etc.). It was soon eventually documented during the routine cave monitoring surveys that the cave was used extensively by the people. As a result, a protection plan was developed and implemented with the permission of the Ministry of Environment. Two entrance of the cave were closed in a way to prevent human entrance from the land while considering the water-wave dynamics within the cave (Figure 5).

Then the cave has been monitored by camera-traps resulting in an increase in frequency of a seal use, in number of individuals using the cave and whelping of three seals over the years. Meanwhile some reports including protection plan were prepared and sent to the relevant Ministries in order to draw attention to the importance of the cave and its protection. In terms of human entrance and use, the activities were remarkably decreased during the first years of the cave closure.

However, over the years construction of roads, hotels and summer houses sites near the cave (Figure 6) resulted in increases the number of people in the area. Unfortunately the cave was again frequently visited by curious people, even the protective metal fence were broken several times by unknown people (Figure 7).

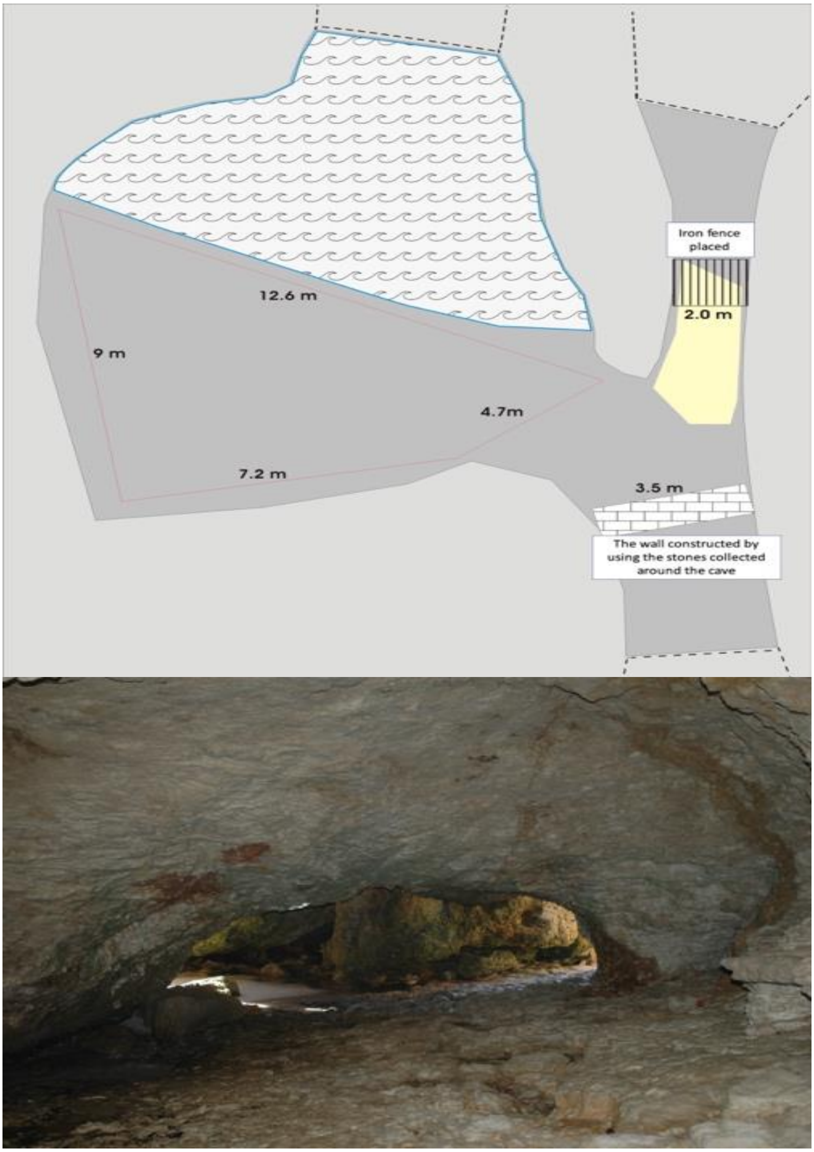

Figure 5. Sketch of Akkum Cave and the closure plan for the two entrances of the cave (upper panel) and general view of the entrance (lower panel)

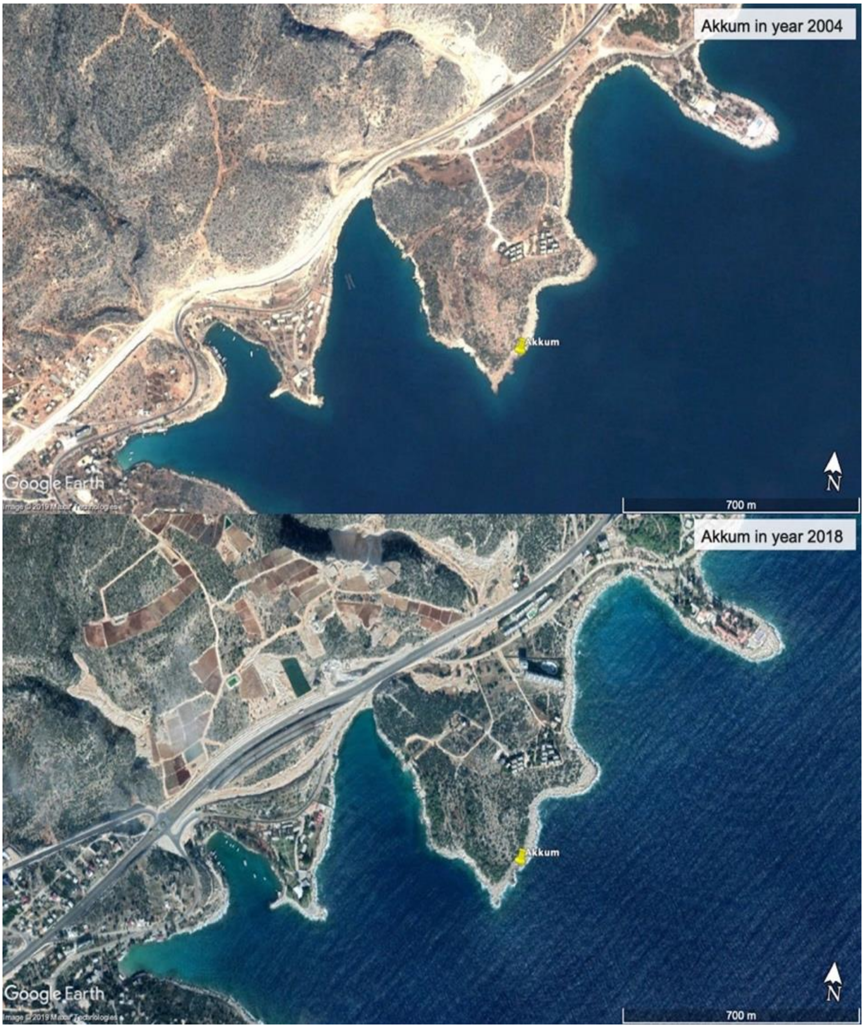

Figure 6. Land use around the vicinity of Akkum Cave in 2004 (upper panel) and 2018 (lower panel)

This situation, which means disturbing the seals, caused some seals to leave the cave again.

The area did not have any protection status and is located close to one of the most important tourism town of the region (Kızkalesi). For this reason, the area was in continuous urban development and hotels and summer house sites were built around the vicinity of the cave. In 2013, the environmental plans for the coastline of Mersin city were revised by contribution of various stakeholders including IMS-METU. The monk seal caves located along the coastline of Mersin including the one in Akkum were also included in these plans as an important monk seal habitat. However, the cave and its near vicinity is still exposed to anthropogenic pressure time to time, especially during summer months as the previously constructed sites are in active use. Therefore, it is very important not to allow any kind of construction development at least 500 meters inside of the cave location (core zone) and to control and limit some of the activities such as fishing, jet-skiing, sailing of excursion boats where necessary.

Figure 7. One of the entrance of Akkum Cave closed by metal fence in order not to change wave dynamics

Case study II: Balıklı Cave, Yeşilovacık, Mersin

Marine caves especially the breeding caves are of primary importance for the survival of endangered Mediterranean monk seals. Despite this fact a large scale marine terminal was constructed just 500 meters away from a well-known Mediterranean monk seals breeding cave in Yeşilovacık bay located in the south coast of Turkey (NE Mediterranean). The cave monitoring indicated that as well as seal activity (Figure 8), the number of seals using the cave before the construction of the terminal was dramatically reduced during the construction phase.

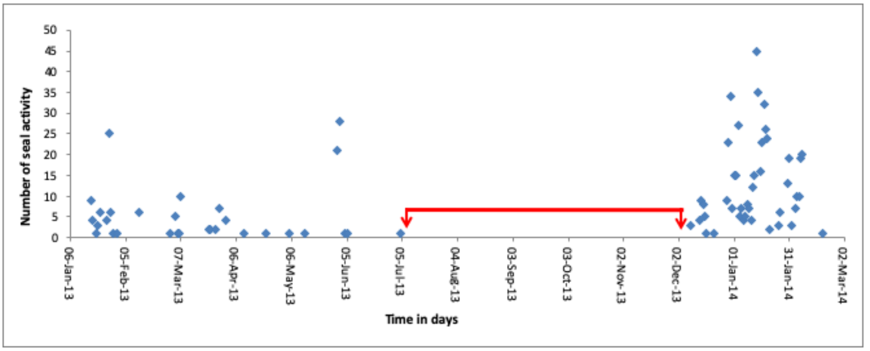

Figure 8. Frequency of seal activity per day in Balıklı cave covering the period from January 2013 – March 2014. Red line indicates the period with no seal activity.

Two whelping events occurred in the cave during the construction phase were ended by disappearance of the weaned pups and carcass of one of these two pups was found in cachectic state in the proximity of the cave (Figure **9**). No further pupping activity has been recorded in this breeding cave since then.

Figure 9. The last photograph of the seal pup (almost 90-day old) taken by camera trap on 22 January 2014 (left panel) before he was found dead on 28 February 2014 (right panel)

Considering the position of the cave with respect the marine terminal (<500 meters), the tonnage of the vessels (>30000 GRT), their speed, and given that the ships maneuver in front of the cave, the estimated noise emission (174dB) were higher than the disturbance level (120 dB) given for the pinnipeds (Figure 10).

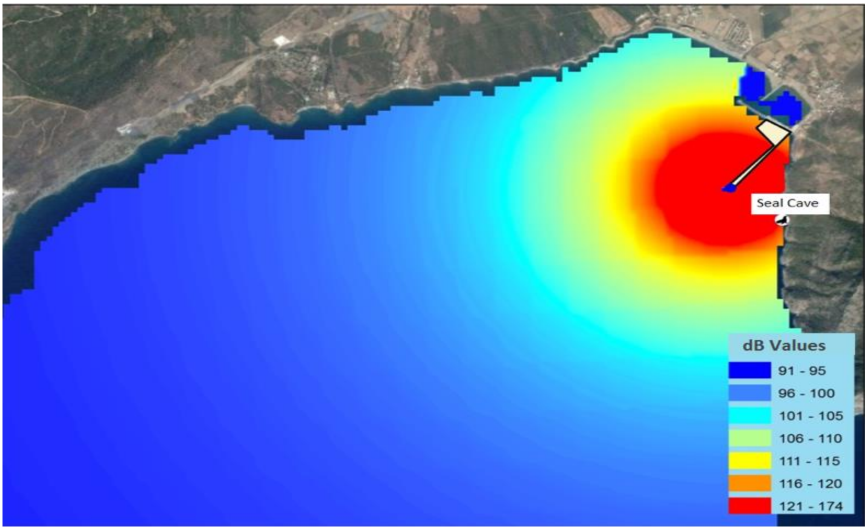

Figure 10. Activity area of the noise having 174 dB intensity at the source (farthermost point of the pier is used as a reference) and underwater noise propagation intensity in the gulf (Prepared by Dr. Serdar Sakınan)

This case is considered as a good example of the negative effect of anthropogenic underwater noise on the pinniped and the cave may perform its function again only by; i) enforcing strict measures, such as limiting the number and tonnage (<1500 DWT GRT) of the ships; ii) declaring a traffic free buffer zone around the cave (10 km); and iii) deploying some additional noise preventive measures, such as bubble curtains, during maneuvers. Unfortunately, none of these precautions were neither included in the plan notes nor implemented although the marine terminal is in operation.

Number of marine caves used by the Mediterranean monk seals are very limited along the Turkish coast of Northeastern Mediterranean and they are the key component for the survival of the seal populations. Some of these caves has even additional functionality as being link between isolated populations which enables connectivity between the populations. Especially, the ones used by seals for breeding are of crucial importance for survival of the monk seal pups which was stated three decades ago by Mursaloğlu (1988). Moreover, these unique habitats are not only important for survival of pups but also for the survival of the population as the high mortality rate at early life stages reported to have adverse effect on the populations (Ok 2006). In addition, whelping may occur in inappropriate time (miscarriage) or in inappropriate caves/coastal sites and mother-pup bond may be weakened (Mursaloğlu 1986) due to habitat destruction and anthropogenic disturbance.

Not only cave habitat destruction and disturbance but also loss of coastal habitats have generally irreversible effect on biodiversity including the Mediterranean monk seal. Therefore, high priority should be given to the protection of these unique habitats during the planning of the development.

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Marine caves biodiversity and conservation in the Turkish part of the Mediterranean Sea: Preliminary results of East Med Cave Project

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Introduction

Marine caves, in general, have a rich biodiversity reservoir, but only a limited number of studies in the Eastern Mediterranean were performed due to lack of experts, requirement of additional equipment and difficulties arising from the study of cave habitats, etc. Nevertheless, over the past few years, marine caves became important in terms of marine biodiversity conservation in the Turkish part of the Mediterranean Sea. Rield (1966) compiled and reported 905 taxa from within Mediterranean marine caves. Vacelet (1996) mentioned that submarine caves share several ecological features with deep-sea habitats in the Mediterranean Sea. Giakoumi *et al*. (2013) reported around 3000 marine caves on the rocky coast of the Mediterranean Sea. Gerovasilieou and Voultsiadou (2012) reported that marine caves appear to be an important sponge biodiversity reservoir. Gerovasileiou *et al.* (2016) reported 56 alien species from the Mediterranean caves. In the Turkish part of the Aegean and Mediterranean Sea, some studies were also done on the marine caves. Şadoğlu (1957, 1967) has studies on the Selective Value of Eye and Pigment Loss in Mexican Cave Fish.
Aygen (1984) listed 15 marine caves in the Aegean and Mediterranean part of Turkey. Hamarat *et al.* (1998), Öztan *et al.* (2004), Bayarı *et al*. (2011), Dipova and Okudan (2011) also studied some caves in the Mediterranean part of Turkey. Besides, some papers have been published about monk seal caves and some grey literature does also exist. However, data deficiency and scarcity are still a fact of the matter for the numerous marine caves in Turkish coast. The aim of this project is to establish the basis of a scientific framework for the conservation of sensitive and key habitat species found in marine caves.

Materials and methods

In early 2019, we conducted a questionnaire with 20 questions under East Med Cave Project (www.tudav.org). The aim of the questionnaire was to collect information, such as the location of the caves, habitat type, depth, diving activity, presence of alien species and monk seal activity (Table 1). This questionnaire was addressed not only to divers and diving schools but also to fishermen and local people who could provide reliable data about marine caves.

As a result of the survey, 10 caves were identified (Figure 1) and they were examined by the authors via scuba diving. Pictures and video were taken in order to record more detailed information about caves and biota within the caves while diving.

Table 1. Questionnaire for divers, fishermen and yacht owners

No	Question
1	Email address, name and surname
2	Name, address and date of establishment of SCUBA school
3	Average number of divers/year brought to marine caves under your supervision
4	Name of the boat used during cave diving
5	Cave name
6	Cave accessibility
7	Location of the cave
8	Depth of cave entrance
9	Horizontal length of cave entrance
10	Status of light inside the cave (darkness or semi-darkness states)
11	Entry and exit status for each dive (single entry/exit, 2 entries/exits, 3 entries/exits, others)
12	Which fish species can be found in marine caves? (pictures if possible)
13	Which invertebrate species can be found in marine caves? (pictures if possible)
14	Was there any trace of ghost-fishing at the entrance of marine caves (net parts, fishing lines, baskets, etc.)?
15	Have you observed any monk seals in marine caves? If so, how many?
16	Do you remember the number of accidents during your diving activities in marine caves?
17	Have you received any prior training in marine cave diving? If yes, when and from which institution?
18	According to your personal experience/from your standpoint, what is the biggest threat to marine caves in Turkey?
19	What are your suggestions to enhance the protection of marine caves?
20	Can you join a conservation network for marine caves in Turkey?

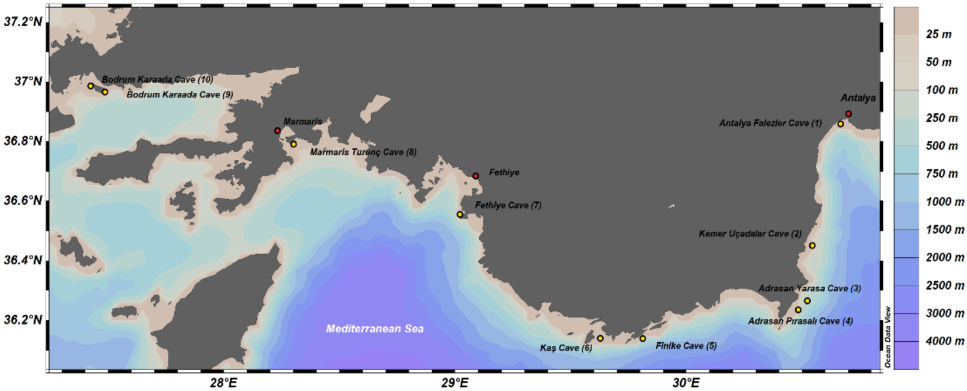

Figure 1. Examined caves between Antalya and Bodrum

Results and discussion

Most of the visited caves were anchored by tourist boats in summer time, whose aim was to travel to more quiet and remote areas (Figure 2a). Caves are attractive to everyone, especially for curious people. Boat anchoring is one of the main threats to the entrance of caves, due to the damage caused to the benthic sessile species. In addition, noise and ship originated pollution is threatening for the monk seals. Aygen (1984) mentioned that marine caves are attractive for tourism, because of its hot springs and the proximity of monk seals. He reported two monk seals from Kaputaş Cave in Kaş-Kalkan area.

A colony of bat species, *Miniopterus schreibersii,* has been observed, with several individuals hanging from the ceiling in a cave located in Adrasan area, which makes it called "Yarasa (bat in Turkish) Cave". Anthropogenic noise can be a threat for the bat population as well.

Fishing activities with set nets (Figure 2b) are harmful for the biodiversity of the cave, not only for fish but also for sessile fauna, such as Neptune's lace *Reteporella grimaldii*, *Hornera frondiculata* and *Sertella septentrionalis,* and some sponges such as *Axinella* spp. Target species of the fishing activities were mainly white and dusky grouper, *Epinephelus aeneus* and *E. marginatus* which are considered as protected species in Turkish waters. In addition, the slipper lobster *Scyllarides latus,* one of the threatened lobster species in Turkish waters, was also found.

Some caves (mainly in Fethiye area) were physically damaged due to intense commercial usage by scuba divers. Massive diving activities are one of the main threats for cave habitats. Yarmacı and Keleş (2016) analysed potential diving tourism in Kaş and overall 50,000 to 70,000 dives were reported during one year on average.

Fishing nets were reported as ghost fishing in Kemer and Adrasan (Figure 2c). Two caves were observed with some plastic debris in Antalya and Finike caves, even though it is not common to find plastic debris in the caves in general (Figure 2d).

A threat matrix was prepared in order to better understand threats looming over these caves (Table 2).

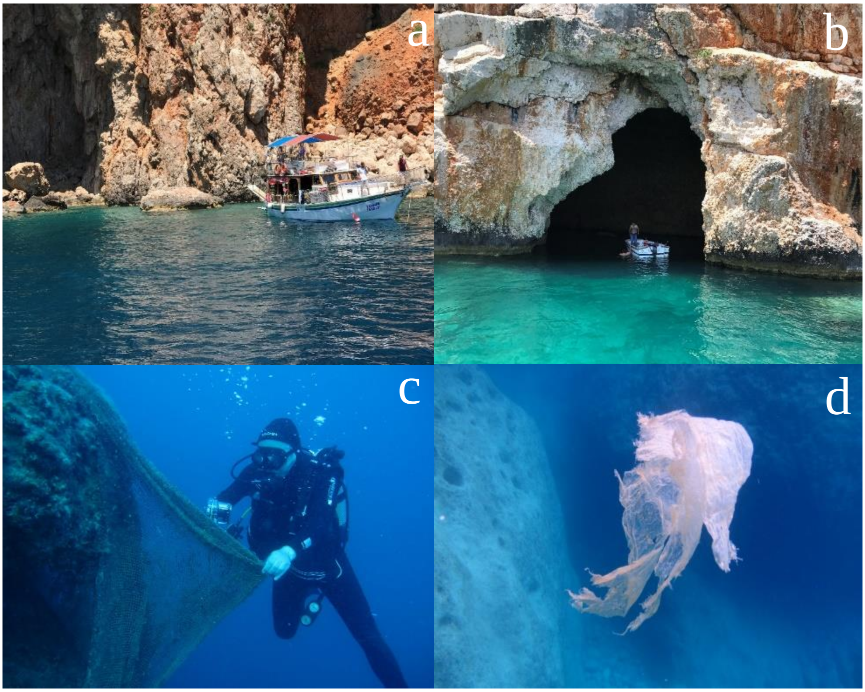

Figure 2. Entrance of a cave and pleasure a boat with tourists in Adrasan area **(a)**.
Set net fishing at the entrance and inside of the cave **(b)**.
Ghost fishing in the entrance of a cave **(c)**.
Plastic debris was also reported in the caves from Antalya and Finike **(d)**.

Anthropogenic activities are the main problem for the caves located in the studied area. Pollution is the main threat for all caves. Physical damage of the cave and cave biota is related with cave tourism and this activity also should be mitigated. The intensity of these threats should be decreased in order to protect cave habitats and biota.

Table 2. Threat matrix of the studied marine caves

Diving places/Caves	Pollution, ghost fishing (net, hook, line, pieces of plastic, etc)	Physical damage of cave and cave biota	Disturbance to monk Seals (M) and bat (B)	Human disturbance anchoring, fishing, spear fishing, snorkelling
Antalya Falezler Cave (1)	X	X	X (M)	X
Kemer Üç Adalar Cave (2)	X	X	X(M)	X
Adrasan Yarasa Cave (3)	X	-	X (B)	X
Adrasan Pırasalı Cave (4)	X	-	-	X
Finike Cave (5)	X	-	X	
Kaş Cave (6)	X	X	-	-
Fethiye Cave (7)	X	X	-	X
Marmaris Turunç Cave (8)		X	-	X
Bodrum Kara Ada Havalı Cave (9)	X	-	X	-
Bodrum Cave (10)	X	X	-	

Bayarı (2003) reported several threats for caves, stating that a more stringent protection for caves was required. He also urged that it was an urgent task in order to protect the invaluable and unique beauties of these habitats. Özel (2018) mentioned that unmanaged touristic visits are pressure for caves. In fact, some caves are used intensively in summer season for scuba diving without consideration for their carrying capacities.

Swallowtail sea perch *Anthias anthias* (Figure 3a) was reported in three caves. *Scyllarides latus* (Figure 3b) was also found in three of the caves. This species is one of the commercial species in the Turkish coasts of the Mediterranean sea so divers and fishermen collect them for commercial purposes. Beside the loss of habitat in caves, disturbance caused by visitors are also a threat. This species is listed as a species whose exploitation is regulated according to the protocol concerning specifically protected areas and biological diversity in the Mediterranean Sea.

