ECOLOGICAL CHARACTERIZATION OF THE COASTAL AND MARINE HABITATS IN TYRE, LEBANON

This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of SPA/RAC and do not necessarily reflect the views of the European Union.

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For bibliographic purposes, this document may be cited as:

SPA/RAC–UN Environment/MAP, 2021. Ecological characterization of the coastal and marine habitats in Tyre, Lebanon. By Michel Bariche, Nancy Sayar and Atef Limam. Ed. SPA/RAC. IMAP-MPA Project, Tunis: 68 pages.

Cover photos credit:

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The present report has been prepared in the framework of the IMAP-MPA project financed by the European Union.

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" *In memory of our beloved friend Ziad Samaha* (1981-2023), *who found peace beneath the waves and whose passion for the Mediterranean Sea inspires our pursuit of learning.* "

ECOLOGICAL CHARACTERIZATION OF THE COASTAL AND MARINE HABITATS IN TYRE, LEBANON

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FOREWORD

The present document is prepared in the context of the regional project «Towards achieving the good environmental status of the Mediterranean sea and coast through an ecologically representative and efficiently managed and monitored network of marine protected areas» ("IMAP-MPA Project"), in which the Specially Protected Areas Regional Activity Centre (SPA/RAC) of the Mediterranean Action Plan (UNEP/MAP) has been designated as co-executing agency.

The «IMAP-MPA» Project is funded by the European Union (EU) - Directorate General for Neighbourhood and Enlargement Negotiations (DG NEAR) and the European Financial Instrument of the 2018-2022 Green MED III: The European Neighbourhood Instrument (ENI) South, for Water and Environment. It is coordinated and implemented by the UNEP/MAP Secretariat and executed through its Programme for Assessment and Control of Marine Pollution in the Mediterranean Region (MED POL) and the Regional Activity Centre for Specially Protected Areas (SPA/RAC) for the benefit of six countries (Algeria, Egypt, Lebanon, Libya, Morocco and Tunisia) with regards to the MPA component exclusively executed by SPA/RAC.

The IMAP-MPA Project aims at contributing towards achieving a Good Environmental Status (GES) of the Mediterranean Sea and coasts. It proposes to consolidate, integrate, and strengthen the Ecosystem Approach (EcAp) for the management of Marine Protected Areas (MPAs) and their sustainable development, which will be achieved by monitoring and assessing the ecological status of the Mediterranean Sea and its coastline, including MPAs, in a comparative and integrated manner.

More specifically, the project aims to improve MPA management through the coordinated implementation of the Barcelona Convention Roadmap for a comprehensive and coherent network of well-managed MPAs to achieve Aichi Target 11 in the Mediterranean and to strengthen the integration of the Monitoring and Assessment Programme (IMAP) into this process. Hence, it will consolidate and further develop the Mediterranean network of ecologically representative, interconnected and effectively managed and monitored MPAs.

In Lebanon, SPA/RAC is jointly collaborating with the Ministry of Environment (MoE) to prepare a synthetic ecological characterization overview of the coastal and marine environment of the Tyre Coast Nature Reserve, with a view to developing a management plan for this Lebanese Specially Protected Area of Mediterranean Importance (SPAMI), and contributing, hence, to improve the effective management and preservation of its terrestrial, coastal and marine heritage components.

EXECUTIVE SUMMARY

The present document has been prepared within the framework of the IMAP-MPA project, funded by the European Union. It aims to achieve a Good Environmental Status (GES) of the Mediterranean Sea and coast through an efficient network of Marine Protected Areas (MPAs). This regional project is co-executed by the Regional Activity Centre for Specially Protected Areas (SPA/RAC) and benefits six Mediterranean countries, including Lebanon. SPA/RAC regularly collaborates with the Ministry of Environment of Lebanon (MoE) and assists in setting national priorities for MPA development and IMAP implementation, as well as monitoring important species and habitats.

The Tyre Coast Nature Reserve (TCNR) is situated in southern Lebanon, in the vicinity of the historical city of Tyre. The TCNR has been protected by several national and international decrees, including being a Specially Protected Area of Mediterranean Importance (SPAMI).

This document aims at preparing a synthetic ecological characterization of the coastal and marine environment of the TCNR in order to detect species and habitats of potential conservation interest and plan efficient management practices. It compiles results from two studies conducted earlier in the area and an additional recent evaluation of some habitats within the protected area.

Marine organisms and habitats found in the TCNR are grouped following the classification provided in the handbook for interpreting the types of marine habitat for the selection of sites to be included in the national inventories of natural sites of conservation interest, published in 2002 by the UNEP/MAP-RAC/SPA.

The marine environment in the TCNR is characterized by a number of biocenoses present from the supralittoral down to the circalittoral zone. Soft and hard bottom communities each include five different biocenoses, with at least 26 different habitats with specific "associations" and "facies" showing dominant flora and fauna. Soft bottoms are mainly composed of coarse sand and gravels, muddy sand and maërl beds. Hard bottoms are rocky and more diverse, with *Dendropoma* and *Neogoniolithon* concretions in the midlittoral zone, while the infralittoral is covered by rich macroalgae communities with associations, defined and based on exposure to sunlight and water circulation. These are:

1) exposed photophilic community;
2) exposed sciaphilic community;
3) sheltered photophilic community; and
4) sheltered sciaphilic community.

A rich coralligenous biocenosis dominates the circalittoral bottoms, as well as the infralittoral enclaves and semi-dark caves. Additional smaller communities are also present around cold water and hot water springs, situated at about 13 and 40 m depth respectively.

Around 300 species of marine organisms are reported in this document. The highest diversity is constituted by fishes (23%), molluscs (18%), and sponges (12%). The most represented macroalgae are rhodophytes (61%), followed by ochrophytes (27%) and chlorophytes (11%). Non-indigenous species constitute a significant part of the marine biodiversity in the reserve and represent about 14% of all taxa observed.