Yellow coral *Leptopsammia pruvoti* (Figure 3.c) occurs on hard substrata at the entrance and within caves and under overhangs in most of the caves up to 45 metre depths in three caves. In six caves narwhal shrimp *Plesionika narval* (Figure 3.d) were detected, as was expected. This species can be found hidden in the dark area of caves. No commercial value for this species is established in the Turkish market for the moment.

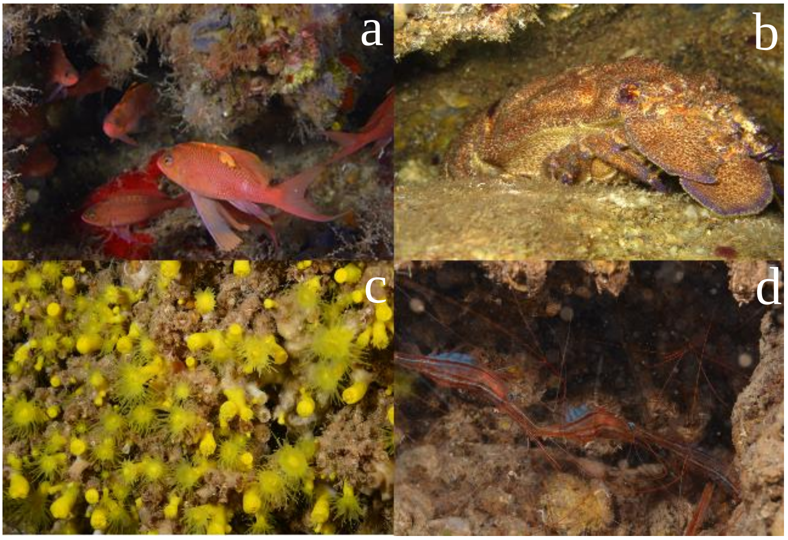

Figure 3. a) *Anthias anthias,* **b)** *Scyllarides latus,* **c)** *Leptopsammia pruvoti* **d)** *Plesionika narval*

There are few studies about non indigenous species and assemblages in marine caves in the Turkish part of the Eastern Mediterranean Sea except for Bilecenoglu and Taşkavak (1999).

Some alien fish and invertebrate species have successfully established in marine caves, which were unfilled earlier with alien biota. Most adaptive fish were lion fish *Pterois miles* and red squirrelfish, *Sargocentron rubrum,* which can be commonly found in every cave. Most of the alien species were found in semi-darkness, however some invertebrate species such as the alien decapod crustacean originating from the Red Sea, *Urocaridella pulchella,* were found in the dark part of the cave. This species was already reported by Yokeş and Galil (2006) from Kaş in the Turkish coast (Figure 4) .Besides, some other alien species, such as *Diadema setosum,* usually found outside caves, have also well adapted to the dark environment.

Table 3. List of non-indigenous species in studied caves (+) for presence and (-) for absence

		Caves									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Fish species	*Apogon imberbis*	+	-	+	-	-	-	-	-	-	-
	Cheilodipterus novemstriatus	-	+	-	+	+	-	-	-	-	-
	Hemiramphus far	+	-	-	-	-	-	-	-	-	-
	Pempheris rhomboidea	+	+	+	+	+	+	+	+	+	-
	Pterois miles	+	+	+	+	+	+	+	+	+	+
	Sargocentron rubrum	+	+	+	+	+	+	+	+	+	+
	Siganus luridus	+	+	-	+	+	-	+	+	+	-
	Torquigener flavimaglosus	-	-	-	-	-	+	-	-	-	-
Invertebrate species	*Cerithium scabridum*	-	-	-	-	-	+	+	+	-	-
	Diadema setosum	+	-	-	+	-	+	+	+	-	-
	Herdmania momus	-	-	-	-	-	+	-	+	+	-
	Phallusia nigra	-	-	-	-	-	-	+	-	-	-
	Synaptula reciprocans	+	-	-	-	-	-	-	-	-	-
	Urocaridella pulchella	-	+	+	-	-	-	-	-	-	-

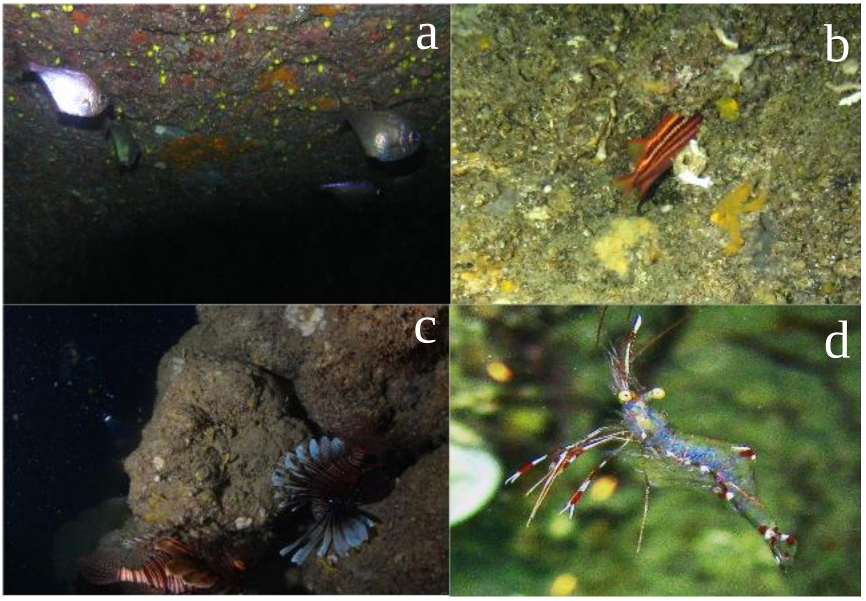

Figure 4. a) *Pempheris rhomoboidea,* **b)** *Sargocentron rubrum,* **c)** *Pterois miles* and **d)** *Urocaridella pulchella*

There is only one cave found in Kaş, one of the Special Environmental Protection Areas. However, invasive alien species such as lionfish and puffer fish, *Torquigener flavimaculosus,* were reported in the entrance and the semi-dark parts of that cave. All caves from Bodrum to Antalya areas host alien species, even invasive alien species such as lionfish. A total of 8 species of fish and 6 species of invertebrates were reported as non-indigenous species during this study.

Conclusion

According to this preliminary study, some threats were identified as intensive diving tourism, pleasure boats, and fishing, as well as invasive alien species such as lionfish. A national conservation strategy for marine caves is urgently needed, by taking into consideration potential long-term risks for cave biodiversity and adopting a serious precautionary approach. An action plan for dark habitats should be prepared and implemented by Turkey in order to protect this unique ecosystem. Caves in the Turkish coasts deserve particular valorization, consideration and attention as an urgent task for Turkish authorities. One reason for this is that marine caves are already considered habitats of high priority in the Mediterranean Sea, i.e. EU Habitat Directive (92/43/EEC) and Barcelona Convention.

There are some legal gaps for conservation of marine caves. Therefore, a more defined and concrete action should be taken for cave conservation. Dönmez (2006) reported that there are several legal loopholes in Turkish laws for the marine cave conservation. As it is, there is an urgent need for a Cave Conservation Act to define the duties of government entities as clearly as possible in terms of cave conservation. In addition, Kaya (2003) mentioned that natural caves are considered as natural assetsaccording to Law 2863. However, it is not sufficient to protect caves because of pending duties among governmental agencies. It is obvious that there has been a lack of management and protection measures for marine caves.

We also suggest that the Turkish Ministry of Environment and Urbanisation should consider opening a department for marine cave conservation in order to manage cave tourism, exploration, research and protection. In fact, within the framework of the Barcelona Convention, a dark habitat action plan was adopted in İstanbul, Turkey, in 2013 during the Eighteenth Ordinary meeting of the Contracting Parties. Turkey is one of the signatory states of the Barcelona Convention and this is a legal obligation that should be taken into consideration.

A national inventory of marine caves and a monitoring program along the Turkish coastlines are needed. This inventory can take a long time, as much as five years, due to numerous marine caves that are yet to be discovered. This inventory can contribute to the conservation of marine caves as well as correct assessment of risks for marine caves' biota. Annual carrying capacity of attractive caves visited by tourists and divers should be calculated, according to which the entrance to the caves must be limited in order to conserve the species and assemblages in those caves.

Marine cave conservation is also a matter of public perception and outreach. Kaya (2003) stated that cave conservation is related to education and awareness. Hence, public awareness and outreach programmes are important for divers, fishermen, yacht owners, tourists and local people. Draman (2018) reported that, in order to protect monk seals, some leaflets and signs are already placed into diving guide books in Kaş. Most of the divers are conscious of the protection of monk seals. Diving schools and other individuals are banned from monk seal caves by Turkish Fisheries' circular in order to not disturb this unique, threatened pinniped species. Fortunately, all visited diving centres are willing to join the cave protection network as well.

Finally, enhancing national capacities with all stakeholders such as diving centers, NGO’s and other entities can be one of the priorities for the protection of dark assemblages. Collecting scientific data for cave habitats and monitoring should also be essential as a part of the national plan of Turkey.

Acknowledgement

Authors thank all divers and fishermen for participating in the cave questionnaire survey as a part of Eastern Mediterranean Cave Project, and Mr. Adnan Büyük for his kind help with some of the pictures.

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Rosh-Hanikra Grottoes, Israel – A refuge for the critically endangered and for opportunistic invasives

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The Israeli coastline, at the southeastern corner of the Mediterranean, describes a slightly curved line with Haifa Bay the sole embayment. The sediments transported from the Nile delta northwards by the prevailing inner shelf and wave-induced longshore currents produce a sandy shallow shelf. Only the very northern part of the coast borders cliffs (Emery and Neev 1960). Rosh HaNikra (in Arabic, Ras a-Nakura) grottoes, semi-submerged shallow coastal caverns, are situated on the Israeli-Lebanese border.

The limestone mid-littoral cave of Rosh HaNikra was formed through a marine invasion into a karst littoral cave system, which had developed in a pre-Quaternary era along a fracture. The cave system consists of two interconnected branches, which connect in the farthest part, some 200 m from the opening. More than 10 known openings lead into the system, some of which are submarine, at between 3 and 5 m depth.

The ridge of Rosh Hanikra is a geological arch, formed by a process of deformation following intense pressing exerted on the rock layers, its axis southwest to the north-northeast. The anticline is cut in several places by systems of faults. The most important of these are oriented east-west at a 45° angle to the longitudinal axis of the ridge. A second fault is invisible, though its existence can be estimated by the nearby seabed structure, oriented north-south. These faults produced the prominent cliff at their point of intersection, but over time, as a result of wave erosion, the cliff retreated to its present location, northeast of its initial position. Secondary faults and fissures may be observed throughout in areas uncovered by soil. The cliff consists mainly of chalky rock embedded with small, dark amorphous flint blocks, and in its northern part there are hard limestone rocks. The faults and fissures are of paramount importance, because even before mountain and sea met, they gave rise to karstic formations, typical of the limestone mountains of the Galilee. Seawater penetrated the fissures and formed the grottoes. But while the karstic caverns are fairly uniform in character and size, this is not the case in the grottoes. The original karstic caverns had developed in fissures wherever rainwater has penetrated, regardless of their orientation. The grottoes, on the other hand, favored fissures perpendicular, rather than those running parallel to the wave action. The most important part of the grottoes system evolved at the intersection of the major faults. The grottoes in their current form are therefore the result of the fissures' intersections, direction, type of rock and sea level. Rosh HaNikra cliff weathered several eustatic sea level changes. Marine grottoes develop in a well-defined zone, ranging from a few meters below sea level to the surf zone. At Rosh HaNikra grottoes' openings were observed at depths of 3-5 m below current sea level, their beds, at a depth of 6-7 m, covered with loose, unconsolidated sediment - evidence of an earlier sea level, lower than the present one by at least 7 m. A layer of pebbles and coarse sand south of the cliff, indicates a sea level 8 m higher. There is evidence of dry periods in between the marine immersions, such as blocks of calcareous aeolianite formed by the lithification of coastal dunes inside the grottoes (Figures 1, 2). Breccia, an aggregate of terrestrial gravel, limestone and flint, fossilized soil, cemented together by a fine-grained matrix was found in one grotto, together with jaws of an early rhinocerid. It testifies to an extensive slope composed of gravel and soil eroded from the nearby cliffs. Ongoing sea floor subsidence and rising sea levels exacerbate erosion: due to the depth of the seafloor the sediment and rock debris that would have accumulated at the cliff's foot and created a moderating slope, are removed from the foreshore by to the action of waves and currents.

Figure 1. Rosh Hanikra's grottoes (photo by Oren Klein)

Figure 2. Rosh Hanikra's grottoes (photo by Shevy Rothman)

In the past the only access to the grottoes was by sea. During World War II, the South African, Australian and New Zealand Corps of Engineers cut a railway tunnel through the cliff for the Haifa-Beirut railroad line. In 1968 a second tunnel 400 m long was dug. Both tunnels connect with the grottoes and with each other and allow access along the former route of the British railroad. A cable car, serving as the main means of access to the grottoes, was added in 1968. It is considered the steepest (60°) and shortest ride in the world, and affords spectacular views of the blue sea against the gleaming white cliff.

Visitors to Rosh Hanikra in winter, during a storm, can watch the waves crashing unto the cliff, with surf spray reaching a height of 35 m or more. The striking waves compress air in fissures causing a booming noise to reverberate throughout the cliff, exerts pressure on the surrounding rock, progressively loosen pieces of rock, and using the scree to batter and abrade the grottoes as well as the cliff face.

***Monachus monachus* in Rosh HaNikra**

Belon (1553), who travelled extensively in the Levant, was the first to describe and illustrate the monk seal *Monachus monachus* (as *Phoca*, Figure 3). The species was regularly sighted on the north coast of Israel up until 1941 (Bertram 1943, *fide* Scheinin *et al*. 2011). A single seal was reported in 1953 and again in 1968 from Rosh HaNikra grottoes (Dolev and Perevolotsky 2004, Bundone *et al*. 2016). In the decade since 2009, there have been scores of reliable reports of monk seal sightings along the Israeli coastline, including a female photographed in 2014, 2015, 2016 and 2018 in Rosh Hanikra (Scheinin *et al*. 2011, Eherlichman 2014, Bundone *et al*. 2016, Hashmonai 2016, Shalan and Eherlichman 2018). The seal, a mature female, was observed feeding and remained in the shallows near the grottoes to the delight of visitors. Similarly, seals were documented inside or adjacent to marine caves in neighbouring Lebanon (The monachus guardian 2010, Society for the Protection of Nature in Lebanon 2017).

The multiple sightings may indicate that the monk seals, likely originating in Cyprus or Turkey, are seeking to recolonize this part of the Levant coastline. The only suitable grottoes along the Israeli coast are at Rosh HaNikra, with the added advantage of an adjoining marine reserve. Yet, though the Mediterranean monk seal is considered one of the world's most critically endangered mammals (IUCN 2010), Israel Nature and Parks Authority (INPA) is actively encouraging diving in Rosh HaNikra grottoes, possibly disturbing and alienating the visitors (Yahel *et al*. 2012).

Figure 3. Monk seal *Monachus monachus* at Rosh HaNikra, near the grottoes (photo by Mia Elasar)

Natives and non-natives

The grottoes community surveyed in 2004 comprised encrusting calcareous algae, sponges, hydrozoans, madreporarians and bryozoans (Ramos Esplá and Valle Pérez 2004). At the grottoes one may encounter colorful native blennies (*Aidablennius sphynx* (Valenciennes, 1836), *Coryphoblennius galerita* (Linnaeus, 1758), *Salaria pavo* (Risso, 1810), *Lipophrys trigloides* (Valenciennes, 1836), *Parablennius gattorugine* (Linnaeus, 1758), *P. incognitus* (Bath, 1968)); gobies (*Chromogobius zebratus* (Kolombatovic, 1891), *Gobius cobitis* Pallas, 1814, *G. paganellus* Linnaeus, 1758); gobiesocids (*Lepadogaster candolii* Risso, 1810, *L. lepadogaster (*Bonnaterre, 1788)); labrids (*Symphodus roissali* (Risso, 1810), *Thalassoma pavo* (Linnaeus, 1758)); tripterygnids (*Tripterygion delaisi* Cadenat & Blache, 1970, *T. melanurum* Guichenot, 1850); *Scorpaena maderensis* Valenciennes, 1833; *Serranus scriba* (Linnaeus, 1758) (Goren unpublished).

The nocturnal Mediterranean slipper lobster, *Scyllarides latus* (Latreille, 1803), was considered common in Rosh Hanikra, where it sheltered in crevices and shallow caves (Ramos Esplá and Valle Pérez 2004). A recent stranding of 20 *S. latus* individuals, on a beach adjacent to the grottoes following severe winter storms, confirms the use of the grottoes as overwintering dens. It is likely powerful waves dislodged those individuals and swept them ashore (Spanier *et al*. 2017). *Scyllarides latus* is protected under the Mediterranean Action Plan, Barcelona Convention, the Bern Convention and the Israeli law concerning National Parks and Nature Reserves. Yet, it has been offered openly for sale on the Acre fish market and in many fish restaurants, and INPA's own marine ecologist admits they are caught within the marine nature reserve in Rosh Hanikra (Arad 2012).

The southern Levant coast, located down-current of the Suez Canal opening into the Mediterranean, is under intense propagule pressure and consequently hosts the highest number of established Erythraean alien species (Galil *et al*. 2018). Ramos Esplá and Valle Pérez (2004) described the biocenosis of the semi-dark caves in Rosh HaNikra-Akhziv as replete with Erythraean alien species including schools of the Redcoat soldierfish *Sargocentron rubrum* (Forsskål, 1775), the Sweeper *Pempheris rhomboidea*, Kossmann & Räuber, 1877 (as *P. vanicolensis*) (Figure 4), the Bullseye Cardinalfish *Apogonichthyoides nigripinnis* (Cuvier, 1828) (as *Apogon nigripinnis*), and the stinging hydroid *Macrorhynchia philippina* Kirchenpauer, 1872. Goren (unpublished) recorded the rabbitfish *Siganus luridus* (Rüppell, 1829).

Figure 4. A shoal of *Pempheris rhomboidea* near the opening of Rosh HaNikra grottoes (photo by Oren Klein)

Acknowledgements

We thank Dr. M. Roditi-Elsar, chairperson of Israel Marine Mammal Research & Assistance Center (IMMRAC), Mr. O. Klein and Dr. B.S.B. Rothman for their generosity in sharing with us and the readers their unique photographs.

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Biodiversity of marine caves and cave-like formations around the Northern Aegean islands of Turkey (Gökçeada and Bozcaada)

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Introduction

Biodiversity is the most crucial and essential part of marine researches. To determine hosting species and recognize their biotope in ecosystems also underline the fundamentals of ecology and biology. In marine science, data intake from these two disciplines serve as a trigger for other scientific studies and pave the ways for new discoveries. Today, we see that biodiversity knowledge has progressed rapidly not only in marine and terrestrial environments in general, but also in the subsystems such as cave sites, coral reefs, mangroves, alpine lakes, hydrothermal vents etc. Differing greatly from site by site according to special characteristics of its own, diversity in habitats may reach beyond the limits on special circumstances.

To date, a total of 17,000 marine species has been reported from the Mediterranean Sea, also known as one of the biodiversity hotspot area in the world (Tyrrhenian Sea, Aegean Sea, Ionian Sea, Adriatic Sea, Ligurian Sea and Strait of Gibraltar and Alboran Sea included), even though many of them such as deep-sea areas, microbe diversity, portions of the southern and eastern regions are presented as poorly-studied and undetermined (Coll *et al.* 2010). This census results at an international level is also highly important for the Mediterranean Sea when comparing to the number of marine species which was recently shared from the coastlines of Australia and Japan over 32000 species and China over 22000 species.

Concerning the taxa rate among these studies, it is resulted that Crustacea, Mollusca and Pisces are the most encountered groups representing for almost all regions in the world (Costello *et al.* 2010). Although the main representing group of invertebrates, Porifera, Cnidaria, Tunicata, Platyhelminthes and Bryozoa are below the average in the same research (Costello *et al.* 2010), it is also stated that the species richness and taxon may vary according to the region. For instance, in a marine research carried out lately in the Mediterranean Sea caves, in which the study is also known as a pioneering investigation regarding cave biodiversity, a total of 905 species was recorded in marine caves and in general contrarily, sponges were given as the dominant group (Riedl 1966).

Caves, cave-like formations and crevice habitats constitute unique hard substrata for sheltering that is suitable for many species in marine environment and they represent one of the key faunal diversity in the seas and oceans. According to the recent research focused on 3000 cave sites in the Mediterranean Sea, 97% of them was found to be located in the Northern basin and the recent census study discovered 738 marine caves in the Eastern Mediterranean (Gerovasileiou *et al.* 2015; Giakoumi *et al.* 2013).

Regarding the richness of biodiversity, these habitats, which have both semi-dark and dark conditions and sometimes with unknown biota, are also mentioned as the hotspot areas of invertebrates like sponges, corals, tunicates, bryozoans and some other aquatic species. Latest studies on diversity, given above as well, showed that a total of 905 species was recorded in Mediterranean marine caves and in general, sponges are known to be dominant species in marine cave systems showing the highest occurrence at these sites, while polychaetes, rhodophytes, bivalves, fishes and gastropods are listed as the other groups following poriferans (Corriero *et al.* 2000; Gerovasileiou *et al.* 2015).

Within nearly 8553 sponge species in the literature (Van Soest *et al.* 2012), a total of 331 poriferans are reported from the Mediterranean Sea, while at occasionally similar condition, it is given as 326 species from the Atlantic marine caves in another study performed recently (Gerovasileiou and Voultsiadou 2012). A census of marine cave diversity in the Eastern Mediterranean Sea revealed that the northern Aegean Sea, where caves are in a great number and well-documented, totally 324 taxa were found, while 175 taxa were found from the Levantine Basin and 156 taxa from the southern Aegean Sea. The northern Aegean caves concerning the diversity host 100% of Mediterranean cave Echiura and Phoronida, while 30% of Porifera, Anthozoa Sipuncula, Cephalopoda, Brachiopoda, Echinodermata and Pisces. In the same study, Polychaeta and Scyphozoa abundance was informed as 25% of Mediterranean cave fauna (Gerovasileiou *et al.* 2015). A latest study showed that Gastropoda and Polychaeta are also among the groups which are diverse and densely occurred group in marine cave fauna (Kano and Kase 2008).

The northern Aegean Islands of Turkey, Gökçeada and Bozcaada, together with Tavşan Islands Group, remain among the biodiversity hotspot areas in the Turkish Seas (Topaloğlu and Evcen 2014). As well as showing high fish diversity the area itself serves as a special ecosystem in which mainly Poriferans are commonly observed around the caves and cave-like formations (smaller caves, holes, crevices etc.) along the rocky shores. The shore rocky substrates are also rich regarding the solitary coral occurrences, *Madracis pharensis* or *Hoplangia durotrix*-associated coverings and overhangs, coralligenous formations, Polychaeta abundance and endangered-species reef banks in the islands.

At some special locations in coastal zones, the endangered coral *Cladocora caespitosa* forms mass-type and bank-like bioconcretions and the dense existence of *Posidonia oceanica* meadows that is almost present all along the islands' coastlines, turning the area a fertile refuge for marine life.

To date, cave habitats and marine biodiversity in the Turkish Islands at northern Aegean region have been limitedly documented. The cave studies related to the islands given above formerly focused on marine mammals (*Monachus monachus*) and the evaluation of their ecological and distributional character in Gökçeada Island. Within these researches, five littoral caves were discovered in the region, sharing no information about the marine biodiversity around the sites (Dede 1998; Öztürk 2007). It is also reported that there are some submarine caves down on the way of Yelkenkaya, Gökçeada (Öztürk 2001). In a recent survey, also known as the pioneering investigation for the area, macrobenthic diversity was studied for the first time in a submarine cave of Gökçeada Island, reporting six different taxa as well as their abundance rate (Topaloğlu 2018).

As given above in detail, the existing knowledge on marine biodiversity around cave sites in the northern Aegean Islands of Turkey is very scarce and data intake is extremely needed to be enhanced for having advanced information on ecological features and cave-based distributional characteristics of invertebrates which are known as the basic and priceless valuable habitats on rocky substrates.

Shore and Biota Characteristics of the Islands

Gökçeada Island

Gökçeada, as the biggest island of Turkey with a surface area over 288 km^2 and a coastal length of 94 km, show rough and steep geological formation. The high variety of rock types along the coastal zone of the island is the key factor in the formation of numerous cave and cave-like structures in the area (Figure 1).

Basically porphyritic andesite (volcanic tuff), also known as Gökçeada domes, lava rocks, granite stones and sandstones are influenced on composition of indented and hollowed rocky shores where marine invertebrates are commonly distributed (Özden *et al.* 2008; Sari *et al.* 2015). Mostly the northern and north western parts of the island and also some locations at the south western regions in a very limited manner, show more complex rocky structure as compared to the other areas in which the shores are mainly composed of pumice stone and sand in littoral zone, also showing the gravelous sandy coast character at some points. Dense rocky fields in the distributional area form caves and smaller cave-like shelters among themselves enabling high species richness and living spaces for many invertebrate communities (Figure 2).

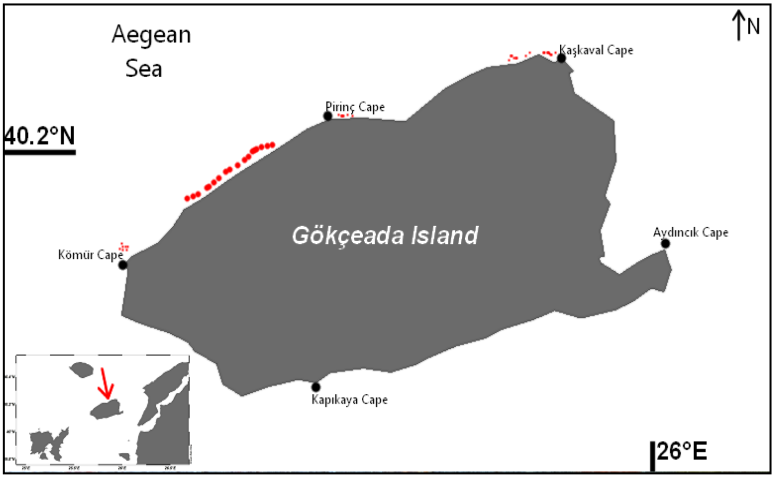

Figure 1. Map of the updated littoral and submarine cave sites of Gökçeada Island

Although there are several wave-cut littoral caves (Figure 3), submarine caves outnumber around the island ecosystem in general. Some of these at littoral zone, also known as the shore cave site, are full of water beginning at the entrance zone and thus form littoral submarine caves on the coastline even if they are highly under effect of tidal movements. During tidal changes, these caves may turn into a submarine cave from the littoral type or vice versa (Figure 4).

In Gökçeada Island, although rare, there are also some special rocky substrates and wall-like rocks involving large spaces offshore at deep waters forming smaller submarine caves which are known to be created mainly due to plate tectonics in early times. These type of caves may usually be located over about two miles away from the main coastline at the northern regions and calcareous bioconcretions are densely occurred around the sites.

Sponges are the most common group of invertebrates both on the ceiling and wall parts of the caves. A recent research carried out in submarine caves around the island showed that sponges are the dominant species with a coverage rate of 78.2% at the entrance and inner parts of the caves, while algae covered the highest percentage of the surface area over 95% outside the cave (Topaloğlu 2018).

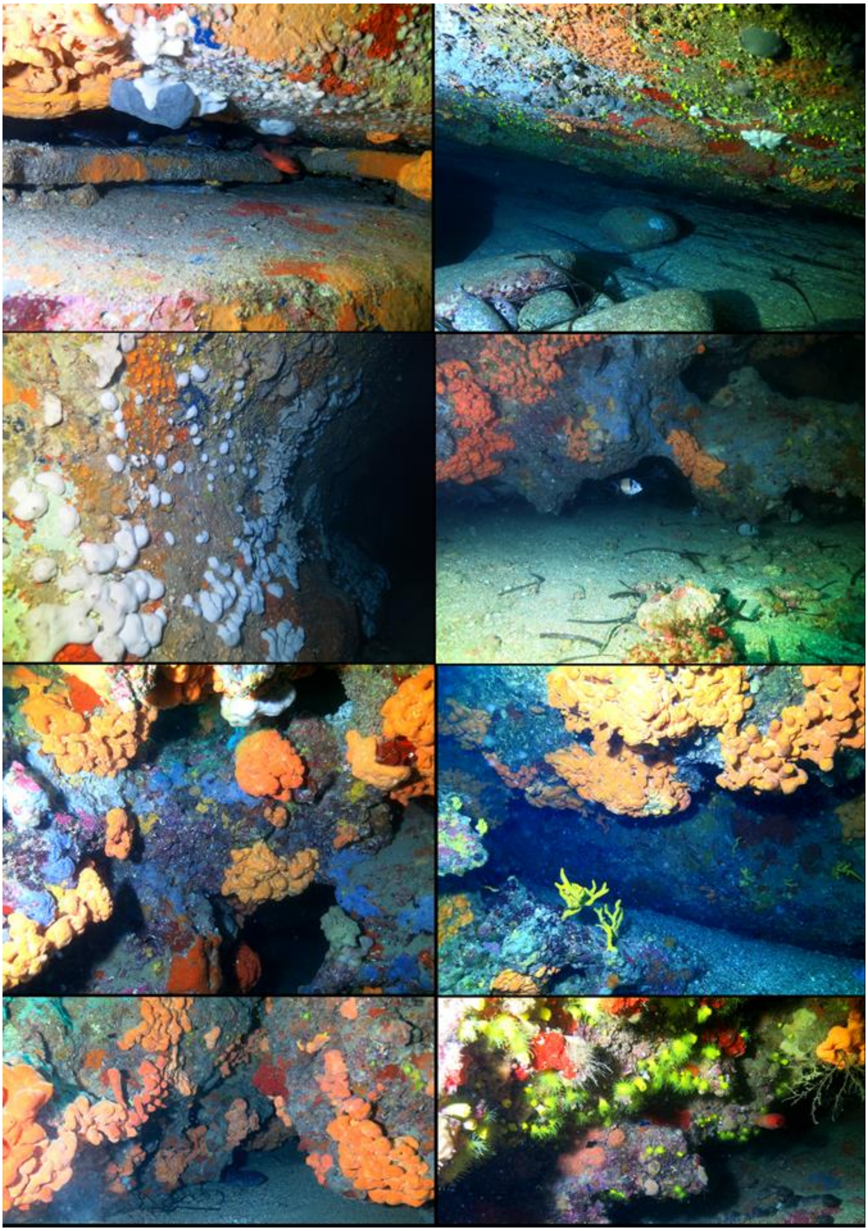

Figure 2. The caves of Gökçeada Island showing the community structure and high species richness

Figure 3. A wave-cut cave in the northwestern coast of Gökçeada

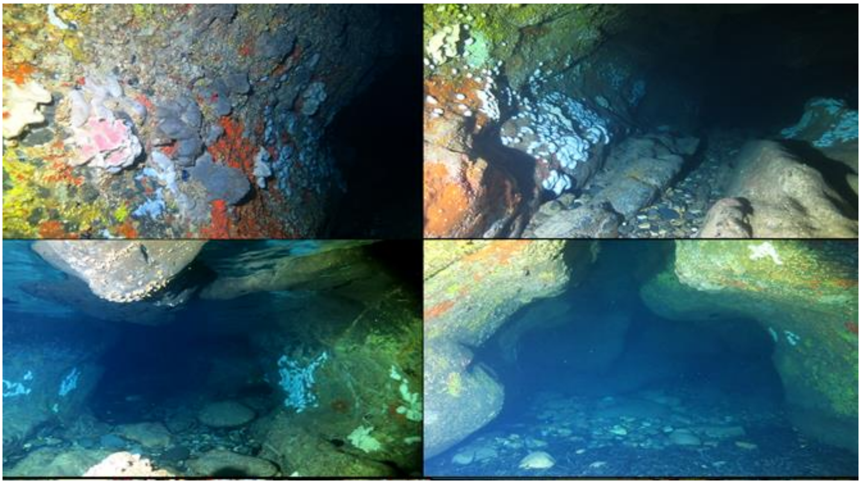

Figure 4. Caves in Gökçeada which are under effect of tidal movements

Scleractinian corals, molluscs and bryozoans, which commonly create dense facies-like substrata on rock surfaces, are also other basic occurring group of invertebrates around the caves of the island. At some submarine caves, coralligenous may form complex formations on ceilings as well which are more suitable micro-habitats for colonial corals (unpublished data, Özalp 2019).

Bozcaada Island

Bozcaada is the third biggest island of Turkey with a surface area over 37 km^2 and a coastal length of 34 km. In terms of rocky area complexity, it represents smooth coastline character in general all along the island coast (Figure 5).

Although very rare, the littoral cave and cave-like formations in the island are located in the south eastern region named Ayana, also known as the only station, Where the Palaeozoic marble basement geology occurs. Dune sands and conglomerate coast types also create some smaller rough-like rock spaces in littoral of the island's west and south western regions.

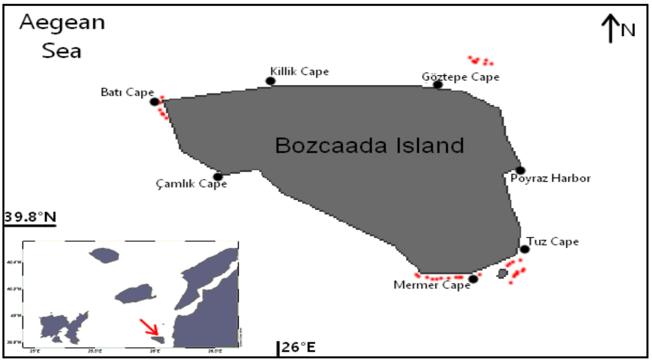

Figure 5. Map of the updated littoral and submarine cave sites of Bozcaada Island

Although there are some rocky depressions and rough coastal features at some sections on the coastline, in which andesite, limestone and sandstone-based regions (Avcıoğlu *et al.* 2015) are other main geological feature of the coasts that are more suitable for cave formation, there is no littoral or submarine caves around them in overall except several south eastern bay and coves (Figure 6).

It can be also mentioned that there are two different submarine cave habitats with rich biodiversity around the rocky substrates in offshore areas and the littoral zone of some surrounding islets in Bozcaada Island (Figure 7).

Benthic invertebrates are the commonly observed animals in the littoral and submarine cave sites of Bozcaada Island. As the basic distributional character in the Aegean Islands, sponges are the most dominant group of biota in the caves, occurring overall area of the cave ceiling and walls, while algae occur at the entrance parts in general.

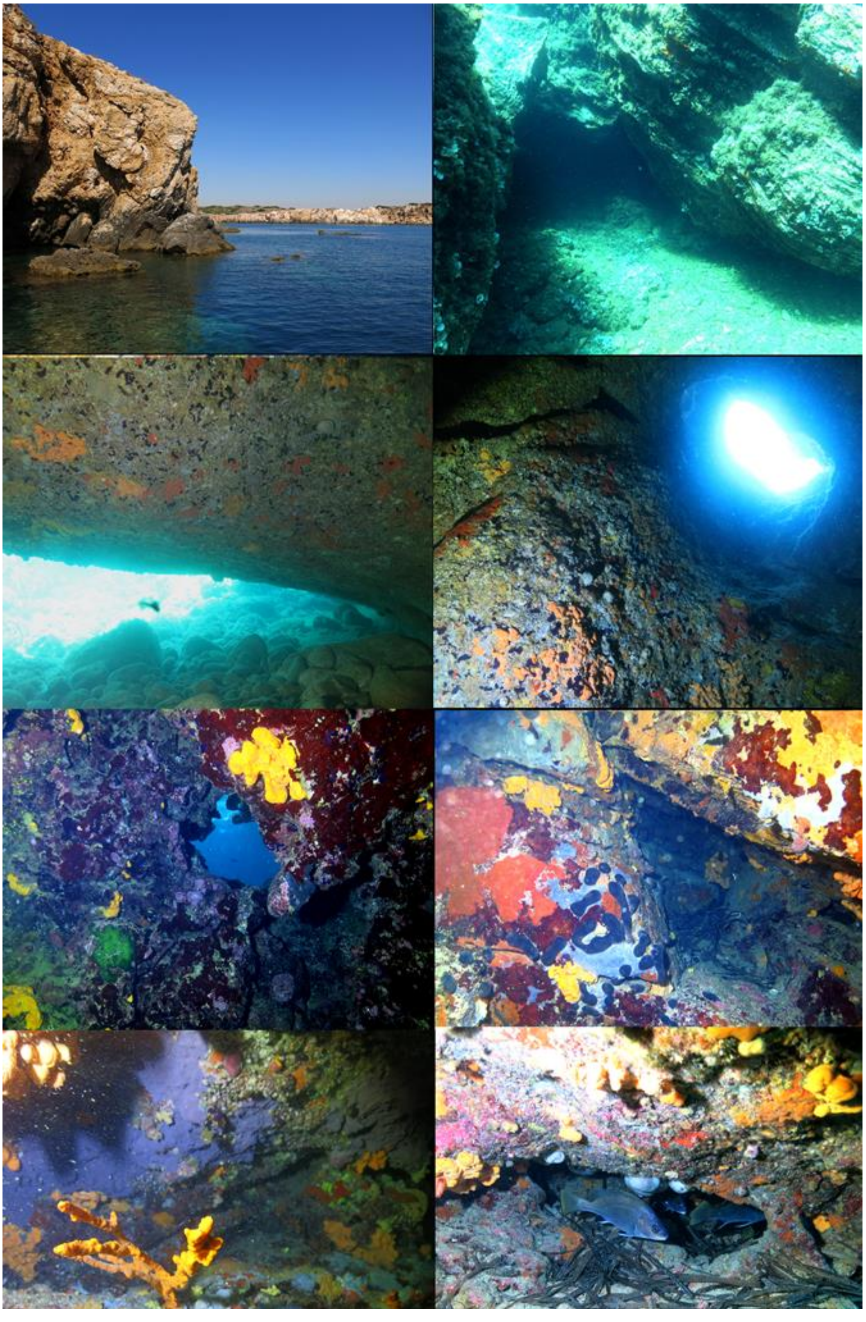

Figure 6. Marine caves and crevices in Bozcaada Island

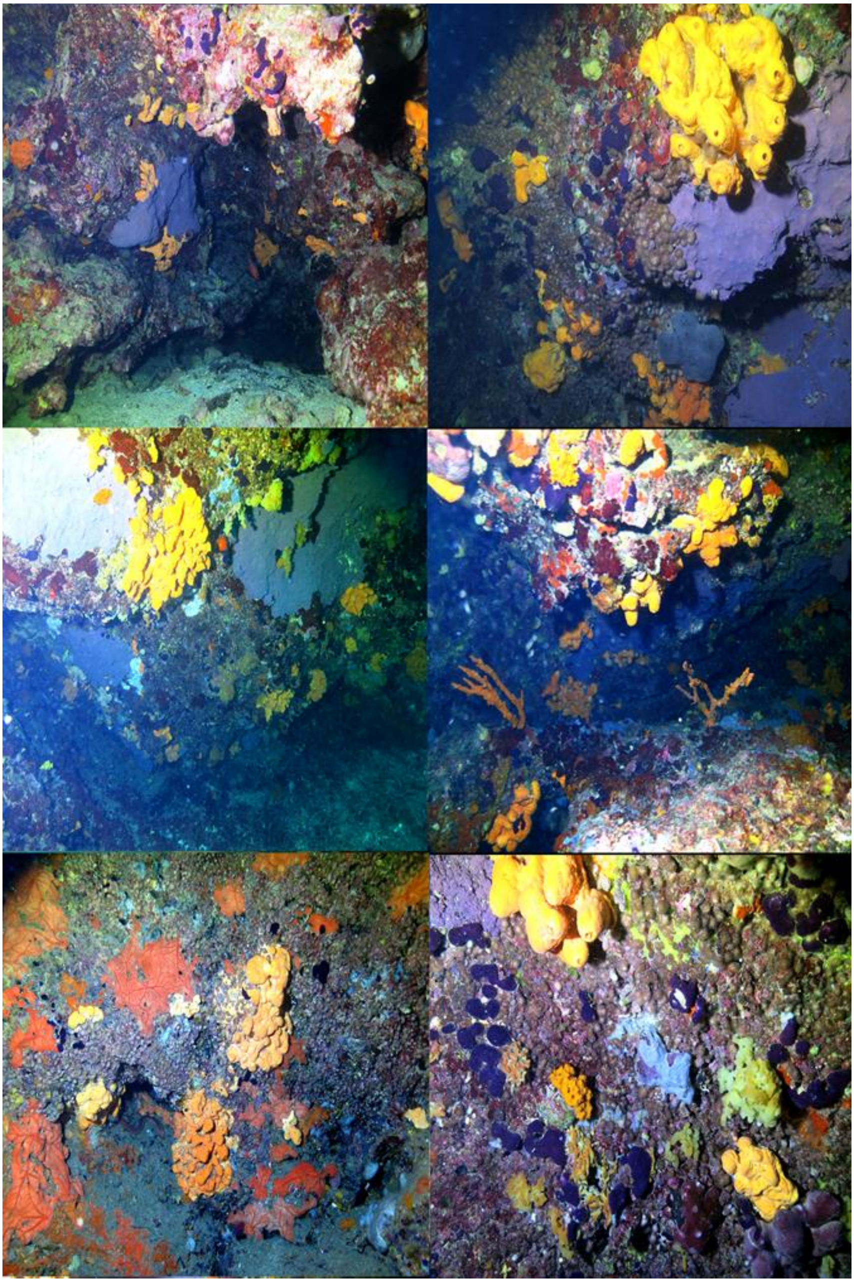

Figure 7. Biodiversity-rich benthic communities in caves and cavities of Bozcaada Island

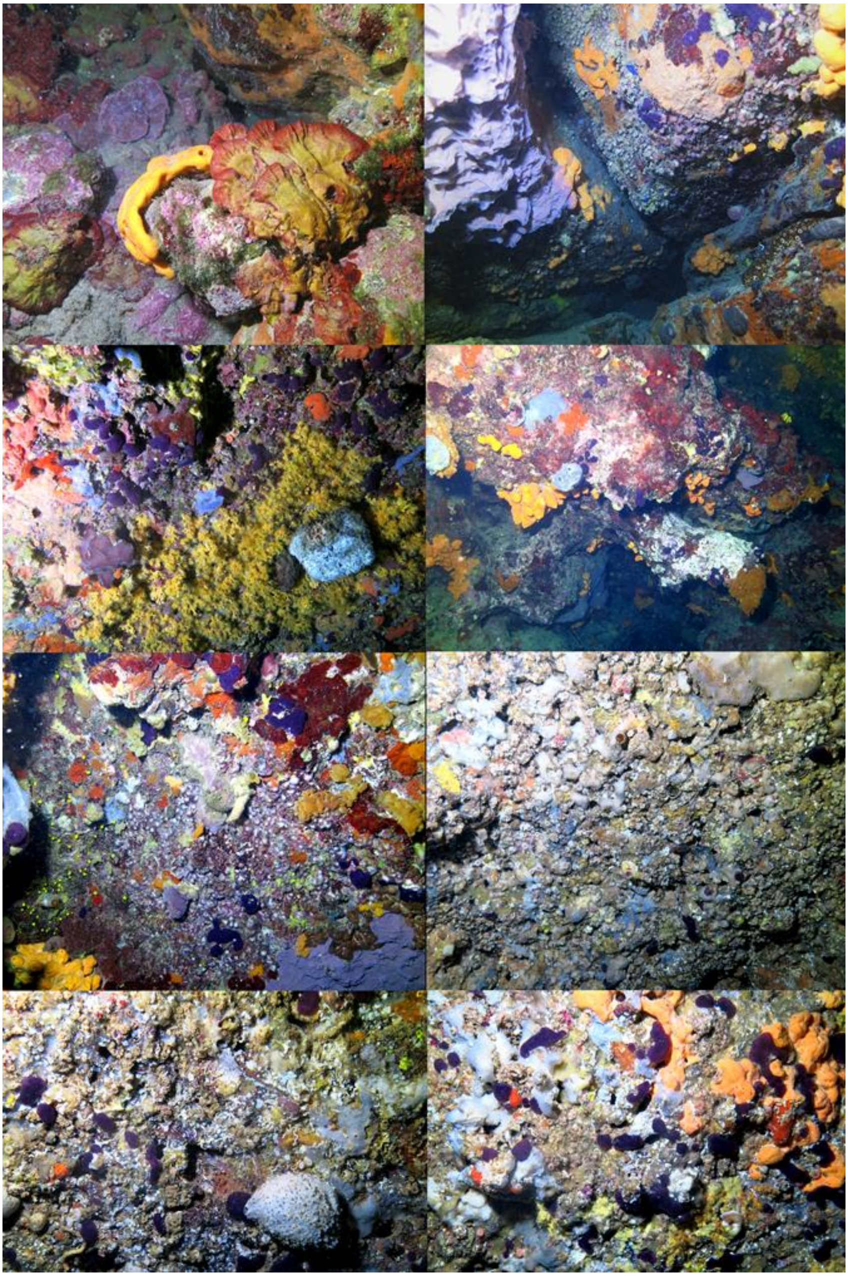

Figure 8. Invertebrates and macroalgae on ceilings and walls in marine caves of Bozcaada Island

In the caves, scleractinian corals and calcareous algae constitute the main facies of the ceiling at some locations, causing intense lamination on substrates. It may be given that the coralligenous abundance rate on ceiling and wall parts of the caves are over 95%. Some colonial corals such as *Madracis pharensis*, *Hoplangia durotrix* and although not common, other solitary coral species *Caryophyllia inornata*, *Caryophyllia smithii* and *Leptopsammia pruvoti* form dense facies as a basement substrate covering nearly 100% of the cave ceilings at several special habitats (Özalp 2018).

There are also some unique cave sites, in which colonial scleractinians (*H. durotrix* and *C. inornata*), other anthozoans (*Parazoanthus axinellae*) or coralligenous formations represent the main types of facies on ceilings and walls (Figure 8).

One submarine cave being located offshore at the north western part of the island is represented by the characteristic benthic community, in which the Mediterranean colonial coral *Polycyathus muellerae*, coralligenous and some calcareous sponges totally cover over 80% of the cave walls and ceiling (Özalp 2018).

Contributions and suggestions

The aim of the present study was to improve the knowledge of biodiversity in marine caves and cave-like habitats (e.g. crevices and cavities) in the Northern Aegean Islands of Turkey (Bozcaada, Gökçeada). The above-mentioned region is known for hosting unique and high biodiversity, among the other places in Turkish Seas, and is also an area with a potential for discovering new species in reef sites and/or cryptic habitats. The mass-colony type of *Cladocora caespitosa* reef that was recently found in Bozcaada Island, also accepted as the only largest mass-type (mound-type, bedding-type) reef site of the species may be a good example of this potential for describing previously unknown characters of marine life (Özalp 2018).

So far, although a small number of caves has been discovered around the island ecosystem in the region, Karayel Islands (Tavşan Islands) included, the ecology and distributional characteristics of marine species in caves are still largely unknown and need to be enhanced. Since facies-creating species group such as coralligenous algae, scleractinians and poriferans, have a key role in these sites, the data regarding biodiversity is in great importance. With this study, marine cave habitats and their relevant regions such as cave-like rock shelters, holes and big crevices were surveyed for the first time. As a brief evaluation, it may be stated that the studied cave sites present similarities in terms of species composition and distribution. However, the rate of abundance of coralligenous and facies-forming invertebrates are much higher in Bozcaada Island.

At several localities in the caves of Bozcaada Island, coralligenous formations are more stratified and scleractinian corals such as *H. durotrix*, *L. pruvoti* and *C. inornata* densely populate on ceiling and wall surfaces, covering over a maximum of 80% of the rock surface (Özalp 2018). However, in Gökçeada Island they cover less than 30% of the surface in cave walls and ceilings. Therefore, marine caves of Bozcaada Island are characterize by a remarkable complexity and density of benthic biodiversity when compared to those of Gökçeada Island.