Fish assemblages present are studied separately. Diversity seems to be high in the Tyre region, as about 70 fish species have been recorded from the underwater survey, among which 23% are non-indigenous and invasive. Species richness, biomass and abundance indices are also calculated and compared. Sparids, labrids, siganids, mullids, serranids, in addition to the pomacentrid *Chromis chromis* and the pempherid *Pempheris rhomboidea*, are the most represented. Two non-indigenous fish, *Parupeneus forsskali* and *Pterois miles*, display a high abundance and biomass in the area. These economically valuable exotic species are significantly contributing to the fisheries of the region.

About 30 marine species, considered as threatened, are reported from the region of Tyre. These are protected under international conventions and directives, including the Barcelona Convention and the Bern Convention. Human pressures affecting the TCNR region include fishing, pollution and habitat destruction. This is particularly relevant since the area is an important touristic zone during the summer season and is relatively highly populated throughout the year. Pollution is mainly constituted by solid waste, sewage discharge and agricultural activities. Spearfishing is another significant threat, particularly when coupled with SCUBA gears and air compressors, as well as other fishing methods used by professional fishers. Minor habitat destruction within the boundaries of the reserve is mainly due to human presence and activities, as well as to non-indigenous species. Finally, the effect of climate change is also discussed in this document, particularly sea level rise, precipitation and freshwater resources.

Tyre is considered an important area for monitoring, according to the National Monitoring Programme for marine biodiversity, which was developed for Lebanon following the IMAP requirements. It includes several

individual monitoring programmes for marine benthic habitats, sea turtles, coastal and marine birds, marine mammals and non-indigenous species.

Deficiencies in the TCNR management are mainly related to financial and human resources. Recommendations for an effective management include the development of an adequate management plan, secure and sustainable financing, staff recruitment and training, defined marine and terrestrial geographical boundaries, enforcement of restricted human activities, monitoring of faunal and floral diversity, as well as communication and awareness activities.

INTRODUCTION

The Specially Protected Areas and Biological Diversity (SPA/BD) Protocol of the Barcelona Convention in the Mediterranean promotes cooperation in management and conservation of natural areas, and the protection of threatened species and their habitats. This supports the establishment of MPAs defined by the International Union for Conservation of Nature (IUCN) as “a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values” (Day et al., 2012). MPAs aim at maintaining healthy oceans, sustainable management of fishery resources, as well as tourism opportunities for business development (SPA/RAC and MedPAN, 2019). They aim to conserve the biodiversity of coastal and marine areas and protect important or endangered sites, as well as key habitats for indigenous or threatened species.

The IMAP-MPA project is contributing to the implementation of the Barcelona Convention Roadmap for a Comprehensive Coherent Network of Well-Managed MPAs in order to reach Aichi Target 11 in the Mediterranean. It supports the elaboration and implementation of MPA management plans and identifies requirements at the national level for biodiversity policies and IMAP implementation.

The SPA/RAC is constantly collaborating with the Ministry of Environment of Lebanon (MoE) to set national priorities for MPAs development and IMAP implementation along with the monitoring of important species and habitats in Lebanon as a Contracting party to the Barcelona Convention.

Conservation of coastal areas in Lebanon, particularly the Palm Islands Nature Reserve (PINR) and the Tyre Coast Nature Reserve (TCNR), has been ratified by several national and international decrees. Lebanon endorsed the Convention on Biological Diversity in 1994 (Law No. 360/94), and adhered to the Ramsar Convention on Wetlands of International Importance especially as a Waterfowl Habitat in 1999, by stating that Palm Islands (Site No: 1079) and Tyre Beach (Site No: 980) are Ramsar sites. Tyre is also considered as a World Heritage site by the UNESCO Convention on the Protection of Cultural and Natural Heritage (1984). According to the Lebanese law, a protected area could be a nature reserve defined as “a terrestrial or marine zone where nature conservation measures are established in order to protect ecosystems, habitats or organisms of particular importance”.

Tyre is one of the most important touristic coastal cities in Lebanon. It is famous for its wide sandy beach and historic harbour (Figure 1). The TCNR is situated in the southern part of Tyre, 80 km south of Beirut, the capital of Lebanon. It covers a total area of 3.8 km^2 and is divided into two zones (Section E1 and Section AG), separated by the Rachidieh Refugee Camp. The characteristics of the two zones can be found in Table 1.

Table 1: Characteristics and extent of the zones in TCNR.

	Section E1	Section AG
Geographical coordinates (degrees-minutes)	Lat. 35°12’30” Long. 33°15’30”	Lat. 35°12’55” Long. 33°13’45”
Characterization	Touristic and Conservation Zone	Agricultural Zone
Dimensions (length x width)	1.8 km x 500 m	2 km
Land type	Sand lined beach, bordered with low shrubs and vegetation	Agricultural Lands
Extent	North: Tyre Rest House South: Rachidieh Refugee camp East: low shrubs and vegetation West: Mediterranean territorial waters	North: Rachidieh Refugee camp South: Chaetiyeh village East: Ras el Ain prehistoric springs (1.5 km from the sea) West: Mediterranean territorial waters

The area has a sub-humid Mediterranean climate with no precipitation between May and October. The precipitation is on average 645 mm per year and the temperature 20.8°C. An average maximum temperature of 30.8°C is reached in August and a minimum of 10°C is recorded in January. The seawater temperature ranges between 17°C in February and 32°C in August and is relatively constant at 70 m depth (17-18°C). The average salinity is around 39 and slightly fluctuates with the seasons.

The TCNR is considered as a Specially Protected Area of Mediterranean Importance (SPAMI) since 2012 and its habitats and species should be protected with an operational management (Figure 1).

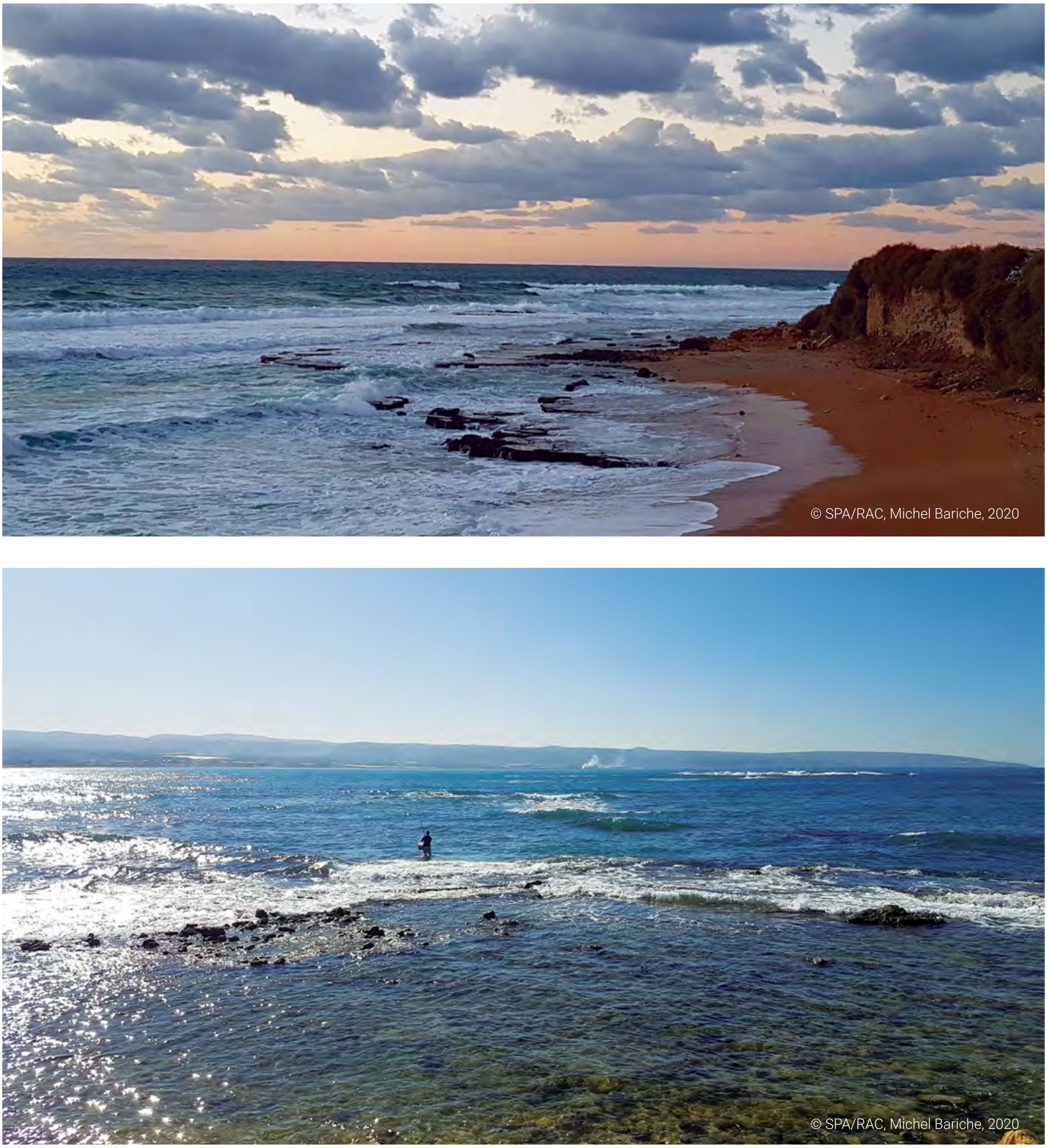

Figure 1: General view of the regions situated north (upper) and south (lower) of Tyre showing the TCNR in the background.

Several administrations have different responsibilities in managing the TCNR. The MoE is responsible for establishing, protecting and managing protected areas (Law No. 690/2005 and Law No. 130/2019). The Ministry of Public Works and Transport controls the implementation of legislation of marine public properties (Law No, 214/1993), the Ministry of Agriculture implements legislation regarding fisheries (Decision No. 31/1995) and manages the agriculture land, and the Ministry of Defense/Lebanese Army patrol and guard coastal waters (Decision No. 22/1981). Furthermore, the Ministry of Culture governs the archaeological sites, the Ministry of Power and Water manages groundwater sources, and the Municipality of Tyre manages the touristic zone (Law 708).

National decrees, laws and decisions governing the TCNR include:

1. Law No. 444/2002: Code of Environment, which specifies the protection and management of nature and biodiversity
2. Law No. 708/1998, which declares the Tyre coast as a Nature Reserve
3. Law No. 508/2004: Hunting Law
4. Decision No. 125/1 of 1999 banning the hunting of marine turtles, monk seals and whales, as well as the selling, use or trade of any derivatives.

In addition to the laws/decisions/decrees that govern the protection and management of the TCNR, an Appointed Protected Area Committee (APAC) manages the site (Articles 4 and 5 of Law No. 708/98). The APAC represents local stakeholders and communities and is composed of five volunteers from the Ministry of Agriculture, the Municipality of Tyre, Kaemakam of Tyre Caza, and two local NGOs. APAC's obligations have been addressed by a decision of the MoE under registry No. 250/B/2003 (29 Jan 2003) that gave the committee financial, administrative and supervisory responsibilities.