In the studied caves, a total of 72 species were reported belonging to the 9 phyla (Cnidaria, Porifera, Chordata, Bryozoa, Mollusca, Arthropoda, Annelida, Echinodermata, and Rhodophyta). Among these, eight species (1 anthozoan, 6 poriferans, and 2 fishes) are reported for the first time from the cave sites of Gökçeada Island, while eleven (1 anthozoan, 1 molluscan, 3 fishes, 1 crustacean, 3 polychaetes, and 2 holothurians) are new for the marine caves of Bozcaada Island. The fish *Lipophrys nigriceps* is recorded for the first time for both islands as well (Table 1).

Although some demanding and outstanding efforts have been done in recent years, extending the scientific information on the subject, the existing knowledge regarding biodiversity around the marine cave sites in the Turkish Seas and territorial waters is still very limited. Regarding high species biodiversity and hotspot areas at some locations around the Northern Aegean Sea in Turkey, all investigations are of vital importance for the scientists. It should not be forgotten that understanding the ecological and biological processes at first, also accepted the fundamental surveys of all researches, in such special habitats in marine life may supply crucial data to science and so that it is about to be beneficial to humanity then.

Table 1. List of species recorded around the cave, cave-like opening and crevice sites in the Northern Aegean Islands of Turkey. (TOC: Type of Cave; CC: Coastal Cave; CUC: Coastal Underwater Cave; UC: Underwater Cave, CLO: Cave-like Opening; CLC: Cave-like Crevice; E: Entrance; SD: Semidark; D: Dark; FR: First record)

SPECIES	STATION		DEPTH	LOCATION	TOC	FR
	Bozcaada	Gökçeada				
Phylum Cnidaria						
Class Anthozoa						
Order Scleractinia						
**Hoplangia durotrix*	+	UP	5-13 m	E, SD	CC, UC, CLO, CLC	UP**
**Cladocora caespitosa*	+	-	11 m	E	CUC	
Phyllangia mouchezii	-	UP	UP		UC	UP**
**Polycyathus muellerae*	+	UP	UP	E, SD, D	CLO	UP**
**Madracis pharensis*	+	UP	UP	E, SD, D	CC, CUC	UP**
**Caryophyllia inornata*	+	UP	UP	E, SD	CC, CUC	UP**
**Caryophyllia smithii*	+	+	5-36 m	E, SD	CC, CUC, UC, CLO, CLC	
**Leptopsammia pruvoti*	+	+	5-36 m	E, SD	CC, CUC, UC, CLO, CLC	
Order Actiniaria						
Actinia equina	-	+	2 m	E, SD	CUC	current study**
Order Zoantharia						
Parazoanthus axinellae	+	-	8-10 m	E, SD, D	CUC	
Epizoanthus couchii	+	-	8 m	SD	CUC	current study*
Phylum Porifera						
Class Demospongiae						
Order Agelasida						
**Agelas oroides*	+	+	4-13 m	E, SD, D	CC, CUC, UC, CLO, CLC	

Table 1. Continued

Order Haplosclerida						
***Haliclona rosea*	-	+	2-12 m	SD, D	UC	current study**
**Petrosia ficiformis*	+	+	2-34 m	SD, D	CC, CUC, UC, CLO, CLC	
Order Clionaida						
**Cliona viridis*	+	-	8-16 m	E, SD, D	CC, CUC, UC	
***Cliona schmidtii*	-	+	9 m	SD	UC	current study**
**Spirastrella cuntatrix*	+	-	8 m	E, SD	CC, CUC, UC	
*,***Diplastrella bistellata*	+	+	5-12 m	E, SD, D	CC, CUC, UC	current study**
Order Poecilosclerida						
**Crambe crambe*	+	+	5-44 m	E, SD, D	CC, CUC, UC, CLO, CLC	
**Phorbas tenacior*	+	+	5-36 m	E, SD, D	CC, CUC, UC, CLO, CLC	
**Hemimycale columella*	+	-	10-12 m	SD	CC, CUC, UC	
Mycale sp.	-	+	12 m	SD	CC, CUC, UC	
Order Chondrosiida						
**Chondrosia reniformis*	+	+	2-36 m	E, SD, D	CC, CUC, UC, CLO, CLC	
Order Suberitida						
Suberites cf. domuncula	-	+	5 m	SD	CUC	
***Axinyssa digitata*	+	-	11 m	E	UC	current study**
**Terpios fugax*	+	+	2-12 m	SD, D	CC, CUC, UC, CLO, CLC	
Order Dictyoceratida						
Spongia officinalis	+	+	2-11 m	E, SD	CC, CUC, UC, CLO, CLC	
Sarcogtragus sp.	-	+	5-12 m	E	CC, CUC, UC	
**Ircinia oros*	+	+	5-16 m	E, SD, D	CC, CUC, UC, CLO, CLC	
**Pleraplysilla spinifera*	+	-	5-13 m	SD, D	CUC	

Table 1. Continued

Order Verongiida						
Aplysina aerophoba	+	+	5-14 m	E, SD	CC, CUC, UC	
*, ***Hexadella racovitzai*	+	+	4-32 m	E, SD	CC, CUC, UC, CLO, CLC	current study**
Order Bubarida						
***Acanthella acuta*	+	+	8-12 m	E	CUC, UC	current study**
Order Axinellida						
Axinella polypoides	+	-	6 m	SD	CUC, UC	
Axinella cannabina	+	+	5-11 m	E, SD	CC, CUC, UC, CLO, CLC	
Class Calcarea						
Order Clathrinida						
**Clathrina clathrus*	+	-	2-32 m	E, SD	CC, CUC, UC, CLO, CLC	
Class Homoscleromorpha						
Order Homosclerophorida						
**Oscarella lobularis*	+	+	4-32 m	E, SD, D	CC, CUC, UC, CLO, CLC	
Phylum Chordata						
Class Ascidiacea						
Order Aplousobranchia						
**Cystodytes dellechiajei*	+	-	5-57 m	E, SD, D	CC, CUC, UC, CLO, CLC	
Order Stolidobranchia						
**Halocynthia papillosa*	+	+	5-57 m	E, SD	CC, CUC, UC, CLO, CLC	
Order Stolidobranchia						
Clavelina sp.	-	+	2-5 m	E	CUC	
Microcosmus sabatieri	-	+	2-13 m	E	CC, CUC, UC	
Microcosmus vulgaris	-	+	11 m	SD	UC	

Table 1. Continued

Phylum Bryozoa						
Class Gymnolaemata						
Order Cheilostomatida						
**Rhynchozoon neapolitanum*	+	+	8-12 m	E, SD	CUC, UC	
Phylum Mollusca						
Class Gastropoda						
Order Littorinimorpha						
Serpulorbis arenarius	+	-	5 m	E	CUC	current study*
Charonia tritonis	-	+	14 m	E, SD	CUC	
Class Bivalvia						
Order Pectinida						
Chlamys cf. glabra	-	+	10-12 m	E, SD	CUC	
Order Neogastropoda						
Hexaplex trunculus	-	+	5-8 m	E	CUC, UC	
Superclass Pisces						
Order Perciformes						
Apogon imberbis	+	+	7-12 m	E, SD, D	CC, CUC, UC	current study*
Parablennius gattorugine	+	+	5 m	E	CC, CUC, UC	current study*
Parablennius tentacularis	+	-	5 m	SD	CC, CUC, UC	current study*
Parablennius rouxi	-	+	2-30 m	SD	UC	current study**
Lipophrys nigriceps	+	+	2-3,5 m	SD	CUC, UC	current study*,**
Conger conger	-	+	4-	SD	CC, CUC, UC	
Labrus bimaculatus	-	+	6-57 m	SD	CC, CUC, UC, CLO, CLC	
Scorpaena porcus	-	+	7 m	E	CUC	
Sciaena umbra	+	+	12-32 m	E, SD	UC	
Chromis chromis	+	-	5 m	E	CUC	
Phycis phycis	+	+	12-34 m	E, SD	CUC, UC	

Table 1. Continued

Phylum Arthropoda						
Class Gastropoda						
Order Decapoda						
Palaemon serratus	+	+	2-12 m	E, SD, D	CC, CUC, UC, CLO, CLC	current study*
Class Hexanauplia						
Order Sessilia						
Chthamalus stellatus	-	+	2-4 m	E	CUC, UC	
Phylum Annelida						
Class Polychaeta						
Order Amphinomida						
Hermodice carunculata	+	+	5-14 m	E, SD, D	CC, CUC, UC, CLO, CLC	current study*
Serpula vermicularis	+	+	5-8 m	SD	CUC, UC	current study*
Protula sp.	+	-	5-7 m	SD	CUC	current study*
Filograna sp.	-	+	2-3 m	D	CUC	
Phylum Echinodermata						
Class Echinoidea						
Order Camarodonta						
Paracentrotus lividus	+	+	2-14 m	E	CC, CUC, UC, CLO, CLC	
Order Arbacioida						
Arbacia lixula	+	+	2-11 m	E, SD	CC, CUC, UC, CLO, CLC	
Order Forcipulatida						
Coscinasterias tenuispina	-	+	2 m	E	CUC	
Class Holothuroidea						
Order Holothuriida						
Holothuria sanctori	+	+	5-12 m	E, SD	CC, CUC, UC, CLO, CLC	*
Holothuria helleri	+	+	5-12 m	E, SD	CC, CUC, UC, CLO, CLC	*

Table 1. Continued

Phylum Rhodophyta					
Class Florideophyceae					
Order Peyssonneliales					
Peyssonelia squamaria	+	+	5-32 m	E, SD, D	CC, CUC, UC, CLO, CLC
Order Corallinales					
Lithophyllum expansum	+	+	5-32 m	E, SD, D	CC, CUC, UC, CLO, CLC

Note: *Species name: The first report of species given formerly from Bozcaada Island (Ozalp 2019; Ozalp 2018).
**Species name: Firstly recorded from Gökçeada Island in the current study. UP: Unpublished paper, Özalp 2019a.
Current study*: Reported from Bozcaada Island in this study; Current study**: Reported from Gökçeada Island in this study.

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Comparison of two small marine caves located on Gökçeada Island (Northern Aegean Sea) and Büyükada Island (Marmara Sea) in terms of macrobenthic cover

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Introduction

The luminosity is well-known for its importance among abiotic factors in marine ecosystems The limited oxygen supply, which results from the low exchange rate of the water masses within marine caves, is also accepted as the reason of why there are limited amount of phyla, species and biomass inside submerged marine caves. Nonetheless, marine caves are considered to host an important semi-closed sub-system among littoral ecosystems (Gili *et al*. 1986). Two types of biocoenosis in marine caves have been described according to the luminosity factor; semi-dark and dark biocoenosis, following a decreasing gradient of brightness from the cave's entrance toward the inner part of the cave (Peres and Picard 1964).

Studies on the subject of submerged marine caves are extremely scarce alongside Turkish coastlines, according to Topaloğlu (2019). Most of studies in Turkish territorial waters only focused on single species (e.g. Mediterranean Monk Seal) or on a predetermined taxonomic group (e.g. Kıraç and Savaş 1996; Bilecenoğlu and Taşkavak 1999; Güçlüsoy and Savaş 2003). İnanmaz *et al*. (2014) highlighted six caves in Karabiga (southern part of the Marmara Sea) as important resting/breeding habitats for the Mediterranean Monk seal. The main coverage of major macrobenthic groups were seasonally studied in the northern part of the Aegean Sea and the southern part of the Marmara Sea via photoquadrate methodology. The present study is important in order to understand the difference between the Aegean Sea and Marmara Sea in terms of macrobenthic coverage, without focusing too much on submerged marine caves (Altuğ *et al*. 2011). Topaloğlu (2019) studied the macrobenthic cover in a submerged marine cave on Gökçeada Island. The author underlined the ecological importance of the studied cave as a primary habitat for sponges through its substrate cover.

Gerovasileiou and Voultsiadou (2012) carried on a study on marine caves in the Mediterranean Sea and reported that caves are an essential reservoir and hotspot for sponges' biodiversity in Mediterranean coastlines. Furthermore, Gerovasileiou *et al*. (2016) performed a study on alien species' biodiversity within Mediterranean marine caves. Authors pointed out the increasing number of alien species. Therefore, caves could act as a stepping stone for alien species. Gerovasileiou and Voultsiadou (2015) studied sponges' diversity gradients in two marine caves in the Eastern Mediterranean Sea. Authors highlighted a great heterogeneity between caves and underlined that understanding marine caves ecology is critical in order to gather key information on the Mediterranean ecosystems.

The Aegean Sea and Marmara Sea have different oceanographic features. Aegean Sea water mass is reported to be around salinity 39.1 ± 0.1 psu (Oğuz, 2015). The Marmara Sea has a unique two-layered current system; the water originating from the Black Sea with lesser salinity is located in the surface layer and extends up to a depth of 25 m, whereas the water mass with higher salinity coming from the Mediterranean Sea occupies the deeper layers (Beşiktepe *et al*. 1994).

In the present study, the macrobenthic cover was compared between two small caves featuring different ecosystems in order to highlight the effect of priorly mentioned environmental factors on the semi-dark benthic biota.

Materials and Methods

Photo-quadrate technic was used as a non-destructive method in this study. Pictures from Gökçeada were taken during Topaloğlu's study (2019). In total, a set of 83 pictures (30 outside the entrance and 53 in the inner part) was used for the present study undertaken on Gökçeada. The cave is located at a depth of 10 m, on the northern part of Gökçeada Island. Coordinates of the cave are: 40°14'8.97" N; 25°53'56.49" E. The cave is also located in the area which is under protection as a marine park. Pictures from the Marmara Sea were taken in a small underwater cave located in southern part of Büyükada Island called "Güvercin Çatlağı". Coordinates of the cave are: 40°50'22.07" N; 29°06'45.26" E. The depth of the cave in the Marmara Sea is around 6 m. A total of 40 pictures (7 outside the cave and 33 inside the cave) were taken for the present study (see Figure 1).

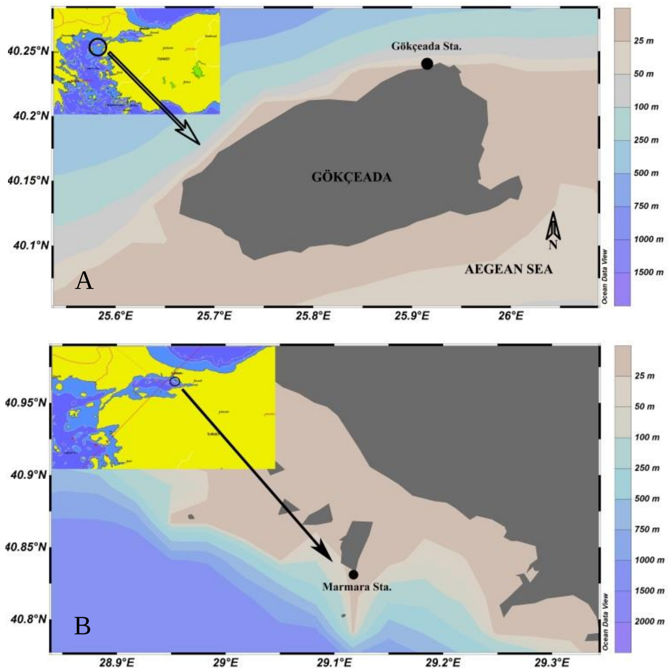

Figure 1. Map of sampling stations in the Aegean Sea **(A)** and the Marmara Sea **(B)**

Photo-quadrate analysis has been used in order to measure the percentage of cover of macrobenthic taxonomic groups. The method is based on Holme and McIntyre (1984) and Foster *et al.* (1991) studies. Additionally, the protocol was modified in order to make it suitable for digital camera usage, according to Pech *et al.* (2003). A total of 123 underwater pictures were taken. Canon G15 camera was used with underwater housing. All pictures were taken with a 14 mm lens at a distance of approximately 1 m, thus the sampling area shown in each photograph was approximately 1 m^2. Afterwards, a selection for clear pictures was performed. Each picture was divided into one hundred (10 x 10) cells. The number of cells with a particular group (taxon) observed was counted (Figure 2). The occurrence of these groups in the accounted number of cells was used to measure the percentage of coverage of macrobenthic taxa. Then, the arithmetic mean of the count for each group at a sampling point was calculated. In the case of multiple coverage in one cell by more than one group, the taxon with the highest coverage in the cell was taken into account for the counting.

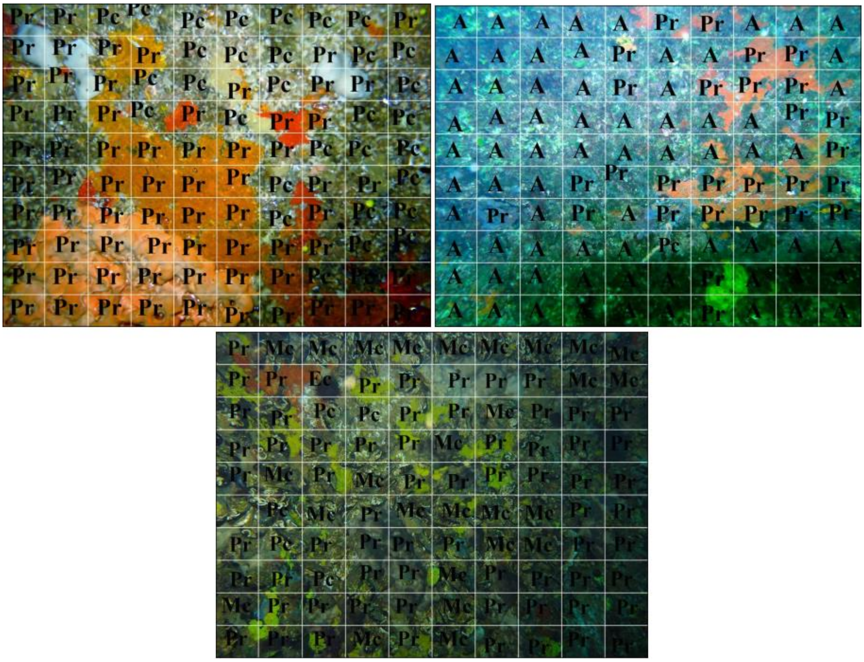

Figure 2. Examples of pictures used for taxonomic groups counting in small marine caves (A: Algae, Pr: Porifera, Pc: Polychaeta; Mc: Mollusca Ec: Echinodermata) (revised Topaloğlu 2019)

Result and Discussion

Results for the outter part of the caves are as followed. The highest percentage of cover from outside the marine cave is measured for algae (64.9%) in Gökçeada and for Mollusca (28.1%) in Büyükada, mostly represented by *Mytillus galloprovincialis*. This species is vastly distributed in the upper layer of the Marmara Sea. Therefore, this result is expected in Büyükada area. In contrast, Mollusca are almost not seen in Gökçeada’s cave. In terms of the highest cover, algae are ranked second in Büyükada while they are the taxon with the highest percentage of cover in Gökçeada. Porifera's taxon is the second group with the maximal coverage in Gökçeada (21.2%), while they are ranked fourth in Büyükada (3.71%). Echinodermata are ranked third in Büyükada (4.43%) while they are at the end of the ranking (0.1%) in Gökçeada. Echinodermata was observed to be one of the most common group in the upper layer of the Marmara Sea. Moreover, *Asterias rubens* was reported in the Black Sea in 2007 by Karhan *et al.* after being reported within Istanbul Strait in 1996. In all likelihood this alien species demonstrated a wide distribution in the area of the present study. *A. rubens* was observed with sea urchins species around the entrance of the cave (Figue 3).

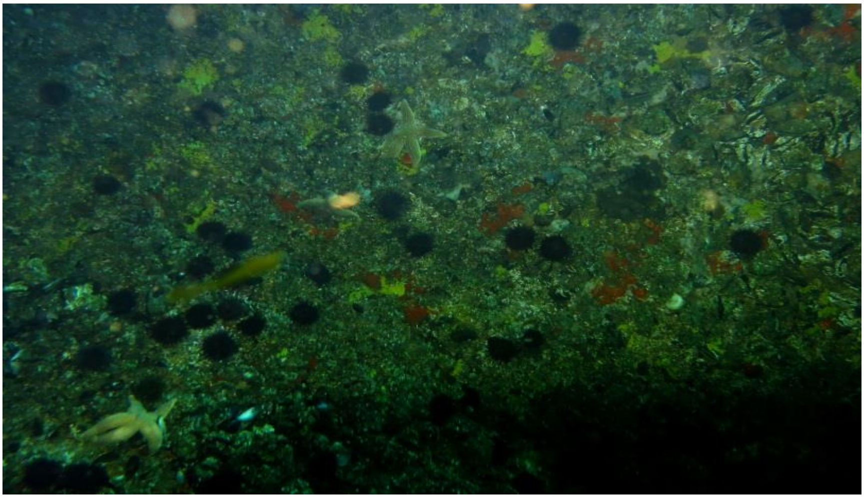

Figure 3. *A.rubens* and sea urchins at the entrance of the cave in Büyükada.

Results for the inner part of the caves are as followed. Porifera had the highest percentage of cover inside the caves when both areas were taken into account, with 76.6% in Gökçeada and 37.51% in Büyükada. The second group with a maximal observed cover were algae (6.5%) in Gökçeada and Mollusca (33.06%) in Büyükada. Polychaeta were observed as the third group in both caves (4.38% in Gökçeada; 7% in Büyükada) with the highest coverage. Then Echinodermata were ranked as the fourth group in Büyükada (5.45%), while Anthozoa detained the same rank in Gökçeada (0.6%). At last, Anthozoa (0.4%) and algae (0.1%) were reported as taxa with the least coverage in Büyükada's cave (see Table 1).

Henceforth Porifera's taxon has the highest coverage in the inner part of the caves in both areas (Figure 4). Caves are an essential reservoir and hotspot for sponges' biodiversity in Mediterranean coastlines, according to Gerovasileiou and Voultsiadou (2012). Results from Büyükada and Gökçeada of the present study corroborate with the previous statement. Furthermore, Mollusca are ranked as the second group with the highest coverage in Büyükada. This fact was expected for the common mollusc species *M. galloprovincialis* due to its great widespread in upper layer of the Marmara Sea. The case of the Echinodermata is another interesting result, depicting the role of caves as a stepping stone for alien species, like Gerovasileiou *et al*. (2016) previously suggested. As a result, *A. rubens,* which is one of the alien species might greatly benefit from the marine caves.

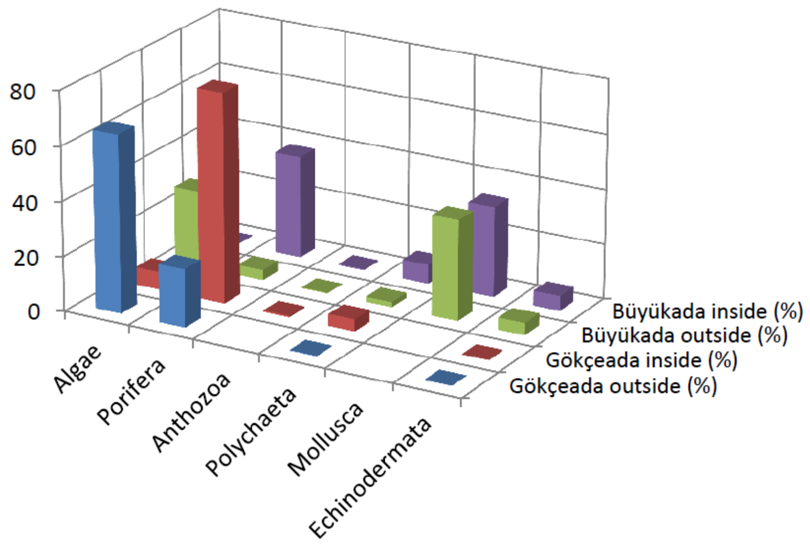

Figure 4. Percent cover of benthic groups per sampling point.