The aim of this work is to prepare a synthetic ecological characterization of the coastal and marine environment of the TCNR. This is achieved by collecting scientific information on the marine fauna and flora, through targeted field exploration and a comprehensive literature review for the site. Significant species and habitats, specifically those of conservation interest and non-indigenous organisms are highlighted. This information should aid in applying efficient management practices when potential threats and suitable monitoring programmes are identified.

The specific aims of this document are:

1. Description of the geography and physical characteristics of the area and its environment.
2. Preparation of an inventory of the habitats and present marine fauna and flora.
3. Identification of significant species and habitats listed in Annexes II and III of the SPA/BD Protocol.
4. Identification of species of conservation interest and non-indigenous organisms.
5. Description of threats and their impacts on the area.
6. Identification of suitable monitoring programmes and potential challenges, and suggested recommendations for efficient management.

This report is a compilation of all available information for the TCNR, particularly from the two previous studies conducted earlier in the same area in 2013 and 2017 (RAC/SPA - UNEP/MAP, 2013; 2014; IUCN-SPA/RAC, 2017 unpublished), which aimed at assessing the natural habitats and marine species, and suggested recommendations for the management of the zones. A more recent field survey also took place in August-September 2020 targeting specific sites within the area, in order to validate some acquired information and eventually update the status of some habitats within the protected area and its surroundings. This document also draws general conclusions regarding the site and its biodiversity, and provides recommendations on its management.

A. Prospected areas

In August-September 2013, surveys were undertaken between 0 and 47 m depth in the TCNR area and its surroundings, while in April 2017, eight localities between 1.5 and 47 m depth were assessed in the same area. In September-October 2020, the field survey took place within the strict boundaries of the TCNR, between 0 and 30 m depth (Figures 2, 3).

B. Chronograms

The 2013 survey was conducted between 26 August and 8 September 2013 (12 days), for Nakoura, Saida and Tyre. In 2017, the survey was conducted between 15 and 22 April 2017, over eight days.

In 2020, the survey and assessment made were conducted on 29 July, 26 September and 4 October 2020 (3 days) (Table 2).

Table 2: Distribution of surveys/day during the 2013, 2017 and 2020 missions.

Days / Surveys	April					July	August		September					October
	16	17	18	19	20	29	29	30	02	03	04	05	26	04
2013							X	X	X	X	X	X		
2017	X	X	X	X	X									
2020						X							X	X

Figure 2: Photographs from the fishing port of Tyre taken during preparations for the 2020 survey.

MATERIAL AND METHODS

A. Study area

A total of 28 sites were prospected in 2013, between 0 and 47 m depth around Tyre in 59 dives. In 2017, 39 sites from eight localities were prospected in 52 dives. In the targeted work of 2020, nine sites were prospected in 10 dives (0-30 m). Seven additional areas were also visited on foot in the supra and midlittoral (Table 3, Figure 3).

Table 3: Locations of the sites prospected in the Tyre area,
during the 2013, 2017 and 2020 missions (RAC/SPA - UNEP/MAP, 2013; IUCN-SPA/RAC, 2017 unpublished).

Mission	Code	Locality	Latitude	Longitude	
2013	T-1	Tyr-N (inlets)	33°17.215' - 33°17.153'	35°11.738' - 35°11.738'	Rocky with boulders and coarse sand patches
	T-2	Tyre-C (Jamal)	33°15.898' - 33°16.059'	35°11.452' - 35°11.687'	Rocky with boulders and sand, roman columns
	T-3	Tyre-S	33°14.380' - 33°14.436'	35°10.449' - 35°11.258'	Muddy-sand and flat rocks with canals
	T-4	Tyre-S	33°14.535' - 33°14.500'	35°11.097' - 35°12.217'	Flat and irregular rocks, coarse and fine sand
	T-5	Tyre-N (inlets)	33°17.017' - 33°17.126'	35°11.935' - 35°11.806'	Coarse sand with boulders and rocks, lagoon
	T-6	Tyre-N (inlets)	33°15.941' 33°16.051'	35°11.476' - 35°11.697'	Rocky with small sand patches, littoral rock
	T-7	Tyre-N	33°19.636' - 33°19.333'	35°12.490' - 35°13.920'	Irregular rocks with sandy canals and large boulders
	T-8	Tyre-N	33°17.387' - 33°17.276'	35°10.477' - 35°11.434'	Flat rocks with small boulders and sandy patches
	T-9	Tyre-C	33°16.216' - 33°16.119'	35°10.262' - 35°11.162'	Flat rocks with sandy canals
	T-10	Tyre-S	33°13.691' - 33°13.765'	35°10.797' - 35°10.158'	Flat and irregular rocks, coarse and fine sand
	T-11	Tyre-C (El Fanar)	33°16.813' - 33°16.911'	35°11.741' - 35°11.736'	Coarse sandy rocky bottom with bottom currents
	T-12	Tyre-C (inlets)	33°16.954'	35°11.326'	Rocky bottom with small sandy patches
	T-13	Tyre-S	33°15.143' - 33°15.078'	35°10.877' - 35°11.645'	Flat rocks with sand
	T-14	Tyre-C	33°18.371' - 33°18.091'	35°11.394' - 35°13.017'	Flat rocks with sandy canals
	T-15	Tyre-N	33°16.987 - 33°16.819'	35°11.784' - 35°12.697'	Lagoon, sandy bottom with cobbles and pebbles
	T-16	Tyre-N	33°16.566'	35°11.858'	Lagoon, sandy bottom with cobbles and pebbles
	T-17	Tyre-N	33°17.028'	35°11.725'	Littoral rocky reefs
	T-18	Tyre-S (Jamal)	33°15.748' - 33°15.815'	35°11.593' - 35°11.537'	Rocky with boulders and sand
	T-19	Tyre-N (inlets)	33°15.995'- 33°15.857'	35°11.187' - 35°11.609'	Flat rocky with sandy canals
	T-20	Tyre-N (inlets, paltier)	33°16.072' - 33°16.016'	35°10.946' - 35°11.567'	Rocky substrate
	T-21	Tyre-N	33°19.965'	35°11.323'	Rocky substrate with freshwater springs
	T-22	Tyre-N (lagoon)	33°16.939'	35°11.933'	Lagoon, small boulders-cobbles with Cystoseira sp. on sandy bottom

2013	T-23	Tyre-C (Jamal)	33°15.922'	35°11.076'	Flat rocky substrate with sandy canals
	T-24	Tyre-N (port, lagoon)	33°16.939'	35°11.933'	Lagoon, small boulders and cobbles on sandy bottom
	T-25	Tyre-N	33°19.946'	35°10.624'	Rocky substrate with warm freshwater springs
2017	S1	Bakbouk	35°12'30.94"	33°17'41.08"	Rocks
	S2	Bakbouk	35°12'28.11"	33°17'38.55"	Rocks
	S3	Bakbouk	35°12'25.61"	33°17'34.13"	Rocks
	S4	Bakbouk	35°12'33.09"	33°17'33.70"	Rocks
	S5	Bakbouk	35°12'35.09"	33°17'37.03"	Rocks
	S6	Bakbouk	35°12'37.09"	33°17'40.53"	Rocks
	S1	Bayada	35°9'59.78"	33°10'5.242"	Rocks
	S2	Bayada	35°10'1.513"	33°10'7.806"	Rocks
	S3	Bayada	35°9'59.10"	33°10'2.924"	Rocks
	S4	Bayada	35°10'4.996"	33°9'56.25"	Rocks
	S5	Bayada	35°10'5.311"	33°9'59.72"	Rocks
	S6	Bayada	35°10'7.946"	33°10'1.761"	Rocks
	S1	East Zire	35°11'56.00"	33°16'56.31"	Cobbles and rhodoliths
	S2	East Zire	35°11'56.61"	33°16'59.75"	Cobbles and rhodoliths
	S3	East Zire	35°11'55.53"	33°16'53.16"	Cobbles and rhodoliths
	S1	Jamal	35°11'36.71"	33°15'47.14"	Rocks
	S2	Jamal	35°11'27.22"	33°15'53.97"	Rocks
	S3	Jamal	35°11'23.18"	33°15'56.25"	Rock
	S4	Jamal	35°11'31.62"	33°15'36.50"	Rocks
	S5	Jamal	35°11'24.13"	33°15'36.09"	Rocks
	S6	Jamal	35°11'24.04"	33°15'46.08"	Rocks
	S1	Jamal Deep	35°11'13.24"	33°15'54.91"	Rocks
	S2	Jamal Deep	35°11'13.05"	33°15'45.01"	Rocks
	S3	Jamal Deep	35°11'12.72"	33°15'49.20"	Rocks
	S1	Qasmieh Springs	35°11'19.39"	33°19'57.89"	Rocks
	S2	Qasmieh Springs	35°10'37.41"	33°19'57.89"	Rocks
	S3	Qasmieh Springs	35°11'8.609"	33°19'57.89"	Rocks
	S4	Qasmieh Springs	35°11'5.866"	33°19'56.74"	Rocks
	S5	Qasmieh Springs	35°11'2.599"	33°19'56.74"	Rocks

2017	S6	Qasmieh Springs	35°11'35.68"	33°19'56.74"	Rocks
	S1	Turtle Reef	35°11'40.91"	33°15'12.36"	Rocks
	S2	Turtle Reef	35°11'38.94"	33°15'13.27"	Rocks
	S3	Turtle Reef	35°11'45.87"	33°15'14.79"	Rocks
	S1	Zire	35°11'50.20"	33°17'0.848"	Rocks
	S2	Zire	35°11'33.76"	33°17'16.23"	Rocks
	S3	Zire	35°11'38.94"	33°17'8.952"	Rocks
	S4	Zire	35°11'45.87"	33°17'5.467"	Rocks
	S5	Zire	35°11'50.20"	33°17'19.29"	Rocks
	S6	Zire	35°11'33.76"	33°16'51.98"	Rocks
2020	1		33°16.418'	35°10.909'	Flat rocky substrate
	2		33°15.678'	35°11.050'	Irregular rocks, pebbles and coarse sand
	3		33°15.589'	35°11.848'	Coarse sand with rhodoliths
	4		33°15.433'	35°11.803'	Coarse sand with rhodoliths
	5		33°15.247'	35°11.043'	Rocky substrate with boulders and sand
	6		33°15.142'	35°11.002'	Rocky substrate with boulders and sand
	7		33°15.252'	35°10.834	Rocky substrate with boulders and sand
	8		33°15.198'	35°11.635'	Sandy substrate
	9		33°15.762'	35°11.529'	Rocky with boulders, cobbles and coarse sand
	10		33°16.000'	35°11.565'	Rocky and coarse sand (supra to shallow infralittoral)
	11		33°15.924'	35°12.184'	Sandy beach, with coarse sand (supra and midlittoral)
	12		33°15.332'	35°12.658'	Sandy beach (supra and midlittoral)
	13		33°14.973'	35°12.725'	Sandy beach (supra and midlittoral)
	14		33°15.141'	35°12.812'	Sandy beach (sand dunes with halophytes)
	15		33°13.840'	35°12.871'	Freshwater pond of Ras el Ain
	16		33°13.516'	35°12.640'	Coarse sandy substrate with rocks (supra to shallow infralittoral)