Table 1. Coverage (%) of the major benthic groups for each sampling site.

	Gökçeada		Büyükada	
Taxonomic Group	**outside (%)**	**inside (%)**	**outside (%)**	**inside (%)**
Algae	64,9	6,5	28,1	0,1
Porifera	21,2	76,6	3,71	37,51
Anthozoa		0,6	0,28	0,4
Polychaeta	0,3	4,38	1,86	7
Mollusca			36,71	33,06
Echinodermata	0,1	0,1	4,43	5,45
Occupation of organisms	**90**	**88,3**	**75,1**	**83,12**
Existance of Group	**4**	**5**	**6**	**6**

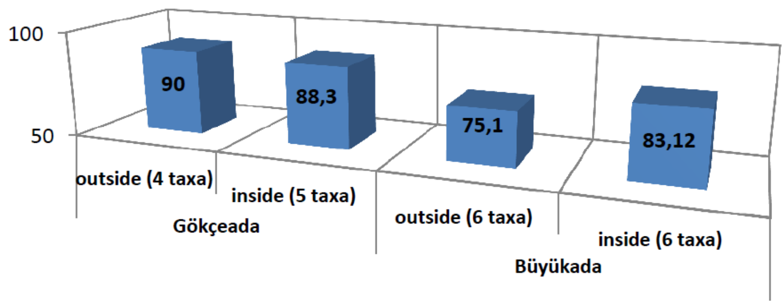

Figure 5. Occupation of the organisms in the sampling sites

The measured organisms' occupation is the highest on the outside of Gökçeada's cave (90%) than on the inside (88.5%) of the cave. In contrast in Büyükada, the maximal organism's occupation rate is reported on the inner part of the cave (83.12%) while the outside of the cave "only" reach 75.1% (Figure 5). This divergence may be caused by kinetic forces in Büyükada's cave present at the entrance of the cave at surface, while they are absent at the entrance of the Gökçeada cave, which is around 9 m deep. Nevertheless a few eggs of Cephalopoda were observed in Gökçeada's cave during fieldwork, which shows that this cavernous habitat is also essential as an egg-spawning site for other benthic species (Topaloğlu 2019). Marine caves are well-known as important hotspot areas, according to Gerovasileiou and Voultsiadou, (2012) and are also vital semi-closed sub-systems among littoral ecosystems (Gili *et al*. 1986). Henceforth more studies are necessary, especially in the area of the Marmara Sea.

Acknowlements

I would like to thank Prof. Dr. Bayram Öztürk for his guidance and scientific advices, Tancrede Barraud, MSc. for his help in linguistic correction of this text and SCUBA diving and at last Mr. Onur Umut Akyüz for his help with SCUBA diving.

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Habitat mapping of underwater Bilge Taş Cave (Wisdom Stone Cave) in the Northeastern Mediterranean Sea: Structure and biodiversity

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Introduction

Marine caves constitute an ordinary highlight of the Mediterranean rough coastline. Up to date, 738 marine underwater caves were reported within the eastern Mediterranean, representing one fourth of the known Mediterranean marine underwater caves (Giakoumi *et al.* 2013). Despite that, data with respect to their biodiversity and community structure is restricted in comparison to their north-western and central Mediterranean regions (Gerovasileiou *et al.* 2016).

Mediterranean marine caves play important roles as reservoirs for the restocking of important species and have a critical environmental value in connection to function (Cicogna *et al.* 2003; Chevaldonne and Lejeusne 2003). Besides, the marine caves are considered to be a connection between closed habitats. (Rastorgueff *et al.* 2015; Bussotti *et al.* 2015). The caves also play an economically important role for a local diving center due to the high frequency of requests from divers to explore them. Management action will need to be evaluated in order to reduce and prevent the impact of recreational divers on the benthic community (Di Franco *et al*. 2009; Di Franco *et al.* 2010).

The primary logical information about the biodiversity of the eastern Mediterranean marine caves were obtained during the Calypso undertaking within the 1950s to Kastelorizo, in the Levantine Basin (Laborel 1961). Afterward, Riedl (1966) gave extra biodiversity information for Aegean caves, centering mainly on the description of uncommon and recent species (Bailey 1969; Hayward 1974; Pulitzer-Finali 1983; Voultsiadou and Vafidis 2004).

There are restricted studies about marine cave biodiversity in the Levantine Basin (Tsurnamal 1969; Tsurnamal 1975; Ben-Eliahu and Ten Hove 1992), which gives information from the coasts of Lebanon, where a number of new species were reported (Pérez *et al*. 2004; Vacelet *et al*. 2007; Harmelin *et al.* 2009).

The objective of the current study was to describe, for the first time, the geomorphology and biodiversity of a marine cave named Bilge Taş (Wisdom Stone) in the Antakya Bay, Northeastern Mediterranean Sea, including the assessment of ecology, biodiversity and structure for the environmental management of critical habitats in the Mediterranean coast of Turkey.

Material and method

The study was carried out in 2018 in the underwater Bilge Taş Cave in the Antakya Bay, northeastern Mediterranean Sea, Turkey (Figure 1). The coordinates of the cave are (35°57'17.2"N 35°55'19.8"E).

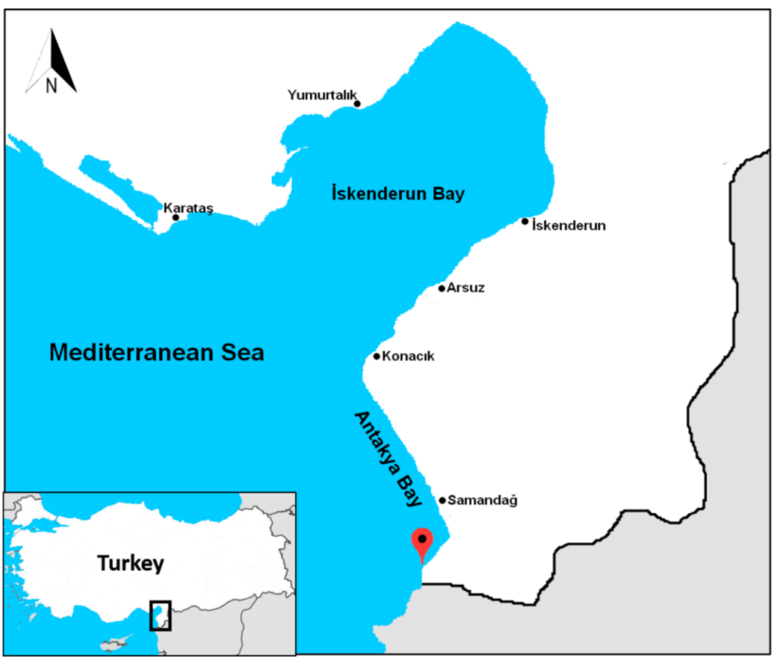

Figure 1. Location of the Bilge Taş Cave.

Nearly 30 dives have been performed since 2018, and average dive time was 45 minutes. Species sampling along the cave was carried out by visual identification, photographing and videos using three underwater cameras. During visual identification and taking videos, three 5000 lumens video lights and 2000 lumens spot lights were used for diving. The species were cross-checked and listed with taken notes, photographs and videos by each diver after each dive. A yellow colored cord was lined along the cave at the beginning of the study in case of any loss or accident. The biggest challenge during the dives was temperature differences between the Galleries in the cave. In Gallery 3, there is a freshwater spring which is 21-22°C along the year that negatively affects diving comfort. During summer, the water temperature is 28°C in the entrance of the cave. In winter, it is reversed, the water temperature in the entrance of the cave is about 16°C, and 21°C in the Gallery 3. Therefore, divers should be ready for temperature shock during dives in the cave.

Geomorphological depictions of the Bilge Taş Cave were carried out with classic topographical and hydrobiological techniques comprising dimensional mapping (Ereskovsky *et al.* 2013; Ereskovsky *et al*. 2016). The coordinates of the Bilge Taş Cave passages were described with a dive watch. The cave depths were instantly measured with a diving gauge. Two divers used underwater meters in cooperation to measure the dimensions of tunnels, domes and other parts. Underwater topographic mapping was carried out with length measured between the entrance and the end of the cave, then navigation survey was followed with an underwater compass. Distribution of species mapping along the cave was carried out using R studio.

Result

Bilge Taş Cave is structured as entrance and 3 galleries. The entrance of the cave is surrounded with sandy ground but the interior of the cave ground was rocky. Width and depth of the cave were measured as 38 m and 27 m for entrance, 33 m - 25 m for gallery_1,33 m and 27 m for gallery_2 and 32 m and 12 m for gallery_3, respectively (Figure 2, 3).

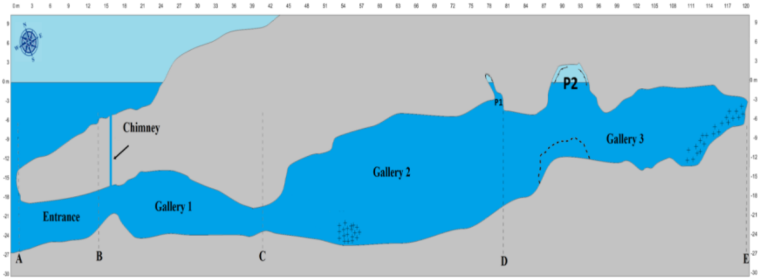

Figure 2. Side profile of the Bilge Taş Cave in the Antakya Bay, Northeastern Mediterranean Sea. P1 and P2, Air pocket; +, small rocks.

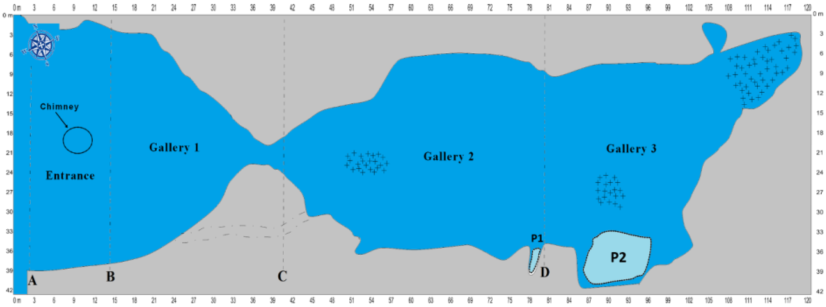

Figure 3. Top view of the Bilge Taş Cave in the Antakya Bay, Northeastern Mediterranean Sea. P1 and P2, Air pocket; +, small rocks.

The length of the cave was measured as 120 m. Moreover, there is 1 chimney in the entrance of the cave which is very narrow and has sun lights. There are also 2 air pockets (P1 and P2, Figure 2,3) in gallery_2 and gallery_3. A total of 27 species were identified in the studied cave, specifically 13 fish, 2 sponges, 4 crustaceans, 4 cnidarians and 4 echinoderms (Table 1).

Side profile and top view of the Bilge Taş Cave in the Antakya Bay, Northeastern Mediterranean Sea are presented in Figure 2 and Figure 3 respectively. The cave can be divided in four sections: entrance, gallery_1, gallery_2 and gallery_3. Moreover, the cave includes two internal air pockets as well as one chimney in the entrance (Figure 3). In the entrance of the cave, 23 species were observed, while the number of species decreased towards to interior of the cave.

For the taxonomic diversity, Pisces were the highest observed with 48%, Porifera species were lowest with 7% (Table 2).

For the origin of the species observed in the cave, Atlantic and Mediterranean originated species were highest (58%), however, non-indigenous species of Indo-Pacific origin was recorded 31% of the species in comparison to the indigenous species. Some observed species belonging to different Phylums in the Bilge Taş Cave are given at Figure 4. Two Porifera species (*Haliclona* sp. and *Axinella* sp.) were unspecified at the species level.

Table 1. List of taxa recorded in the Bilge Taş Cave. Cave zones are given at Figure. 1. U: origin Unidentifed; A, Atlantic Ocean; IP, Indo-Pacific; C, Cosmopolitan; *, Threatened (IUCN)

Species	Entrance	Gallery_1	Gallery_2	Gallery_3	Origin
Kingdom Animalia					
Subphylum Vertebrata					
Superclass Pisces					
Sargocentron rubrum (Forsskal, 1775)	x	x			IP
Pagrus caeruleostictus (Valeneiennes, 1830)		x	x	x	A
Diplodus vulgaris (Geoffroy Saint-Hilaire, 1817)	x	x	x		A
**Sciaena umbra* Linnaeus, 1758	x	x	x	x	A
Mycteroperca rubra (Bloch, 1793)	x	x			A
Pempheris rhomboidea (Kossmann & Räuber, 1877)	x	x	x		IP
Apogon imberbis (Linnaeus, 1758)	x	x	x		A
**Dasyatis pastinaca* (Linnaeus, 1758)		x			A
Epinephelus costae (Steindachner, 1878)	x	x			A
Parupeneus forsskali (Fourmanoir & Guézé, 1976)	x	x			IP
Cheilodipterus novemstriatus (Rüppell, 1838)	x				IP
Torquigener flavimaculosus Hardy & Randall, 1983	x	x			IP
**Umbrina cirrosa* (Linnaeus, 1758)		x			A
Phylum Porifera					
Axinella sp.	x	x			U
Haliclona sp.	x	x	x		U

Table 1. Continued

Phylum Arthropoda					
Subphylum Crustacea					
Scyllarides latus (Latreille, 1802)	x	x	x		A
Plesionika narval (Fabricius, 1787)		x	x	x	C
Diogenes pugilator (Roux, 1829)	x	x			A
Saron marmoratus (Olivier, 1811)	x				IP
Phylum Cnidaria					
Cerianthus membranaceus (Gmelin, 1791)	x				A
Aglaophenia octodonta Heller, 1868	x				A
Actinia equina (Linnaeus, 1758)	x	x			C
Anemonia sulcata (Pennant, 1777)	x				A
Phylum Echinodermata					
Arbacia lixula (Linnaeus, 1758)	x				A
Sphaerechinus granularis (Lamarck, 1816)	x				A
Echinaster sepositus Retzius, 1783	x				A
Diadema setosum Leske, 1778	x				IP

Table 2. Taxonomic diversity and origin of species observed in the Bilge Taş Cave.

Taxonomic Diversity		Origin			
Taxonomic Group	**Total**	**Atlantic Species**	**Indo-Pacific Species**	**Cosmopolitan Species**	**Unidentifed at Species level**
Pisces	13	8	5	-	-
Porifera	2	-	-	-	2
Crustacea	3	2	1	-	-
Echinodermata	4	3	1	-	-
Cnidaria	4	3	-	1	-
Total	**27**	**16**	**8**	**1**	**2**

Figure 4. Some observed species from the Bilge Taş Cave. **A:** Cheilodipterus novemstriatus, **B:** *Sciaena umbra*, **C:** *Parupeneus forsskali*, **D:** *Plesionika narval*, **E:** *Arbacia lixula*, **F:** *Saron marmoratus*, **G:** *Axinella* sp., **H:** *Cerianthus membranaceus* and **I:** *Echinaster sepositus*.

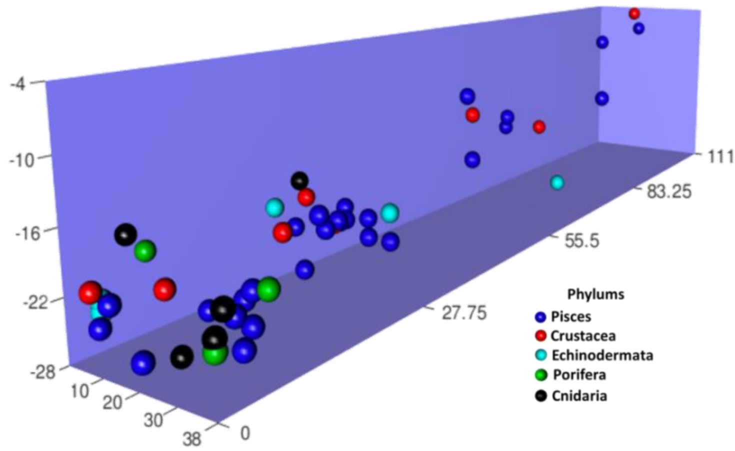

Figure 5. Distribution and location of the Phylums along the underwater Bilge Taş Cave. The dimension of the figure box is given as actual size of the cave as meter.

Distribution of the Phylums along the cave was given in Figure 5. In the entrance of the cave, relatively many species were observed, while the number of species decreased towards to interior of the cave. Porifera species were only observed at the entrance of the cave but were not observed in other parts of the cave. The species were generally observed at the bottom layer of the cave. Fish and crustacean species were monitored commonly in the most interior part of the cave.

Discussion

Caves are morphologically complex ecosystems with strong environmental gradients (Gerovasileiou and Voultsiadou 2012). The caves are generally administered with restricted studies in the eastern Mediterranean in comparison to the western Mediterranean, just about one study per year for the eastern basin, versus five studies per year for the Mediterranean (Gerovasileiou and Voultsiadou 2012; Gerovasileiou *et al.* 2015).

This study on the Bilge Taş Cave is just a preliminary study that surveys biodiversity and habitat mapping in the Mediterranean coast of Turkey. In total, 27 species were reported from the cave, of which 8 Indo-Pacific non-indigenous species (31%) inhabit the cave. In another cave study, Bussotti (2003) and Bussotti and Guidetti (2009) described a list of 34 fish species from three caves placed within the northwestern Ionian Sea (Bussotti *et al.* 2017). This percentage is higher compared to the Atlantic-Mediterranean species (55%). There is an increasing trend in the number of non-indigenous species in this region (Turan *et al.* 2016; Gerovasileiou *et al.* 2016; Doğdu *et al.* 2016;

Erguden *et al.* 2018 and Turan *et al*. 2018) which indicate that the effects of the climate change and nonindigenous species on the cave habitats in this region should be further investigated.

In similar studies, alien species were observed quite a lot at the entrance and semi dark zones in the Mediterranean caves (Gerovasileiou *et al.* 2016), indicating that dark caves are acceptable as highly selective habitats (Harmelin 1985; Bianchi and Morri 1994; Bussotti and Guidetti 2009; Gerovasileiou *et al*. 2016).

The present study contributes to fill the gap on underwater cave information as a sensitive habitat in the north-eastern Mediterranean. Moreover, one more important finding in the present study concerns the pattern of species diversity and the related possible conservation measures about some fish species such as *Sciana umbra*, *Umbrina cirrosa* and *Dasyatis pastinaca* that were represented on IUCN the Red List (IUCN 2018) and observed in Bilge Taş Cave. Therefore, the cave habitats can be helpful to protect these species and may be considered as marine protected areas (MPAs). Moreover, on account of ecological importance, Bilge Taş Cave in which endangered species live should be recognised as priority habitat for conservation purposes. A monitoring program in this cave should also be conducted in future conservation plans, in order to contribute to the underwater cave biodiversity in the north-eastern Mediterranean.

In conclusion, this study provides first information on marine species diversity and structure in underwater caves in the Mediterranean coast of Turkey, especially, endangered species according to IUCN inhabit caves that indicate conservation of cave biodiversity. Therefore, these important underwater marine caves should be prioritized for considering future MPAs and inclusion oin themarine special management plans for the Mediterranean coasts of Turkey.

Acknowlements

We thank Nature and Science Society (www.dogavebilim.com) for financial support of the project (Mapping of Marine Sensitive Areas in the northeastern Mediterranean).

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Health problems in cave diving

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Introduction

Cave diving is an important part of different scientific fields, as diving is needed to collect many data from this closed environment. These disciplines are; aquatic sciences, archeology, geology, ecology, biospeleology, speleomorphology, anthropology, marine sciences and biology. Remnants of our ancestors and many animals, artifacts related to agriculture in ancient times have been discovered in caves all over the World (Zumrick 1988). That is why scientists have been willing to explore the caves accessible by the sea. Furthermore, many divers are willing to specialize in cave diving, and the reason of their interest rely on the individual preference and the level of training in dives. Cave diving is generally considered a good alternative to diving in open water. Some divers are interested in exploring underwater caves in order to make new discoveries and collect information about where no one can reach them.

If we describe the environment of these semi-closed spaces, it will be easier to understand the challenges of the cave diving. There are some difficulties in terms of physical, biological, physiological and psychological conditions. From the point of view of biology, divers should be prepared of occasional large fish such as nurse shark, grouper or moral eels in coral caves. Marine sea caves are home for sea life such as sea anemone, sea urchins, sea mammals, fish and shellfish. From the point of view of the physical environment, marine habitat, power of waves, absorption of the light and tidal effect must be carefully evaluated in caves. Furthermore, caves may also contain extensive amount of clay and silt that can reduce the visibility to zero if stirred up by a diver (Figures 1 and 2) (Zumrick 1988).

Figure 1. Divers should be aware of visibility may not be clear as shown in this picture due to the clay and silt in the cave.

Although divers have skills, competence and are given appropriate training in cave diving, they may also suffer diving related illness that is also common in all level of diving experience. Barotrauma, decompression sickness and drowning-related injuries were the most common morbidities associated with recreational scuba diving. The prevalence of incidents in scuba diving ranged from 7 to 35 injuries per 10,000 divers and from 5 to 152 injuries per 100,000 dives (Buzzacott 2012). Cave diving carries an inherent amount of risks, just as any other diving activity. These risks are; depth, breaking the safety rules in diving, lack of knowledge about the diving equipments, over-reliance on experience and discontinuance of prudence, lack of skills in first aid techniques and how to rescue the injured diver. Furthermore, buoyancy changes at depth, thermal protection loss, injuries with marine animals, restriction of environment may also accelerate the occurrence of the diving accidents (Lloyd 1967). Due to the limited physical conditions in caves, cave diving may not be recommended if the diver experience discomfort or fear as the dark environment restricts vision, if the basic skills and abilities for diving have not been developed, or if the idea of not being able to float on the water surface creates fear, stress and restlessness.

In this chapter, we describe main health problems that may occur during a cave dive, more particularly those that may be eliminated by training and knowledge.

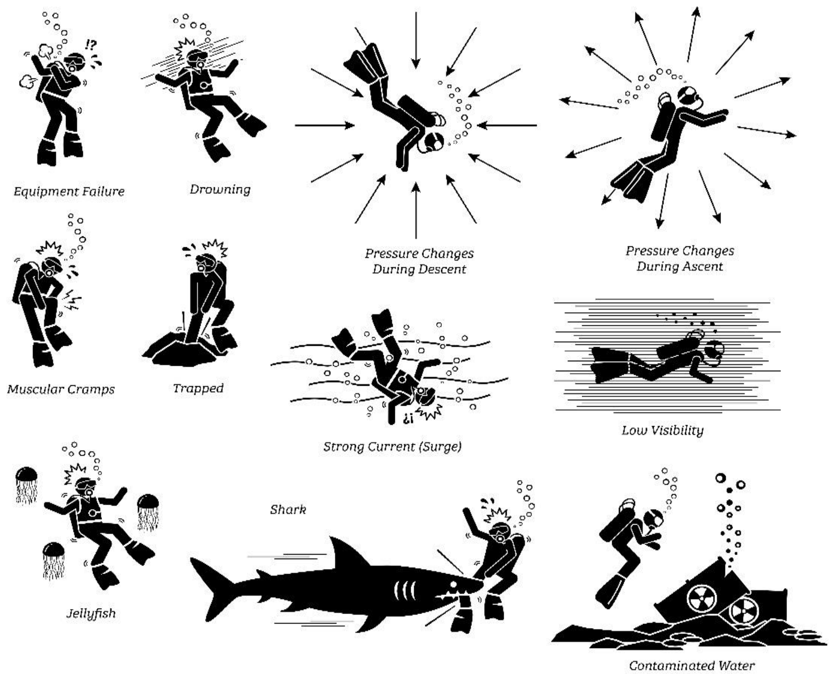

Figure 2. Divers may encounter various unpredictable risks in cave diving.