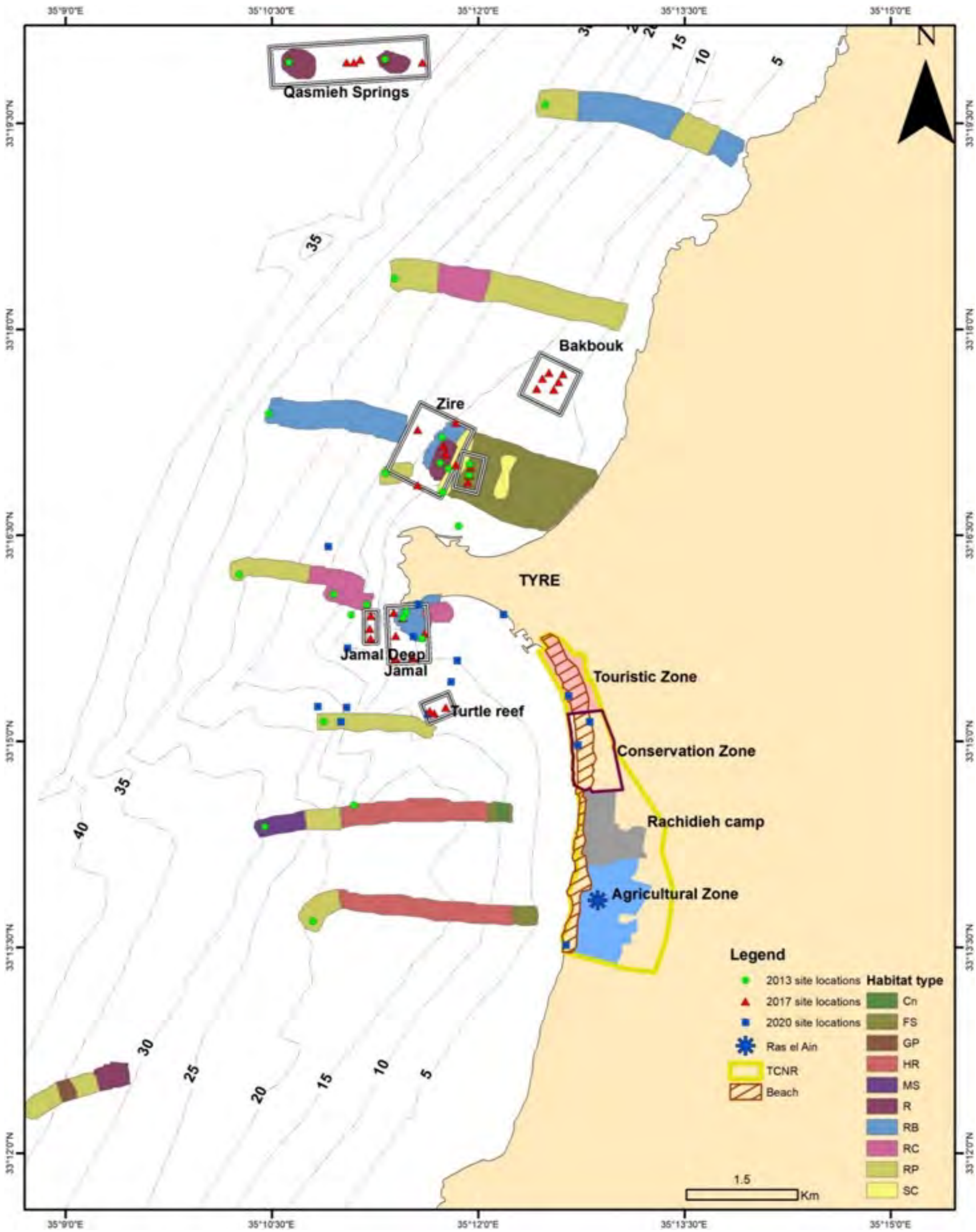

Figure 3: Map of the Tyre region, showing the locations of the prospected sites in the 2013, 2017 and 2020 missions, including the bionomical mapping based on the RAC/SPA - UNEP/MAP (2014), as well as the Protected Area Profile for TCNR zones from the World Database of Protected Areas (UNEP-WCMC and IUCN 2020).

(Cn) *Cymodocea nodosa* meadow; (FS) fine sand; (GP) gravel and pebbles; (HR) high rocky outcrops; (MS) muddy sand; (R) rock; (RB) rock and boulders; (RC) rock and coarse sand-gravel channels; (RP) rock and pebbles; (SC) sand and cobbles.

B. Methods

The seabed was surveyed by boat using a trawled hydroplane and towed divers in 2013. The divers were dragged along transects and recorded their observations on plastic plates and used an underwater camera. The marine habitats encountered were characterized following the classification of marine habitats in UNEP/MAP (1998) and UNEP/MAP-RAC/SPA (2002). In the surveys of 2017 and 2020, the seabed was categorized using scuba diving and underwater photographs (Table 4). The percentage algal coverage was assessed using quadrats (50 x 50 cm) placed along 50 m transects in 2017. Some macroscopically unidentifiable marine organisms were collected as vouchers for an accurate identification.

Visual fish censuses were done through diving in all three surveys (2013, 2017 and 2020). Fish assemblages were assessed following strip transects (50 x 4 m and 25 x 5 m for 2013 and 2017, respectively), as per the methodology of Harmelin-Vivien et al. (1985). In the 2020 survey, fish assemblages were only observed underwater, without quantification (Figures 4, 5, 6).

The supralittoral and midlittoral of the TCNR were surveyed in 2020, early in the morning at low tide. In each site, the surveyor walked and explored various microhabitats present on both soft and hard bottoms. Encountered organisms were recorded and some specimens were collected, as per bankside counts methodology developed in the Protocols for Invasive Alien Species Monitoring in the Marine Environment of Lebanon (IUCN-SPA/RAC, 2017 unpublished). Along the vermetid platforms, particular attention was given to searching for populations of living vermetid snails (*Dendropoma anguliferum, Vermetus triquetrus*), as well as the associated calcareous encrusting algae (*Neogoniolithon brassica-florida*). On soft bottoms, the main focus was on visible organisms (e.g. halophytes, ghost crabs, empty shells).