Physical trauma

Underwater caves may contain air sections that are home to animals such as seals, bats and spiders. In case of perception of threat to the living things, they may be disturbed and, the stone may fall from the ceiling of the cave and pose a danger to divers. In some conditions, there may be air pockets which are likely to be oxygen deficient or air inside the cave can be contaminated. As a result, inhalation of the air can be harmful to the body due to the toxic effects of the inhaled gases. Snowball effect may appear and even the experienced divers can get into difficult situation (Zumrick 1988; Palmer 1997).

Cave diving has challenges in terms of environment such as flowing water, changes in water level, low visibility, restriction to the exits, entanglement, barrier that limits the divers to ascend to surface in case of emergency situation. Cousteau and Dumas documented the record of first scuba dive within a flooded cave in 1953. Death is an unpredicted event and may occur as a result of inappropriate behaviours during the dive. Researchers try to identify the causes of death which are reported from the autopsy findings, medical examiner reports, or death certificates. The main characteristic of divers who lost their lives were old age, without dive partner, further into the cave, and dives to deeper depths. Furthermore, divers deliberately or unintentionally may break rules that are the hard core of the dive plan directly resulting in death of the diver (Potts *et al.* 2016).

Panic and stress

Experts define stress as feeling of physical or emotional tension which can be caused by any event or thought that makes one angry or frustrated. The main causes of stress; 1) duty 2) responsibility 3) time 4) problems related to distance and direction 5) physical threats (fatigue, insomnia, decrease in body temperature, inexperience). It's a natural body reaction that helps one to avoid danger. Stress is necessary in daily life, but stress above a certain level is harmful, both physically and mentally. As a consequence, response to the stressful condition can be inappropriate and ineffective. Then, panic may appear with the uncontrolled behaviours. Therefore, recognition and control of stress is always crucial to protect human body from deleterious effects of threats (Edmonds 2005a). There are physiological and psychological symptoms/signs of stress which may create serious problems in diving. These are by and large lack of concentration, loss of attention, perceptual deficits, frustration, discordance of task related skills, increased heart rate and blood pressure, changes in breathing rate and so on (Morgan 1995; Anegg *et al.* 2002).

Panic reaction can be prevented by elimination of the reasons that created it. There are several factors that help to cope with panic reaction; knowledge, experience, safe materials and equipment, accurate and complete planning in diving. It is essential to be well trained diver or diving buddy and equipped with the suitable diving gears. If one is susceptible to panic, uneasy, tired, irritable and sleepy, not in shape, excited, the diver should stop diving. The signs of panic are increased breathing frequency, difficulty concentrating, eyes opened with fear, irregular swim, improper movements, and rapid ascent to the surface. In such cases, diver should force himself to think about other things, do things to be calm down (Edmonds 2005a).

Inert gas narcosis

Inert gas narcosis is a reversible alteration in consciousness that occurs while diving at depth. Because nitrogen has an anesthetic effect to the body while diving at higher partial pressure (Palmer 1997). It is also important to note that nitrogen is not the only gas with a narcotic effect on the diver, however it is the most common used gas. There are other gases that may have narcotic effects. For instance, argon, neon, krypton and xenon are other inert gases that associated with narcosis. Carbon dioxide (CO_2) may also exert narcotic effect itself (Clark 2015; Rocco *et al.* 2019). Even though there has been a lot of research done on the effect of nitrogen narcosis, the underlying mechanism is still not fully understood. There are several factors that increase the risk of narcosis such as cold temperature, anxiety, fast descent to the deep, drugs (sedatives), fatigue, alcohol, carbon dioxide excess (Plantz *et al.* 2019). Nitrogen narcosis can be difficult to identify, but a few symptoms may indicate that diver has had one. The most common symptoms of nitrogen narcosis are: vision changes, confusion, an altered level of consciousness, dizziness, over confidence. Altered mental status for mental judgment can even cause hallucinations while underwater (Figure 3 and Table 1) (Clark 2015; Melamed 1992).

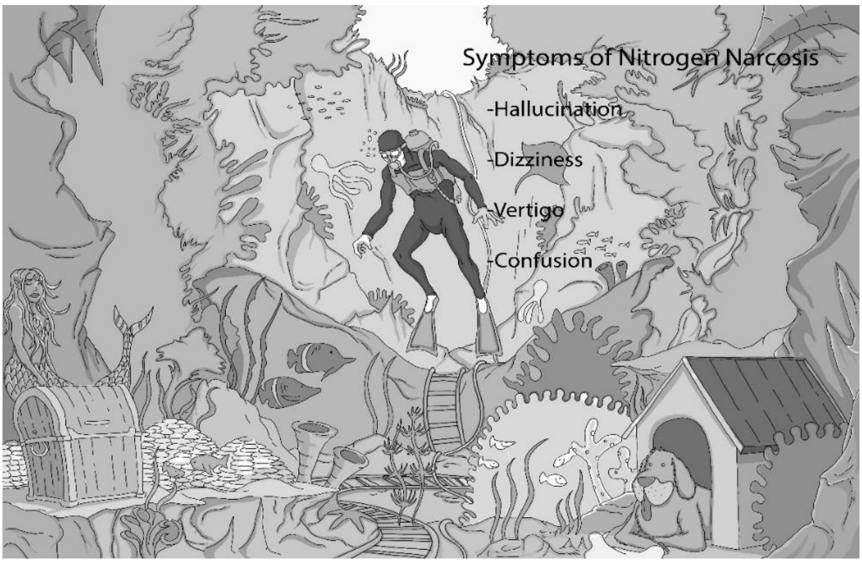

Figure 3. Inert gas narcosis with signs and symptoms. It commonly occurs deeper than 25-30 m in water (drawing by Ali Yiğit Ertan).

As breathing gas at depth increases its partial pressure, narcotic effect may be induced. The rule of thumb is Martini effect may occur where every 15 meter (50 feet) of compressed air is approximately equal to drinking one glass of Martini that varies by the individual tolerance (Lowry 2005). Nitrogen is a very weak anesthetic gas but if one breathes at around 100 meters the diver will become unable to respond to stimuli and appears to be sleepy. Given the fact that CO_2 builds up to 10% of breathing gas, diver will lose consciousness unexpectedly. CO_2 is usually retained in lungs during deep diving, when there is heavy exercise and when there is resistance in the breathing equipment. Consequently, Nitrogen and CO_2 in the breathing gas can add up and accelerate the appearance of sudden loss of consciousness. This condition is named as deep water blackout. The combined effect of the carbon dioxide and nitrogen is responsible for the deep water blackout (Palmer 1997; Arthur and Margulies 1987). Divers usually aren't aware of one of the hazards about having to do heavy work at deep depth. That is why it is really good practice to maintain as low at work as possible during deep dive. The only way to avoid nitrogen narcosis is to avoid deep air diving and adhere to the guidelines. Alcohol in the blood, carbon dioxide level, increased stress level, medications being taken, may induce the narcotic effects (Lowry 2005).

Although new gas mixtures such as trimix is highly recommended in deep dives, high costs, thermal properties are the reasons why compressed air is mostly preferred in most diving operations.

Avoidance of deep diving to prevent inert gas narcosis is essential in diving (Melamed 1992). If the diver suffers from the complaints of nitrogen narcosis, resting and being calm down will reduce the symptoms, then dizziness may disappear after several deep breaths. Immediately, the diver should descend safely to the shallower depths in order to get rid of these symptoms (Lowry 2005).

Table 1. Symptoms and signs of nitrogen narcosis

Light headedness	Dizziness	Overconfidence
Uncontrolled laughter	Hallucination	Memory loss/post-dive amnesia
Perceptual narrowing	Impaired sensory function	Loss of consciousness
Loss of manual dexterity	Euphoria	Vision changes
Confusion	Decreased coordination	Impaired mental performance

Hypothermia

If the human body looses too much heat and the body temperature reaches unsafe levels, the condition is called as ‘‘hypothermia’’. In normal physiological state, a body functions best between 36.5-37.5 degree Celsius (°C). A drop in the core body temperature less than 35°C is defined as hypothermia. It is a life-threatening condition which deteriorates the normal metabolism and body function and may result in death (Pennefather 2005). The body’s thermo-regulation mechanism adjusts to environmental temperature changes. Given that the body is exposed to cold and the thermo-regulation mechanism is unable to preserve the heat, a drop in the core body temperature will occur.

Figure 4. Water temperature decreases due to the spring water in caves. As a result, hypothermia is a serious problem and may result from unprotected clothing.

Hypothermia occurs after the exposure to low water temperatures and may be precipitated by alcohol consumption, poor clothing, excessive fluid loss, older age, poor nutrition, hypoglycaemia (Figure 4). In addition to that, hypothermia may result from breathing cold helium oxygen gases even if the diver's skin is warm (Lloyd 1979). Main symptoms and signs include shivering, cold and pale skin, fast breathing, tiredness, altered mental status such as confusion and poor judgment. The ailment is categorized mild, moderate, severe hypothermia. Symptoms of hypothermia depends on the degree of hypothermia, so the victim may slowly lapse into an unconscious state (Table 2). A diver's response to immersion in cold water depends on the degree of thermal protection worn and water temperature. Responses to falling core body temperature are individual. Eventually, mental confusion, irrational actions or responses will develop resulting in a diver who is unable to complete basic tasks such as handling diving gear or swimming normally. Furthermore, shivering, collapse, unconsciousness, dangerous rhythm of the heart, depressed respiration may result in death (Pennefather 2005). Knowing limitations of the body individually, comfort range and taking necessary precautions will decrease the deleterious effects of hypothermia.

Table 2. Symptoms and signs of hypothermia in mild, moderate, severe cases

Severity of the Hypothermia	Symptoms and Signs
Mild Hypothermia (32-35°C)	Increase in heart rate Increase in respiratory rate Changes in speech, gait, judgment, motor skills Shivering
Moderate Hypothermia (28-32°C)	Decrease in heart rate Decrease of cardiac output Atrial fibrillation Decrease level of consciousness Ataxia
Severe Hypothermia (<28°C)	Decrease in respiratory rate Ventricular fibrillation Asystole Unresponsiveness

Treatment should be started promptly in doubtful cases. If the diver begins to shiver during exposure to cold water, this is the point where diver should get out of water and warm up. Prolonged exposure to the cold beyond this point can be dangerous resulting in fatalities. In severe cases, the main approach is to remember the victim needs to be handled gently. The diver should be removed from the water and to a safe and dry place. The treatment of hypothermia consists of rewarming the diver (Sward and Bennett 2014). A simple indicator that rewarming is complete, is the onset of sweating. In case of mental confusion or unconsciousness, medical emergency and rewarming must be started instantly. Recommendations are listed below in case of hypothermia in diving (Pennefather 2005).

1. Bring the diver out of the sea handle gently the diver, not allow to walk
2. Restore body temperature by rewarming techniques; using warm water (38-44°C) either in a bath or directed under the diver's suit
3. Remove the wet clothing and wrap the diver with a warm, dry blanket
4. Alternative to hot water is to dry the diver and provide warm clothes, a sleeping bag or blankets and a warm room
5. Fluid re-hydration with warm beverages free of alcohol or caffeine
6. Loosen the tight fitting wet suit in order to prevent constricting peripheral circulation
7. Do not massage the diver
8. Give warm humidified % 100 oxygen, if the oxygen is available
9. Transport horizontally to prevent heart arrhythmia
10. If the diver does not response and is without pulses, one should immediately start lifesaving cardiopulmonary resuscitation (CPR). It should be done consistently until the diver is warmed to at least 30 to 32°C.

Barotrauma

Barotrauma (BT) is a physical damage to body tissues caused by a difference in pressure between an air space inside or beside the body and surrounding environment. Barotrauma typically occurs in air filled spaces within the body because gases are compressible, fluid filled tissues are not compressible during an increase in ambient pressure. Barotrauma may occur during ascend or descend of the dive (Melamed 1992). The human body has several different gas spaces. The lungs are the most obvious of these. But one also has assorted sinus passages, the middle ears and gastrointestinal system as well in. In addition, other gas space is inside masks each of these gas spaces must be equalized to the surrounding pressure at depth.

Divers mostly do not notice the equalization process in the case of the lungs where it happens by normal breathing or they are taught to manually equalize the air-filled spaces to surrounding pressure by using various techniques as in the case of the middle ear spaces. When the diver is unable to equalize these gas spaces the potential for trauma exists in diving (Raymond and Cooper 2019). A change in altitude may also induce barotrauma if one is flying in an airplane, diving in the mountains. Middle ear barotrauma is the most commonly observed in the diving society (Mirasoglu and Aktas 2017). The primary symptoms are related to the tissues mostly effected.

Middle/Inner/Outer Ear Barotrauma

Common symptoms of ear BT include; pain, a feeling of fullness or pressure in the ears, moderate to severe hearing loss, dizziness. Treatment for ear BT includes chewing gum and yawning to relieve the pressure. Medications such as decongestants, antihistaminics, painkillers may also help to relieve the symptoms. Damage can also be produced if the hood fits too tightly over the ears, so as to produce an airtight seal over the external ear (Glazer and Telian 2016).

Pulmonary Barotrauma-Pulmonary Overinflation

Pulmonary barotrauma may develop with the symptoms of coughing, pink & blood stained sputum chest pain, hypotension, changes in breath rate, and cyanosis. Manifestations of lung barotrauma may appear in different clinical conditions; pneumothorax, mediastinal emphysema, subcutaneous emphysema, arterial gas embolism (Table 3, Figure 5). Pneumothorax is defined as the presence of air in the cavity between the lungs and the chest wall causing collapse of the lung. As the collapsed lung is not functional if more gas leaks into the chest cavity or if the gas expands further like during an ascent, the pressure in the chest can increase to such an extent that it also compresses the other lung (Figure 6). This situation is called a tension pneumothorax and is deadly in minutes as the increased pressure in chest prevents blood from returning to the heart (Sümen 2019).

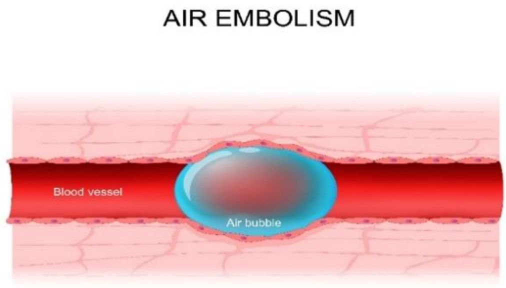

Figure 5. As air bubble blocks the circulation in blood vessels, the perfusion of the tissues deteriorates.

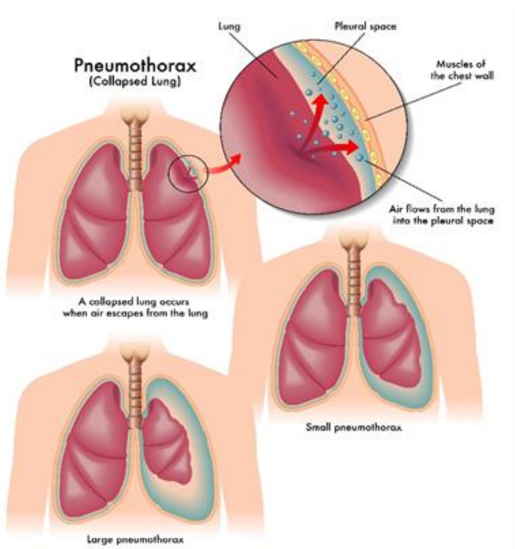

Figure 6. Pneumothorax may develop soon after the rupture of air sacs of lungs.

Mediastinal emphysema is defined as gas filled areas around the heart. Subcutaneous emphysema refers to gas tracking upwards out of the chest in the tissue layers. Arterial gas embolism appears on ascent and manifestations develop soon after the rupture of air sacs of lungs always after surfacing in the sea. Some cases present with neurological complaints which may change from slight mood alterations to loss of consciousness (Adir and Bove 2016; Oh *et al.* 2003; Muth and Shank 2000; Arthur and Margulies 1987).

Table 3. Symptoms and signs of pulmonary barotrauma (pulmonary over-inflation)

Pneumothorax	Mediastinal emphysema	Subcutaneous emphysema	Arterial gas embolism
Breathing faster than normal	Increase in the breathing rate	Feeling of fullness around the throat	Impairment of breathing
Chest tightness	Feeling faint	Change in voice	Failure of cardiac functions
Chest pain	Chest pain & tightness	Difficulty swallowing	Changes in mood
Breathing shallow	Shortness of breath	Feeling the gas in the tissues around the base of the throat on palpation	Loss of consciousness
Bluish discoloration of the lips and tongue	Change in the diver's voice	Crackling sound	Sudden cardiopulmonary arrest

Treatment includes, refrain from diving, breathing 100 % oxygen and the diver should be transferred to a fully equipped hospital. Pneumothorax does not require recompression treatment in a hyperbaric chamber unless there are signs of arterial gas embolism or decompression sickness (Arthur and Margulies 1987).

Sinus Barotrauma

There are four pairs of sinuses and named as frontal sinus, ethmoid sinus, sphenoid sinus, maxillary sinus. They are arranged around the nasal cavity. When the sinus cavity is blocked it can't be equalized properly. Pain occurs immediately. Then it follows by bleeding in nostrils. This is often seen after the dive or blood appears in the mask during the dive. The frontal sinus is the most affected and pain behind the eye is one of major symptoms (Raymond and Cooper 2019; Livingstone and Lange 2018). There are less commonly seen types of barotrauma which include the following (Melamed 1992; Bowman, *et al.* 2019; Livingstone and Lange 2018).

Face mask barotrauma

Mask may also act like a partial vacuum, resulting in conjunctival hemorrhages. This develops when the diver does not exhale through the nose into the dive mask while equalizing.

Gastrointestinal barotrauma
This refers to the expansion of the gas in the bowels during ascent. It is manifested by the symptoms of colicky pain and abdominal fullness, nausea, epigastric discomfort, flatus expulsion, anorexia, malaise.

Suit squeeze
This occurs mostly in divers using dry suit. It tightly compresses the body surface and red or bluish discoloration, slight edema, hemorrhagic lesions may appear on the skin.

Dental barotrauma
Air may get trapped quite close to the pulp at the base of a carious lesion. Diving will then cause a partial vacuum and affect the nerve of the pulp. Due to the unfilled holes in teeth, some divers may suffer from toothache. The pain may persist for some time. Rarely, a filling can be dislocated or a tooth can explode during ascent due to the air trapped in a filling cavity (Sümen 2019).

Decompression sickness

This is a serious health problem for professional divers, but does rarely affect cave divers, unless one does repeat dives or deep dives. Decompression sickness refers to the ailment that occur after the pressure differences between the body and the environment forming bubbles in blood stream or tissue. It is manifested by joint pain, impairment of motor and sensory functions, shortness of breath, coughing, or visual disturbances after scuba diving or decrease in environmental pressure (Buzzacott 2012) (Melamed 1992). When the diver descends the partial pressure of the nitrogen in breathing air gets higher, because the environmental pressure increases. Body does not use nitrogen it dissolves into tissues. As the partial pressure increases more and more nitrogen dissolves into tissues until they are saturated. The pressure gradient of nitrogen in breathing air and the nitrogen dissolved in the tissues becomes higher and higher as diver goes up. If the pressure gradient stays low enough, nitrogen comes out of the body without causing any problem. If the diver ascends rapidly to the surface, stays longer at depth, or performs repeated and deep dives, air bubbles form both in tissues and in the blood which are responsible for the disease (Glazer and Telian 2016; Aktaş 2019; Aktaş 2000; Aktaş *et al*. 1990).

Usually these micro-bubbles do not cause blockages/problems as they diffuse into the alveoli without problem. These bubbles are called ‘‘silent bubbles’’. If the diver exceeds the safe limits of pressure and time, these bubbles may cause a problem. In case of accumulation of a lot of nitrogen, by staying too long at depth or come up too fast to the surface, more nitrogen has to leave the tissues as the diver ascend. As bubbles increase in size, larger bubbles can block blood flow in narrow blood vessels (Hall 2014). Signs and symptoms of decompression sickness do usually appear immediately or a few hours after a dive (Table 4). They can arise up to 48 hours later. There are two types of decompression sickness (DCS). DCS type I is the least dangerous and 3/4 of cases are of this type. Decompression sickness type II is rare but serious and can lead to death (Arthur and Margulies 1987). The chance of getting DCS on a recreational dive is 1 in 10,000. In a study conducted in cave diving, the incidence of DCS in Australian cave divers was estimated to be 2.8:10,000 (Harris, *et al.* 2015). Most cases of decompression sickness are caused by diver error. As the professional divers dive deeper and longer, the majority of cases of DCS occur after technical dives. Signs and symptoms of decompression sickness can be categorized as mild or serious symptoms. Mild symptoms can progress to the serious symptoms (Glazer and Telian 2016). Although, the majority of symptoms arise within 12 to 24 hours (Pendergast, *et a.l* 2015).

Table 4. Severity scores of symptoms in Decompression Sickness

Mild Symptoms	Fatigue Rash “Skin bends” Joint pain Nausea
Serious Symptoms	Numbness and tingling Motor weakness Altered mental status Confusion Abnormal mood or behaviour Visual changes Loss of balance and coordination Paralysis Urinary retention/incontinence Seizure Coma Cardiopulmonary symptoms Death

Treatment should be administered immediately, as waiting until the occurrence of more severe symptoms may deteriorate the clinical conditions of the diver resulting in perminant neurological sequelae. Diver should be transported to the hyperbaric treatment center in order to be treated with recompression therapy (Bennett *et al.* 2012; Sward and Bennett 2014; Toklu *et al.* 2014). The main initial treatment includes oxygen (through a nonrebreathable face mask with reservoir bag) and administration fluid (Ashken *et al.* 2015).

The treatment algorithm follows;

I. 100 % Oxygen inhalation
II. Fluids (Oral/Intravenous)
III. Pain/anti-inflamatory medications
IV. Hyperbaric oxygen therapy
V. Don’t wait to see what happens, call Hyperbaric Oxygen Treatment Center available 24 hours.

Drowning

Drowning denotes the death of an air breathing victim as a result of oxygen deprivation due to immersion in fluid environment. (Edmonds 2005b). Drowning is the most common cause of death. The exact number of incidents related to drowning are difficult to estimate. Divers can drown, as a result of loss of mask or mouthpiece, running out of air, or inhalation of small quantities of water. This may occur from the failure of the air supply with the panic reaction in a hazardous situation. The most serious problems may happen due to the effect of oxygen deprivation of the brain. Oxygen deprivation is directly related to the duration of immersion until resuscitation is started. Furthermore, pulmonary edema and pneumonia due to inspiration of mud, sand and vomit will exacerbate the symptoms of the ailment. Main symptoms of drowning are blue discoloration of the skin, irregular heartbeats, decrease in breathing, loss of conscious, chest pain, hypotension (Buzzacott 2012).

The treatment of drowning falls into two phases; 1) maintain breathing and circulation 2) call for help from qualified medical personal. Proper first aid attempt saves human lives (Figure 7). The diver's vital signs regarding breathing rate, blood pressure, pulse and temperature should be recorded. As the complications such as pulmonary edema, pneumonia may occur many hours after the incident, proper medical observation is essential. Regardless of the severity of a drowning case, all victims should be transported to a medical facility for follow-up care immediately. 100 % oxygen should be administered in the transport vehicle (Edmonds 2005b). An attempt to remove water from the airway of the diver by any means of other than suction is usually unnecessary and dangerous, because it could eject gastric contents and cause aspiration into the lungs. Patients may suffer late effects of the incident and die days later at the health care center. So, the medical care specialists should consider the clinical consequences and management of near drowning. The prevention of drowning is best ensured through training in safe diving practices and qualified diving personal. A trained diver should not easily fall victim to drowning.

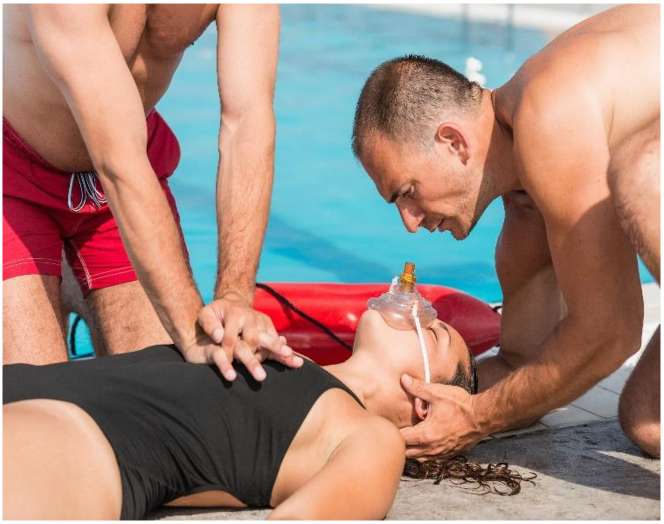

Figure 7. Proper first aid attempt saves human life.

Problems related to rebreather use

The use of closed-circuit 'rebreather' devices has become more preferred in technical or cave diving as re-breathers have many advantages over other diving equipments. These devices help to decrease gas consumption by means of recycle exhaled gas. Chemical damage and accumulation of CO_2 are the major problems that may arise from these high-tech devices can threaten the health of the cave diver (Mitchell and Doolette 2013; Edmonds 2015c; Sümen 2015).

CO_2 retention

There are two main causes of CO_2 retention in the body of diver. 1) difficulty to exhale from the lung 2) inhalation of excessive amount of gas due to the faulty or inefficient CO_2 absorbants (canister). Ventilation of the diver can be limited due to the effect of breathing gas density and dynamic airway compression (Edmonds 2005c). Eventually, diver can't increase the airflow to the lungs and tries as hard as he likes, but that puts more pressure on the outside of the airway. As a result, he hardly breaths more and implications that have for exercising in CO_2 retention. Diver can find himself in a situation where he is producing more CO_2 than he is capable of exhaling it even if he wants to. Increase in partial pressure of CO_2 in body may also result from re-breather with faulty canister. As the CO_2 build up in the body, the effects are clear within a couple of minutes. Main symptoms are flushing of the skin, sweating, tremor, increase in breathing rate, difficulty in breathing. These symptoms may result in drowning in depth. It is a key issue that diver doesn't attempt to work hard when he does deep dive (Pendergast *et al.* 2015).

Chemical Injury

The term ‘‘chemical injury’’ refers to the burn of the upper airway of a diver by the introduction of a caustic alkaline solution from the scrubber of the re-breather. As the chemical trauma injures the air passage it requires immediate hospitalization. Due to the thermal injury of caustic material inhaled by the diver, the victim may present with the symptoms of laboured breathing, burning of sensation of the mouth and throat, headache, choking, gagging, foul taste and so on. Treatment should include rinsing the mouth with fresh water, if only sea water is available, rinse the mouth but diver should not swallow and not attempt to induce vomiting, transport to a medical facility (Edmonds 2005c).

Accident analysis and fatalities in cave diving

Analyzing accidents provide to identify the causes of the casualties and to determine all the precautions that should be taken. Due to the lack of sufficient information or network regarding the total number of dives yearly, and the exact number of diving accidents and the causes of deaths in cave diving, there is uncertainty on exact statistical number of incidents. As a result, we learn more from the assumptions of the diving society and from news on the social media. It is not possible to say if the recent number of diving casualties in cave dives is less that previous years. Diver Alet Network (DAN) has been collecting the data of diving casualties annually by means of digital network with limited information of some countries (Buzzacott and Denoble 2018).

If we search in scientific literature, we may find some published case reports from different countries. In history, the causes of fatalities were discussed for the first time and published in the book *“Basic Cave Diving: A Blueprint for Survival”* in 1979. The book also covered the suggestions on taking preventive measures. It was also concluded that guidelines should be prepared, air supply system should comply with the third rule in planning, the importance of not violation of maximum operating depths in caves (Exley 1986). Although the author of the book ‘’Basic Cave Diving’’ is widely appreciated with his contribution to the educational part of cave diving, he unfortunately died of the accident during a cave expedition. In 1990’s, it was strongly recommended that proper training should be required in cave diving. Divers should be equipped with proper lighting with minimum three lights. Furthermore, in another research new items were inserted in the analysis of causes of diving accident; age of the diver, new technologies (side mount dive gears, re-breathers, e.g.), inappropriate breathing gas mixtures, solo diving, equipment and skill maintenance.

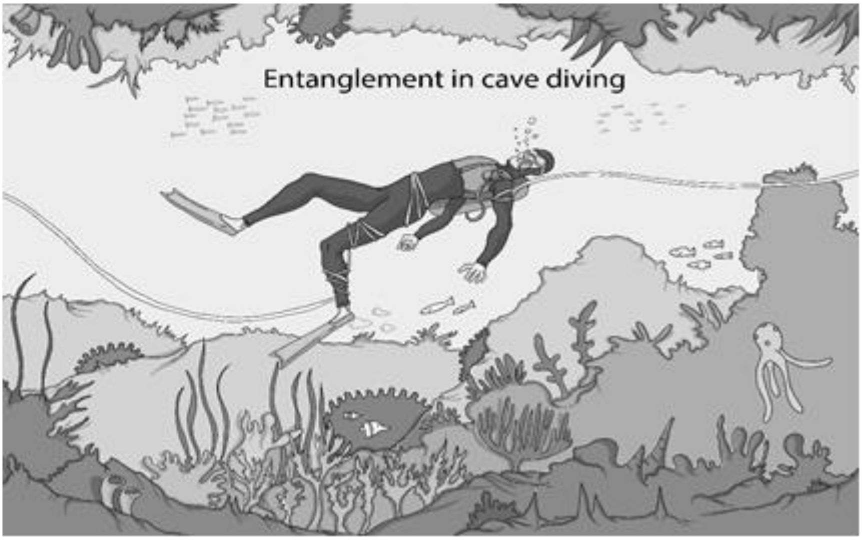

Figure 8. Entanglement in cave diving causes to run out of air and led to drowning (Drawing by Ali Yiğit Ertan).

Data including 287 cases have been analyzed the potential causes of cave diving fatalities in 1997, and results indicated that the majority of causes of death was related to drowning (93%). The chief contributing factor was the lack of training skills and improper use of guideline back to safety. Running out of air (72%), losing the exit (44%) of the cave and entanglement (9%) were the primary preceding events for drowning (Figure 8). Poor gas planing was the primary reason of diving with insufficient gas (Table 5) (Byrd and Hamilton 1997).

According to the results of cave diving fatality report between 1969-2007, it was stated that the most common cause of deaths remains drowning due to the lack of breathing gas. The majority of divers (more than 2/3) ran out of air and the main reasons are poor planning with insufficient gas supply and unable to find the way out of the cave. Additionally, most divers appear to be untrained (Buzzacott *et al.* 2009). In consistency with the cave diving fatalities report published in 2016, the most common cause of death was asphyxia due to drowning. Drowning was introduced by running out of breathing gas, by and large after getting lost in the cave preceded by poor visibility due to stirred silt (Potts *et al.* 2016).

Table 5. Summary of some cave diving fatalities
(year, country, number of victims, causes)

Year	Country	Total number of deaths /Causes
1980	United Kingdom	11/ 8 of death overrunning the air[1]
1980	South Australia	11and 3 running out of air as a result of either deep-diving with inadequate gas reserves or getting lost in silty, low visibility conditions [2]
1997	USA	287 Drowning[3]
1985-2015	USA	161 asphyxia due to drowning, running out of breathing gas, getting lost owing to a loss of visibility caused by suspended silt
1946-2006	United Kingdom	20 drowning[4]

[1] Churcher and Lloyd, 1980, [2]Horne, 1981-1987, [3]Byrd and Hamilton, 1997, [4]Brock, 2006

When the database of cave diving accidents is searched in Turkey, it is not possible to access the records of all casualties. The main restriction of the planning research is the difficulty to clearly estimate the exact number of divers lost their lives in cave diving due to the limited access to the continuous systematic monitoring system of scuba divers. The total number of accidents related to cave diving is unknown and unattainable to calculate. Because this activity is not regularly recorded and controlled by regulations. After searching in the scientific database regarding fatality reports of cave diving published in Turkey, we found only one case record in the thesis covering diving accidents published in 2019 (Koca *et al.* 2019). In this study, the deaths of the 52 fatal diving accidents were evaluated retrospectively in the archive scan of the death reports. 20 of the accidents were found to be associated with scuba diving and only one diver's body was recovered in cave diving. Drowning was found as the primary cause of death in the study. Due to the lack of adequate information we aimed to search other victims and review the descriptive analysis of fatality cases associated with cave diving. Thus, we aimed to obtain additional information in order to find the numbers and the causes of the cave diving accidents in Turkey. Both electronic database and website of news were searched and information was collected face to face from the reference of some fisherman or diver. As a result, we reached the limited information of 7 fatal cases. The detailed information of these cave diving fatalities in Turkey summarized in Table 6. In accordance with the previous reports, drowning was the main cause of the death in these seven fatalities.

Table 6. The descriptive analysis of cave diving fatalities in Turkey between 1990's and 2019

No	Year	Gender Age	Diving type	Nationality	Diving gear	Diving depth (m)	Name of Cave	Depth of Cave (m)	City	Cause of Death
1	1994 a	M	Scuba	Foreign	Air diving	60	Suluin	122	Antalya	Drowning Nitrogen narcosis
2	1994 a	M	Scuba	Foreign	Air diving	60	Suluin	122	Antalya	Drowning Nitrogen narcosis
3	2006 b	M 18	Free diving	Turkish	Spearfishing	20	Kargı	20	Bodrum Muğla	Drowning
4	2011 c	M 40	Scuba	Turkish	Air diving	11	Küçük Pınar	60	Kemalpaşa İzmir	Drowning Lost of the entrance
5	2015 d	M 33	Scuba	Foreign	Air diving	*	Fosforlu	*	Alanya Antalya	Drowning Lost of the entrance Turbid water
6	2015 e	M	Scuba	Turkish	Air diving	41	Antrum	26-52	Kekova Antalya	Drowning Entaglement
7	2015 e	M	Scuba	Turkish	Air diving	41	Antrum	26-52	Kekova Antalya	Drowning Running out of air

*Unknown

Abbreviations; a, b, c, d, e indicate the website access of the news in reference list.

a. https://www.haberturk.com/yasam/haber/170051-magara-dalisina-akademik-tepki (accessed 04 Sept 2019).
b. http://arsiv.sabah.com.tr/2004/07/14/gun102.html (accessed 27 Jan 2019).
c. https://www.trthaber.com/haber/turkiye/magaraya-dalis-yapan-dalgica-ne-oldu-20744.html(accessed 04 Sept. 2019).
d. https://www.turkiyegazetesi.com.tr/yasam/320425.aspx (accessed 04 Sept. 2019).
e. http://www.milliyet.com.tr/2-nefesi-daha-olsa-kurtulacakti-gundem-2075967/ (accessed 27 Jan 2019).

Conclusion

Cave diving has challenges and the majority of accidents are associated with relatively few potential causes. Divers should follow the guidelines remembering the Pareto principle, named after economist Vilfredo Pareto. It states that 80 percent of consequences come from 20 percent of the causes. In cave diving, divers should focus on preliminary research, detailed planning, special equipment, turn around after using one third of the gas rules technical knowledge and experience, keep track of the use of a guideline that must be followed and to have adequate health conditions. Divers ideally should maintain a reasonable level of cardiovascular condition, display strength and flexibility. So, periodic physical examination of diver getting older is essential in order to find and prevent problems before the cave dive.

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Recommendations for safety to prevent health problems in cave diving

- ✓ Always use a single continuous guideline from the entrance of the cave throughout the cave
- ✓ Limit the dive's penetration to 1/3 of the starting air volume
- ✓ Avoid deep diving in caves
- ✓ Diving not beyond a safe depth for the type of gas being used
- ✓ Avoid stirring up silt
- ✓ Proper technical and first aid training
- ✓ Avoid panic by building up experience slowly and being prepared for emergencies
- ✓ Always use at least three lights per diver, each capable of outlasting the dive
- ✓ To comply with the permission of local authorities regarding the access to the cave
- ✓ Diver should not break cave diving safety rules
- ✓ Plan adequately for one's gas needs to avoid running out of air and drowning
- ✓ Stick to follow closely all rules and guideline
- ✓ Practice emergency procedures with your partner before going cave diving, and review them often

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Risks and safety measures during cave diving activities

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Introduction to cave diving

Caves are terrestrial cavities with entrances and exits, which enable any living creature to pass through, as long as these opening's widths and heights allow it. Caves' length may vary from a few metres to several kilometres, their depths may also reach hundreds of metres, depending on their formations and structures. Caves are separated into two groups; natural and artificial caves depending on their development. Artificial caves encompass rock tombs, underground cities, rock houses and temples, which were shaped by human hands in volcanic tuffs or marls. On the other hand, prior or after the formation of bedrocks with carbonate (limestone, dolomitic limestone, dolomite, carbonate-cement conglomerate, and sandstone), sulphate (gypsum), and chlorine (salt), natural caves are formed through underground waters or subterranean movements. Caves can be classified into three groups; horizontal, vertical, semi-horizontal or semi-vertical, and underwater caves can be classified according to parametres of the formation (location, structure and height), the position of limestone and of impermeable rocks in relation to each other, and lastly according to their position to rivers, lakes, or the sea level.

Caves are divided into three main zones based on their depth and visibility (Figure 1).

Cave Zone 1 (daylight zone): This part is defined as the zone of the cave nearthe entry (cavern) with direct visual contact and access to the water surface. The visibility is at least 10 m and the depth is at most 20 m. The distance to the water surface is 50 m. Penetration in this zone requires a specific training (CMAS Cave Diver 1 or equivalent) and a complete diving equipment for sport diving as a basis plus the additional required items.

Cave Zone 2 (zone of complete darkness): It is defined as the zone beyond zone 1 with complete darkness. Maximum depth is 30 m, visibility is between 3 m and 10 m, diving activities are limited by the consumption of at most a third of the initial total gas volume without deposit or stage tanks included. Diving in zone 2 no longer belongs to the area of "normal" recreational diving, but rather to cave diving in the truest sense of the word. In this zone it is very common to have dives with longer decompression stops. This zone requires the level (Apprentice) Cave Diver (without stage tank usage) as defined by other organizations such as NACD, NSS, as well as CDAA (including Sinkhole Class 2).

Cave Zone 3 (highest competence level): It is defined as the zone which does not correspond to the criteria of either zone 1 or zone 2. Visibility is less than 3 m, the depth is between 30 m and 40 m. CMAS neither recommends nor endorses diving deeper than 40 m with compressed air. This zone requires the level Full Cave Diver as defined by other organizations such as NACD, NSS, or Penetration as with CDAA (including Sinkhole Class 3).

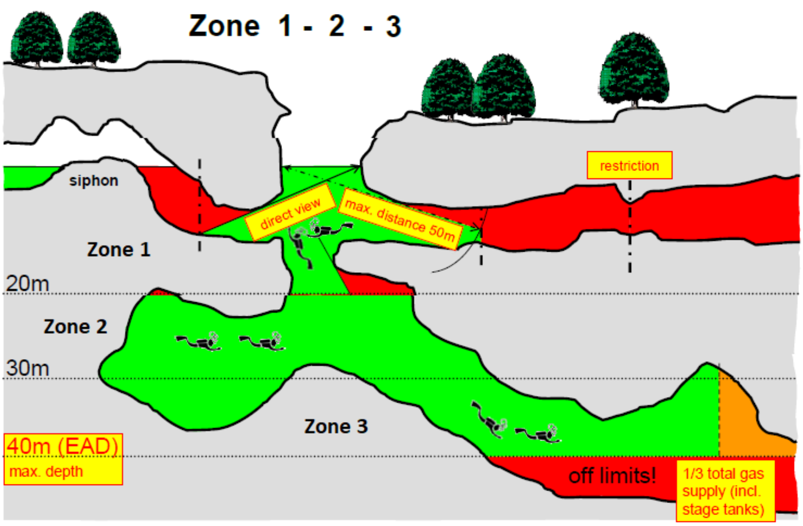

Figure 1. Cave zones (CMAS 2010)

Cavern diving means that diving will take place in the entrance area of water-filled, natural or artificial cavities and in the zone with natural daylight. Cave diving means that diving will take place in water-filled, natural or artificial cavities and in zones beyond natural daylight (total darkness). Cave diving commonly refers to underwater activities performed in structures that comply with the above-mentioned definitions, by athletes or employees with sufficient certifications using diving equipment and gas mixtures. It is usually an activity attended by organizations teams on land and under-water.

The following rules apply to the self-dependent cave diver with no direct connection to surface installations. In agreement with such definitions, a serious training is required to work in these fields for sportive, scientific, or commercial purposes.

Cave diving training

For cave diving, it is required to receive Basic Mountaineering Training followed by Basic Caving Training, Advanced SCUBA Diving Training followed by Technical Diving Training, and Specialization Training (turbid water diving, flowing water diving, night diving, and confined space diving training following basic cave diving training). In addition, the people who will carry out such activities must meet necessary health requirements.

When evaluated in terms of risks, cave diving can be classified as the riskiest technical diving category. Hence, the diving experience and technical knowledge of divers must be at the highest level. Divers must be experienced and cautious, and abide by the plans. With excessive experience comes extreme self-confidence. Extreme self-confidence always increases the risk of mistake. Therefore, in order to perform each activity, the plan must be followed to the letter, from the beginning prior to the dive and to the dive briefing after the cave diving. It is highly likely that diving without following the above-mentioned training, without gearing up with the suitable equipment for the location and without being aware of the geological data or maps related to the cave, can result in casualties.

Prior preparations and measures may also vary depending on whether or not the cave has a connection to the land or is a sea cave. Tidal movements must be taken into account in sea caves. Waves and coastal currents must also be considered. Risks are minimized by taking appropriate measures in account of the location of the diving site and by ensuring communication between the diving team and the surface team.

Guidelines to follow during cave diving

Possessing enough information about the cave
If insufficient information is gathered regarding the cave, divers will not be able to take the appropriate precautions. Therefore unexpected risks may arise during the cave diving.

Diving in company of a guide with extended knowledge on the cave
A good guide who knows the cave enables divers to minimize the risk of accidents and of going astray. An inexperienced guide who doesn't know the cave may result in various problems (jamming, exceeding the planned time, going adrift).

Proper planning
The lack of a suitable plan may generate a great deal of problems such as failure to comply with the dive time, insufficient air, and mismatch of buddies, etc.

Completing and verifying calculation of bottom time, dive time, and depth
If the bottom time, dive time, and depth calculations are not performed completely, divers may run out of air. Subsequently the risk of affliction related to diving may increase with miscalculated decompression stops.

Selecting and checking the appropriate equipment
If the appropriate equipment is not selected for the dive site, problems may occur during the dive, hence causing accidents.

Equipment verification and buddy-checking prior to cave diving
Equipment to be used must be checked and repaired one by one, if there are any deficiencies or faults. Buddies must check each other before diving. A last check usually prevents many accidents. Failure to do so may lead to unnoticed faults that may result in accidents. These accidents do not only affect the diver, but also the dive partner.

Powerful, spare, and sufficient amount of lighting apparatus
Considering that caves are confined and dark habitats, it goes without saying that maintaining visibility is crucial. Lighting is very important for divers' safety and sense of direction.

High quality and purpose-built survey rope
The rope is very important for divers in order to return and not go astray. The rope must be used up to entry from the land. Therefore, the guide rope must be suitable for the purpose and of high quality. It must be resistant to wear and tear.

Taking only the necessary material
Dispensable load and excessive material must be avoided. Otherwise, it may result in problems of excess weight and increased diver volume during dive, leading to getting stuck. Unnecessary and excessive load can lead to excessive effort and accumulation of nitrogen in the body, leading to diving diseases.

Appropriate communication network
Communication problems may occur if divers' communication is not good and clear enough. It may eventually lead to misinterpretations when divers give a warning to their partners. A dysfunction in communication apparatus can cause dangerous situations or endanger divers and their partners.

Following the guide rope and direction arrows in the cave and sticking to the predefined route
Undergoing a pathway other than the pre-specified route means going out of the plan made prior to the dive, creating changes in dive times and depths, which puts divers at risk. It may lead divers to run out of air or eventually cause incompatibility with the dive table, hence resulting in diving diseases. If the guide rope is left on the designated route, then divers may fail to find the return

path and get lost. The diver acting in such way, not only endangers him/herself, but also his/her diving partner.

Avoid diving in parts of the cave which are not suitable for diving activities
Areas that are not suitable for diving in the cave may cause divers to get stuck, to be cut or get injured. It may also damage their diving equipment, hence jeopardizing them.

Usage of underwater directional arrows on the line
Directional arrows which are essential for the return, are very important during cave diving. Arrows must be fixed to the guiding rope and directions must point at the entrance of the cave.

Usage of helmet and underwater scooter recommended
Helmets and underwater scooters are recommended in some places. The helmet must be light and sturdy. It must not hamper the diver's ability to move. A heavy helmet causes excessive effort, exhausting the diver. The scooter provides fast, fatigue-free mobility, but there is also a risk of ascending too fast. Improper handling of the scooter may result in injury. Thus inexperienced and untrained people are not recommended for scooter's usage during cave diving.

Required knowledge of the flora and fauna encountered during cave diving
It is necessary to know about creatures encountered during cave diving. Local fauna in caves should not be disturbed under any circumstances. If they feel threatened or invaded in their natural habitat, fauna may display hostile behaviours toward divers, causing harm (such as eels, snakes, and seals depending on the dive site). It is essential that diving activities are carried out without scaring the fauna, preventive measures must be taken to avoid any possible damages injuries.

Diver must at first be physically fit and have the necessary experience to dive. With greater physical condition and more diving experience, it is far easier for the diver to save him/herself from any predicaments that may occur. However having a good physical condition alone is never enough. The diver must also be psychologically prepared for diving in an enclosed space. If the diver is not emotionally prepared, accidents or problems related to diving will be unavoidable, despite his/her good physical condition. Cave divers should have neither claustrophobia nor nyctophobia. Hence, every diver is not suitable for cave diving.

During hollow diving, which is the preliminary stage of cave diving training, cave entrances must be kept in sight, and divers must enter the cave at a maximal depth of 40 m from the water surface. It provides the possibility of a controlled emergency ascent in case of emergency. Hollow diving training can be provided by institutions such as TDI, NAUI, PADI and SSI, which also provide recreational diving training.

Cave diving require the penetration into dark areas and there is a limited number of institutions that can provide training at this level since it is a type of technical diving. Leading organizations in this respect include: NSS-CDS (National Speleological Society Cave Diving Section), NACD (National Association of Cave Divers) and GUE (Global Underwater Explorers).

Guidelines during a dive in a known cave

Divers must know the concept of cave and the formation of caves in general. The geological structure of the cave where diving will be planned must be known. All plans for diving must be prepared by examining the sketches and layout of the cave before the cave dive. The diving system to be used must be determined according to the structure of the cave. Appropriate equipment must be obtained and necessary controls must be made. The appropriate dive team must be determined for this operation. Transportation possibilities of the region must be determined. The dive operation must be planned. The risk assessment must be made. Emergency action plans must be made and conveyed to the relevant personnel. For the emergency action plan, it is required:

- To determine the route to be followed in case of emergency,
- To determine the means of transportation to be used,
- To determine the person to drive the vehicle, providing the road information,
- To determine emergency health centres, hospitals, and hyperbaric treatment centres,
- To prepare the transportation and communication information of the military, police, and search and rescue teams of the organizations for assistance,
- To prepare an emergency work plan,
- To give a briefing to the team before the dive operation,
- To determine the way of communication with light,
- To determine the way of communication with rope,
- To identify the personnel responsible for the emergency action plan by ensuring that the entire team understands the emergency action plan and keeping it in a place for the land team to see,
- To determine the times to start and end the dive,
- Divers must be prepared psychologically before the day of diving,
- Divers should avoid overexerting activities on the day before the dive,
- They must have had enough sleep,
- They must avoid drinking alcohol or using drugs the day before the dive,
- Their physical condition must be completely suitable for diving,
- On the day of the dive, divers must have nothing but diving in mind

(they must be mentally attuned to diving).