Supplementary oceanographic information was acquired from the vicinity of Tyre (Nakoura and Qasmieh) and resulted in producing hydrological profiles (0-200 m depth) for the two sites in 2013, situated north and south of the studied region.

Table 4: Research activities of 2013 and 2017 missions in Tyre (Number of dives in brackets).

Mission	2013	2017	2020
Depth range (m)	0-47 m	1.5-47 m	0-30 m
Hydroplane transects	9 (9 dives)	-	-
Scuba diving plots	13 (38 dives)	39 (52 dives)	9 (16 dives)
Fish visual census	7 (12 dives)	During the dives	During the dives
On foot census	-	-	7
Total sites	28	39	16

C. Physical characteristics

1. Geomorphology:

The continental shelf in Tyre is not very steep, reportedly having littoral sandstone reefs with a wide abrasion platform. In the northern part of Tyre, flat rocks, detritic channels, high rocky massifs and big blocks exist from shallow waters down to about 20 m depth. Rocky bottoms and coarse sand bottoms are common. In *Jamal*, low and smooth flat rocks are present. High irregular rocks are observed in *Zire, Turtle Reef* and *Qasmieh Springs*. Cobbles with rhodoliths are abundant in some places situated at about 9-10 m depth, such as in East Zire. A soft bottom is present in the lagoon between the rocky reefs and the northern Tyre beach and flat rocks are present in its southern part. In *Bakbouk, Jamal Deep* and *Zire*, low and irregular flat rocks with shell gravel coarse sand channels are dominant. Fine sand is situated between the surface about 16 m depth off Rachidieh, and muddy sand bottoms are also very common down from 27 m depth (Figure 3; Table 3).

Figure 4: Photographs during the survey with the use of an underwater scooter.

Figure 5: Underwater survey of the different habitats present within the TCNR.

Figure 6: Photographs from the survey of different habitats.
All habitats available within the TCNR were surveyed, sampled and photos were taken.

Figure 7: Underwater view of the TCNR with the Dusky spinefoot *Siganus luridus* and Painted grouper *Serranus cabrilla*.

2. Hydrology:

In the region, the temperature profiles measured in September 2013 were relatively similar between the surface and 40 m depth in Nakoura and Qasmieh, about 28-29°C (Figure 8). The main thermocline was located between 50-80 m depth (20-28°C) and dropped below 18°C from 110-200 m depth in September 2013. The salinity ranged from 38.41-39.15.

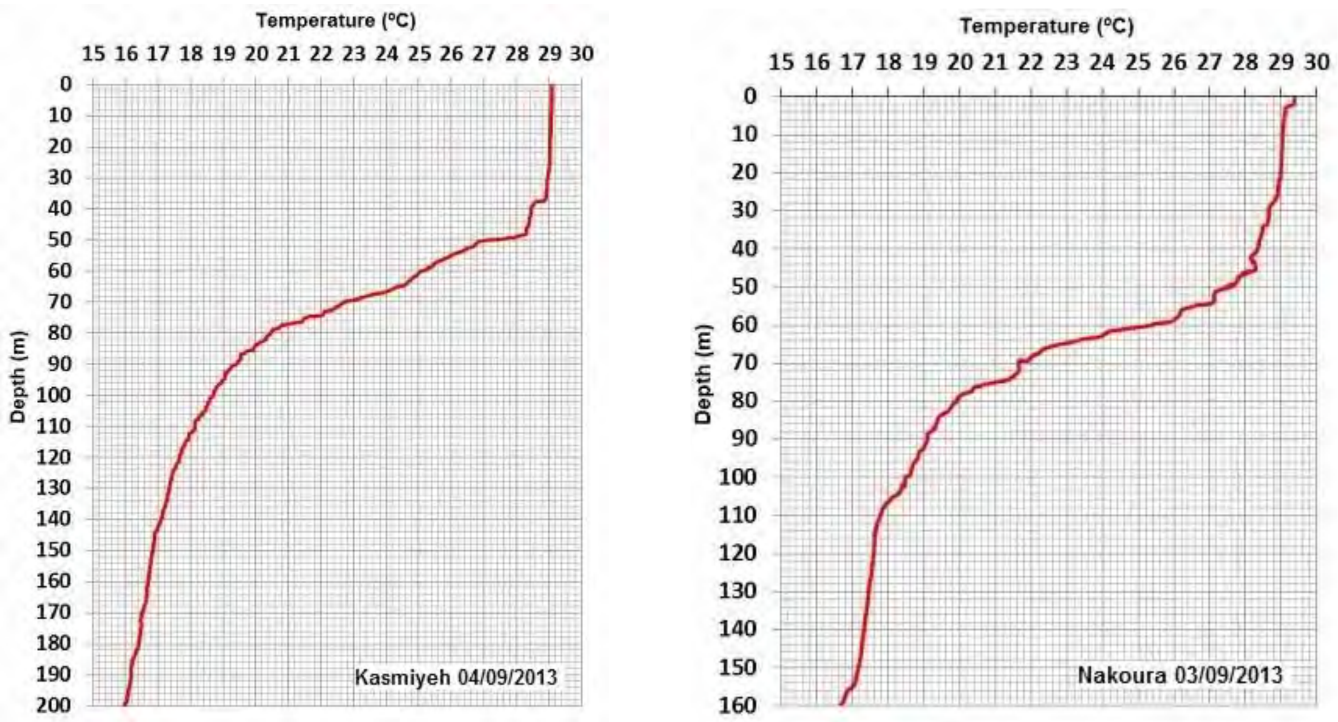

Figure 8: Temperature profiles in Nakoura and Qasmieh.
Credit: RAC/SPA - UNEP/MAP (2013)