- Control of the equipment to be used in diving and buddy check must be performed.
- The spare equipment to be used in diving must be in place for storage in working condition,
- Divers must go down to the dive point in a controlled way with the approval of the land team, and the dive must be started in the control of and via communication with the leader, by moving to the guide rope on the route,
- Divers must comply with the rule of 1/3 during the dive in the middle of the route determined for the dive,
- During the dive, directional arrows must be checked before leaving the guide rope and diving should be carried out without leaving the route, and the emergency action plan must be followed in case of any problems,
- The dive must be completed in accordance with the decompression limits with the instruction of the group leader in a controlled and coordinated manner with the divers and must be terminated with the help of the land team.
- After diving, the dive should be evaluated by briefing with the land team and the dive team.

The above points are the rules and standards for cave diving. These are rules, standards and experiences; TDI, CMAS Cave Diving Standards & Training System, NOAA manuscripts and cave dives (NOAA 1979, 1991). All the procedures so far have been aimed at getting to know the dive site, developing the appropriate dive system and technique, and forming the appropriate dive team.

Equipment used during cave diving
Guide rope: A durable, preferably white rope, that can be laid continuously in one piece without floating in water starting from the entrance of the cave and must be used during the dive. Hemp ropes are not recommended as they easily dissolve and absorb water. Polyurethane type synthetic ropes may float in water, increasing the risk of entanglement. The most ideal rope is nylon ropes with a tensile strength of 80 kg/m.

Rope's severance in cave diving is not caused by low tensile strength, but because the same rope is trapped in crevices. Thus twisted ropes are preferred over braided ropes. On average, ropes with a length of 150 m are required for sea caves and 60 m for land caves. Using longer ropes may cause problems when reeling.

In general, guide rope is fixed at the dive point and follows the route.

Reel: It is a mechanism which prevents the rope from floating, dispersing, and entangling in water. It helps the diver to return safely. There is a lever to reel up the rope. The reel holder can be carried in the same hand with the flash-light, while the other hand remains free. No gaps must be left in order to avoid jamming while laying the rope. The reels must be made of impact and corrosion resistant materials and must be floating. Divers must have at least two reels.

Torch: One of the torches must be battery operated and bright. Adjustable flashlights may be favoured. The torch must be used steadily and systematically. The use of torch irregularly can be confused with the emergency sign. During the dive, each diver must have at least 3 torches. These torches must be turned on at the beginning of the dive, as to not disturb other divers, and kept on until the end of the dive.

Helmets: They must be resistant to impacts and light enough to not disturb the diver. Torches should be mountable on helmets, as to not restrict the user's view. Usage of this equipment is recommended.

Underwater scooter: This equipment eases diver's mobility at greater speed by increasing the distance that can be reached underwater. Scooters are available in two types: electrical and air-pressured. Regardless of which equipment is preferred, the 1/3 rule must be followed.

Food: Adequate provisions must be arranged according to the duration (days) of the diving activity. Foods high in calories should be selected to satiate divers. Tools such as forks and spoons should, if possible, be multi-functional camping tools.

Bivouac: It is a simple and light-weighted tent which is used for resting and sleeping during lengthy cave diving, providing protection against hypothermic effects.

Carabiner: It is used for securing a rope to two points and to easily separate them from one another.

Hammers: Multi-purpose equipment used in mountaineering and caving.

First aid kits: It must contain equipment to be used for emergency (special equipment for diving as well as for caving). The kit must be waterproof. It can be taken during specific type of dives, but the land team should be in possession of a more advanced one.

Technical BCD: It must have a hard back and a saddle suitable for connecting two tubes. It is recommended that the fabric of the BCD is made of high strength cordura fabric and that the same material is present in the wings. It must have a high carrying capacity. Side-mount systems can also be preferred depending on the dive.

Cutting tools: The cutting equipment must be resistant to oxidation and blunt. Line mules, scissors and knives can be selected.

Masks: Silicone diving masks made of tempered glass suitable for diving must be favoured. Each diver should have two personal masks (according to technical dive rules).

Regulators: Piston or diaphragm regulator may be selected according to the diving schedule. In addition, ICE-KIT regulators should be preferred depending on the water temperature. The gauge of the regulator should consist of only manometres (indicating the pressure of the air in the tube). The hose of the 2nd stage of the regulator must be the standard size and the octopus hose must be 210 cm long. The diver, who is using the backup air source, must allow the second diver sharing the same air source to go after him, while passing through a narrow zone. Two regulators should be used.

Fins: It enables the diver to move forward underwater. Short fins are recommended for cave diving, especially for walking backwards underwater, partially walking on land and for its strong propulsion capacities.

Diving suits: Wet diving, semi-dry diving, or dry diving suits may be recommended. Suits must be selected according to environmental parametres to allow a greater freedom of movement for the diver.

Tank: Tanks with the appropriate amount of breathable air volume must be chosen. Steel, carbon-fiber, and aluminium tanks may be used. During technical dives, aluminium tanks are preferredin most cases. The isolator valve must be used for single-tank. If two tanks have to be used, then tanks must be interconnected with a steel ring in addition to a double tank separation manifold.

Direction arrows and distribution rings: Used on the guiding line, they continuously show the ascent route to divers on the determined dive route. If the cave diverges in more than one direction, the usage of distribution rings makes it easier for the diver to find the right direction.

Diving computers: The device with diving algorithms that allows divers to dive safely.

Additional recommendations for tools

According to technical diving standards, diving tank, decompression tanks, regulators, technical diving BCD, diving computer, fins, mask, diving torch, knife, weight belt, clothes must be available. When selecting the equipment, attention must be paid to the choice of fins. Short fins must be preferred to increase the mobility inside the cave, to walk when necessary, to maneuver in narrow spaces, and to move backwards more easily. Divers must avoid raising dust while using their fins as the floor of the cave may be sandy or slimy. Short fins also offer more advantages than long fins in such cases. The whip of the regulator's octopus must be 210 cm long. The octopus used in case of emergency must be longer than usual in order to allow the diver in need to follow from behind the holder of the emergency octopus without difficulty (as there is no possibility to go side by side in confined spaces). The 1st stage regulator must be compatible with the dive site. For example, in cold water dives, the regulator must be frost resistant. If the selection of regulator is not made properly, it may cause diving accidents. The 2nd stage regulator must be resistant to environmental conditions. It must be shielded and resistant against impacts and dust. During cave diving, fine sand may get into the diaphragm of the 2nd stage regulator, creating a free flow. Therefore, a shielded regulator should be favoured. The same preference applies to the regulator of the octopus.

The regulator must be secured on the diver's regulator in order to prevent the unused one getting trapped somewhere. The helmet must be impact resistant and lightweight. The direction arrows must be properly mounted on the guide rope as the direction sign is fixed. The direction of the arrow must point towards the exit. When choosing the diving torch, a focused, wide-area or multi-lighted source is recommended.

Considerations during cave diving preparation

Depth, additional restricting factors, dive distance, bottom time, visibility, variation in water currents, narrow corridors where water flows may accelerate, amount of available air source (limiting factors) directly affect the planning. Before diving, each diver must calculate the safety threshold of air for diving and return.

The two most violated rules in diving accidents are not using guide rope continuously and the violation of 1/3 rule. A diver may consume up to 5 times more air than normal during entry, depending on environmental factors (temperature, flow direction and velocity). Therefore, a maximum of 1/3 should be used in the dive, and 2/3 of air should be spared for return and emergency situations. The planned time, the planned depth, the planned distance (since it will extend the return time) are strictly followed. If the dive is started with 210 bar of air, divers go in the cave until 140 bar of air remains in the tank, then return.

Justification for the rule of 1/3

If two divers are supposed to share the same air source, twice the amount of air will be needed. When turning back, entanglement may occur while reeling, which increases air consumption. Divers also move slower on the way back as the water is turbid. Another benefit of the rule of 1/3 is justified by the fact that it creates additional air reserves for re-compression, which may be required after exiting the cave. Another issue arising is that divers start with the same amount of air at the beginning.

Gasses used during diving should be selected according to the depth and dive time. Gasses are classified as normal air, nitrox and trimix diving. Dives are named after inhaled gases. Among them, one is used depending on the diving conditions. Preparation of gaseous mixtures must be done by fully professional people.

For air dives, effort must be made to ensure the cleanness of filters and that oil-free and dry air is filled during the preparation of air reserves. Air used for filling must be fresh. That is, the amount of CO and CO2 in the filled air must be extremely low (preferably non-existent). Exhaust gas and indoor air must be avoided when filling the tanks. If these instruction are not abided by, then the diver may be poisoned.

Dive tanks containing gaseous mixtures must be prepared by fully professional people. Great care should be taken in storage and transportation of the tanks. Divers must have received a complete training in mixed-gas diving. Gas changes and decompression stops must be performed in a timely and complete manner. Failing to do so may result in diving diseases.

Closed circuit or semi-closed circuit systems can be used according to diving parametres. Divers using these diving systems must be competent and experienced with the system they operate on. Otherwise, it may result in death.

Ending the cave diving

The dive leader is informed about the problem underwater. If the problem can not be solved, then the dive leader aborts the dive with all the group members. If there is no emergency, the dive is ended following the normal procedure. However, in case of an emergency, the dive is immediately ended in a controlled manner by applying the emergency protocol. Diving is not ended without one's knowledge, except when there are no other options. Otherwise, members of the diving group will think that a member went astray and will apply the lost diver emergency procedure. They will be endangered. Therefore it is necessary to continue the dive until an emergency situation arises. All group members diving have the right to leave the dive whether or not there is an emergency. But the most important fact is that others have knowledge of it. Divers must remember that anyone in the diving group can make mistakes at any time, and therefore must frequently do emergency exercises on land. This way the knowledge is kept fresh in mind. Divers' movements must be in harmony with their buddies. After making sure that the whole team is ready, divers can start ascending. An assessment is made and a report is prepared after each dive. The dive, events, accidents, information about the dive route, information about the dive team and equipment, and observations should be stated in the report. No diving can be skipped by saying everything was perfect. While events are fresh, divers should discuss and negotiate. it ensures the safety and perfection of subsequent dives in the same location. The shape, temperature, appearance, risks and dangers in the cave, characteristics, depth, directions, and places to avoid must also be stated in the report.

Finally, for any kind of cave diving, safety comes first and team work is essential. Besides, marine creatures should not be destroyed, injured or harmed during diving.

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The legal status of caves in Turkish legislation

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Turkey has a unique structure in terms of formations and geological features. The location of caves in Turkey's geomorphological features are important. Caves are known as important ecosystems, when their geological formations and biological functions (Albayrak 2005a) are taken into account. Covered with carbonate and sulphated rocks suitable for karstification, our country is the first ranked among European States with regards to the width of karstic areas. There is no doubt that these rocks, which have such a wide surface, will develop very intensely in natural caves, formed by underground and surface waters (General Directorate of Mineral Research and Exploration 2018a). Considering the fact that all of these caves have not been studied, it is not possible to give a precise figure on the number of caves in our country. However, it is estimated that approximately 35.000-40.000 caves can be found in our country depending on the type of research undertaken in karstic areas (General Directorate of Mineral Research and Exploration 2018b).

A large part of the cave research (General Directorate of Mineral Research and Exploration 2018c) was carried out by the Karst and Cave Research Unit, which was established in 1979, within the Geological Studies Department of the General Directorate of Mineral Research and Exploration.

Caves in Turkey are used for different purposes. Caves have been inhabited by humans and were used as nesting sites by animals. Even medical virtues were given to some caves, given their healing properties for patients. It has been a place of research for scientific studies and a place of visits for tourism. However, caves were unfortunately used as dumping sites for waste material. Therefore caves have been polluted and their ecosystems have been destroyed. Although caves have already been studied by different disciplines, the amount of studies found in the literature, undertaken within a legal framework, is quite noteworthy.

Caves as Natural Assets

According to Turkish Constitution on the protection of historical, cultural and natural assets (article 63) ***"The State shall ensure the protection of the historical, cultural and natural assets and wealth, and shall take supportive and promotive measures towards that end. Any limitations to be imposed on such privately owned assets and wealth and the compensation and exemptions to be accorded to the owners of such, because of these limitations, shall be regulated by law"***. Under

Turkish law, caves are protected as “immovable cultural and natural assets” within the scope of Law on the Protection of Cultural and Natural Assets (No. 2863).

According to this law, “illustrated caves” are considered as immovable cultural assets and “historical caves” are considered as immovable natural assets. In regard to this law, "Natural asset" shall refer to all assets on the ground, under the ground or under the water pertaining to geological periods, prehistoric periods until present time, which are one of a kind or require protection due to their characteristics and aesthetics. “Natural site” areas which belong to geological periods and possess extraordinary features due to their rarity are required to be protected above ground, underground or under water.

The identification process of immovable, cultural and natural properties of natural sites shall be coordinated by the Ministry of Culture and Tourism, via the expertise of the relevant institutions and organisations, whose activities will be affected (article 7/1).

Such identification shall take the history, art, region and other characteristics of the cultural and natural properties into account. An adequate number of exemplary nature (antiquities) reflecting characteristics from period they pertain to, shall be identified as cultural properties to be protected to the extent of the means of the State (article 7/2).

Following the identification process immovable, cultural and natural properties to be protected shall be registered with a decision to this end, by the Regional Council for Conservation (article 7/3).

Caves as Natural Assets: Natural Caves

The Ministry of Environment and Urbanization is responsible and authorized in terms of works, transactions and decisions foreseen in the Law on the Protection of Cultural and Natural Assets, regarding natural assets and natural protected areas, except for movable natural assets.

Prepared by the Ministry of Environment and Urbanization By-Law on the Procedures and Principles Regarding the Determination, Registration and Approval of Protected Areas [1] regulates the “Natural Caves”. According to the By-Law, “Natural caves: dolomitic limestone, dolomite, carbonate, cemented conglomerate and sandstone, such as carbonated limestone, sulphated (gypsum) and chlorinated (salt) rocks formed by or after the formation of physical cavities caused via erosion by the groundwater" refers to caves. Distinctive features of caves are determined in the By-Law. In accordance to the By-Law, caves containing one or more of the following characteristics are natural assets:

[1] Official Gazette, date: 19.07.2012 number 28358.

a) Caves that are to be identified as natural assets are those which were formed naturally without any human interference.

b) These caves are defined by shapes and structures, which make up their ecosystems and whose distinctive features are characterized.

c) Communities of living entities, that are vital for each other, are present within these caves.

d) Characteristic physical and chemical sediments that are growing and keeping their vitality are present in the caves.

e) In the caves exists a delicate habitat whose evolutionary cycle would be disrupted by any interference.

f) Subterranean rivers and waters, which form the cavernous system, interact with the internal ecosystem such as distinctive cracks or galleries that are interconnected via narrow paths, as well as with the external ecosystem such as the atmosphere, the soil, the vegetation, and the living entities.

g) In the cave exist shapes and structures that would characterize or shed light on the geological, geomorphological, hydrological, climatic, biological, and anthropological formation of the region.

Caves are determined in a way that they would encompass the protection band, to the extene that they perform ecosystemic finalias.

Caves as a Natural Asset: Resolutions of Natural Caves[2]

The Natural Caves principle decision, which will be determined as the Nature Asset has been published, stated as follows:

1) It has been decided that caves shall be defined as geomorphological formations which have natural, aesthetic, scientific and ecological value, formed as a result of decomposition, erosion, transportation and re-deposition processes via underground and surface water resources, within the geological formations which are suitable for caves' formation.

2) Taking into consideration the natural, aesthetic, scientific, ecological value and the health and eco-tourism potential of natural caves, this principle formulated by the General Directorate of Protection of Natural Assets, in line with the By-Law on Procedures and Principles Regarding the Registration and Approval of Detection of Protected Areas in terms of protection and use in accordance with the Technical

[2]Official Gazette, date: 25.03.2016 number: 29664.

Principles Regarding the Conditions for the Determination, Registration and Protection of the Caves to be Determined as Natural Asset.

3) Group A Caves: These caves are very valuable in terms of scientific and ecological features. This group of caves possess rare and sensitive properties, which are important in regard to natural balances and the need to be protected for scientific and educational purposes.

Within the cave and cave plan projection;

a) Apart from scientific and ecological research subjects, activity which may adversely affect the existing ecosystem and natural aesthetic structure, shall not be carried out.

b) Carrying out afforestation activities without altering the natural plant texture, is in line with the opinion of the General Directorate of Forestry and is also deemed appropriate by the Regional Commission for the Protection of Natural Assets.

c) Stone, soil, sand cannot be taken (marble, sand, mine and so on). Furnaces shall not be opened and any solid wastes shall not be poured.

d) Existing licensed structures and activities may continue within the license period, in accordance with measures to be taken by the Regional Commission for the Protection of Natural Assets and shall be liquidated at the end of the licensed period.

e) The maintenance and repair of existing registered and licensed buildings shall be made by the decision of the Regional Commission for the Protection of Natural Assets and the current status.

f) Scientific and educational research studies and technical infrastructure services (lighting, road, drinking water, sewerage, energy transmission line, natural gas line, etc.) required by public institutions within the cave and the cave protection area, made for caves within this group Protection of assets, may be performed by the decision of the Regional Commission.

4) Group B Caves: These are caves which are valuable in terms of natural aesthetics, scientific and ecological features. However, they can be used for health and eco-tourism purposes, which are carried out for the benefit of humanity, as long as natural balances are taken into account.

Within the cave and cave plan projection;

a) Taking into account the cave plans and sections, in line with the approved conservation zoning plan provisions, daily facilities for recreation purposes, conservation, development and promotion of the cave and its immediate surroundings may be constructed with the permission of the Regional Commission for the Protection of Natural Assets.

b) Until the zoning plan for conservation is approved, conditions of temporary construction in such caves shall be determined by the Regional Commission for the Protection of Natural Assets.

c) Traditional agricultural activities in line with the cave ecosystem may be carried out, provided that the permission of the Regional Commission for the Protection of Natural Assets is maintained, in order to maintain the existing land uses, agricultural and livestock activities.

d) Stone, soil, sand etc. material which can be taken are limestone, brick, marble, sand, mine and etc. furnaces shall not be opened and solid waste shall not be poured.

e) Existing structures and activities that are already licensed may continue, within the license period in line with measures to be taken by the Regional Commission for the Protection of Natural Assets, and shall be re-evaluated by the Regional Commission for the Protection of Natural Assets at the end of the license period, by taking the opinion of the relevant institutions.

f) Forestry activities above caves that will not hinder the cave ecosystem will be allowed.

g) Permission from the Regional Commission for the Protection of Natural Assets will be required for all of the above activities.

5) Group C Caves: These are the caves which are important in terms of health and eco-tourism, with natural cave characteristics that are suitable for controlled use (recreational activities, agriculture and tourism activities allowed to be carried out in and around caves).

Within the cave and cave plan projection;

a) Taking into account the cave plans and cross sections, in accordance with provisions of the approved conservation plan, daily recreational facilities and tourism facilities shall be constructed for public purposes with the permission of the Regional Commission for the Protection of Natural Assets.

b) In addition to continuing the existing agricultural and animal husbandry activities, new agricultural and animal husbandry activities may be carried out. Cavern shelters, storage facilities and guano (bat manure) can be extracted with the permission of the Regional Commission for the Protection of Natural Assets.

c) Without disturbing the cave ecosystem and geological-geomorphological structures, mining activities can be carried out using appropriate techniques, without drilling and blasting outside the cave's protected area.

d) Existing licensed structures and activities may continue within the license period, in line with the measures to be taken by the Regional Commission for the Protection of Natural Assets, and shall be re-evaluated by the Regional Commission for the Protection of Natural Assets after the approval of the relevant institutions at the end of the license period.

e) All of the above activities will require permission from the Regional Commission for the Protection of Natural Assets.

6) If the registered cave coincides with the natural protected area, the highest protection rules will be required to preserve the area.

Caves as Cultural Assets

Legislation on the protection of cultural assets defines what is the subject of protection. Under the Law on the Protection of Cultural and Natural Assets, “illustrated caves” are accepted as immovable cultural assets. According to this Law, “Cultural asset” shall refer to movable and immovable asset on the ground, under the ground or under the water pertaining to science, culture, religion and fine arts originating from before and after recorded history or hold a unique scientific and cultural value for social life before and after recorded history.

Immovable cultural assets registered as Tap immovable cultural assets, which need to be protected and parcels containing immovable cultural and natural assets, which are prohibited due to their archaeological sites and natural sites, are exempt from any kinds of taxes, duties and fees. However, this exemption shall not apply to half of the real estate tax and any of the environmental cleaning tax for the ones used in commercial activities other than those, which are taxed in the simple procedure among the immovable properties mentioned above, within the boundaries of the metropolitan municipality.

Caves as Cultural Assets: Tax Exemption

To identify the purpose of the protection of cultural assets, projects, maintenance, repair, restoration, and the condition to be used for the safety of the museums with excavations, the Presidency, the Grand National Assembly of Turkey, Ministry of Defence, the Ministry and the General Directorate for Foundations of all kinds from outside will be brought tools, equipment, machinery, technical material and chemical substances, gold and silver foil, all taxes, duties and fees are exempt. (article 21) In accordance with the decision of the conservation zone boards, the repair and construction works in these immovable cultural properties are exempt from shares of taxes, fees and expenses, which are to be collected in accordance with the Law on

Municipal Revenues (article 21).

Caves as Cultural Assets: Ownership of immovable cultural and natural assets

Public goods are subject to various classifications from different angles. The distinction according to the purpose of allocation, is manifested as unclaimed goods, intermediate goods and service goods. Private asset is not established on unclaimed goods. These goods, unlike the non-owner goods covered by private law, include goods that are not suitable for private ownership (Özel 2018). These goods, which are directly under the rule and disposition of the State, are open to everyone's direct use and benefit. In accordance with Turkish Civil Code (article 715), unclaimed property and public goods of benefit are under the rule and disposition of the State. Unless proven otherwise, public waters and non-arable lands such as coasts, hills, mountains, caves, glaciers, and resources resulting from them are not owned by anyone and cannot be subjected to private ownership in any way.

Legislation on the Protection of Organism in the Caves

It is important to protect organisms (flora and fauna) living within caves. A total of 32 bat species are in existence, living inside caves, buildings and trees in Turkey. Some of them are frugivore while some others are insectivore (Albayrak 2005b). The bat fauna varies according to the size of the cave (Albayrak 2005b). There are legal arrangements for their protection. The most important of these regulations is the European Convention for the Protection of Wildlife and Habitats (Bern Convention) (Council of Europe 2019**)**. The Convention aims to ensure conservation of wild flora and fauna species and their habitats. Special attention is given to endangered and vulnerable species, including endangered and vulnerable migratory species specified in appendices. The parties undertake to take all appropriate measures to ensure the conservation of habitats of the wild flora and fauna species. Such measures should be included in the parties planning, in development policies and in pollution control, with particular attention to the conservation of the wild flora and fauna. Parties to the Convention are compelled to take appropriate and necessary legal and administrative measures, to ensure the preservation of wild flora and fauna species' endangered habitats, especially those listed in Annexes I and II.

There are also provisions in the Environmental Law[3] (1983) concerning the protection of flora and fauna.

Article 9-With the purpose of environmental protection;

a) It is mandatory to protect the biological diversity that forms the natural environment and ecosystem preserving this diversity. Biological diversity protection and usage principles shall be determined by taking into account the opinion of local

[3] Environmental Law (No: 2872) (Official Gazette Dated 11.08.1983 and No 18132, amended by Law No. 5491, dated 26.04.2006).

governments, universities, non-governmental organizations and other related institutions.

b) It is mandatory to show to areas that have gained a protection status by taking under protection through the national legislation and the international agreement, that we are party to and the sensitive areas having ecological value in all kinds of scaled plans. Areas that have been given a protection status and areas having ecological value shall not be used except for the plan decision.

As a result, caves within the scope of conservation are natural formations that should be protected not only due to their geologial charecteristics, but also because of their biological value. Caves should be protected as a whole, including indoor and marginal living spaces.

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