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RESULTS

A. Benthic communities and habitats found in the TCNR region

1. Soft bottom communities of the supralittoral and midlittoral

a) Biocenosis of the supralittoral sands

This zone comprises the sandy upper beach lying along the coast of the reserve (Figure 9). It is composed of fine sand with dispersed debris. The Tufted ghost crab *Ocypode cursor* is present; juveniles and adults scavenge in this area. Ghost crab burrows are common in the supralittoral, as well as on the sand dunes situated more inland. This area is also important for sea turtle nesting for two species, the Loggerhead sea turtle (*Caretta caretta*) and the Green sea turtle (*Chelonia mydas*), recorded in the area (SPA/RAC-UNEP/MAP, 2020). The supralittoral is used by hatchlings of those endangered sea turtles to reach the marine environment. Among other encountered organisms were the Yellow-legged gull (*Larus michahellis*) hovering for food and empty shells of various snails and bivalves (e.g. *Acanthocardia tuberculata, Glycymeris nummaria*) washed onshore. This zone is also home to several terrestrial halophytes, such as the Sea daffodil (*Pancratium maritimum*), the Sea holly (*Eryngium maritimum*) and the Narrow-leaved bugloss (*Echium angustifolium*) (Figure 10).

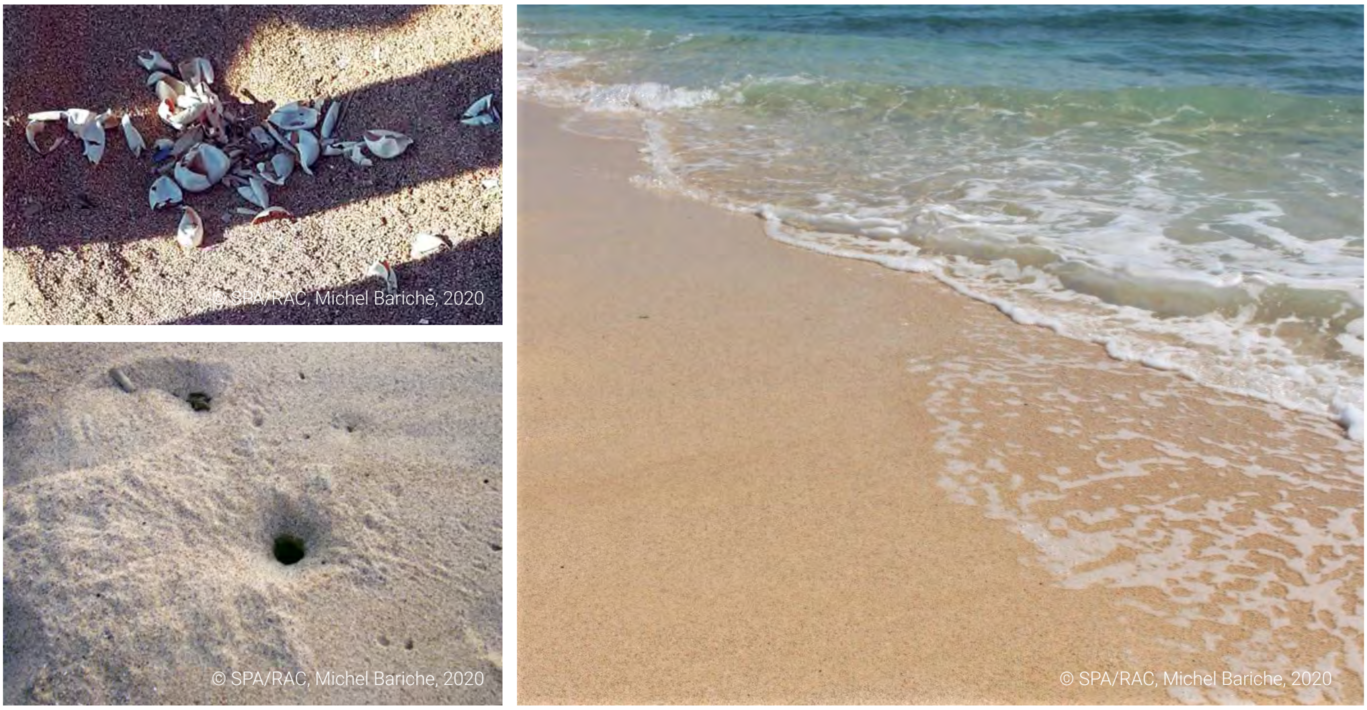


Figure 9: Sandy habitat of the supralittoral zone showing sea turtle eggshells and ghost crab burrows.

Figure 10: Some of the most common halophytes present on the sandy beach of the TCNR.The Sea daffodil *Pancratium maritimum*, the Sea holly *Eryngium maritimum* and the Narrow-leaved bugloss *Echium angustifolium*.

b) Biocenosis of the midlittoral sands

The midlittoral is similar to the soft supralittoral zone along the sandy beach of the reserve (Figure 11). It is not a clearly identified biocenosis as in many regions of the World. It is characterized by fine and coarse sand, with shell gravel, some debris and no vegetation. The number of marine organisms is low and is mainly composed of meiofauna (<1 mm), such as polychaetes, mysids and isopods. Among the visible organisms were the Slender swimcrab (*Portumnus latipes*) and the non-indigenous Common moon crab (*Matuta victor*). The Tufted ghost crab (*Ocypode cursor*) also uses this area on its way to the shallow infralittoral. Other organisms are juveniles of seabreams (*Diplodus sargus, Lithognathus mormyrus*) and the non-indigenous Suez whiting (*Sillago suezensis*). Various empty bivalves (e.g. *Glycymeris glycymeris, Donax trunculus, Venus verrucosa, Gafrarium pectinatum, Peronaea planata*) are also found washed onshore.

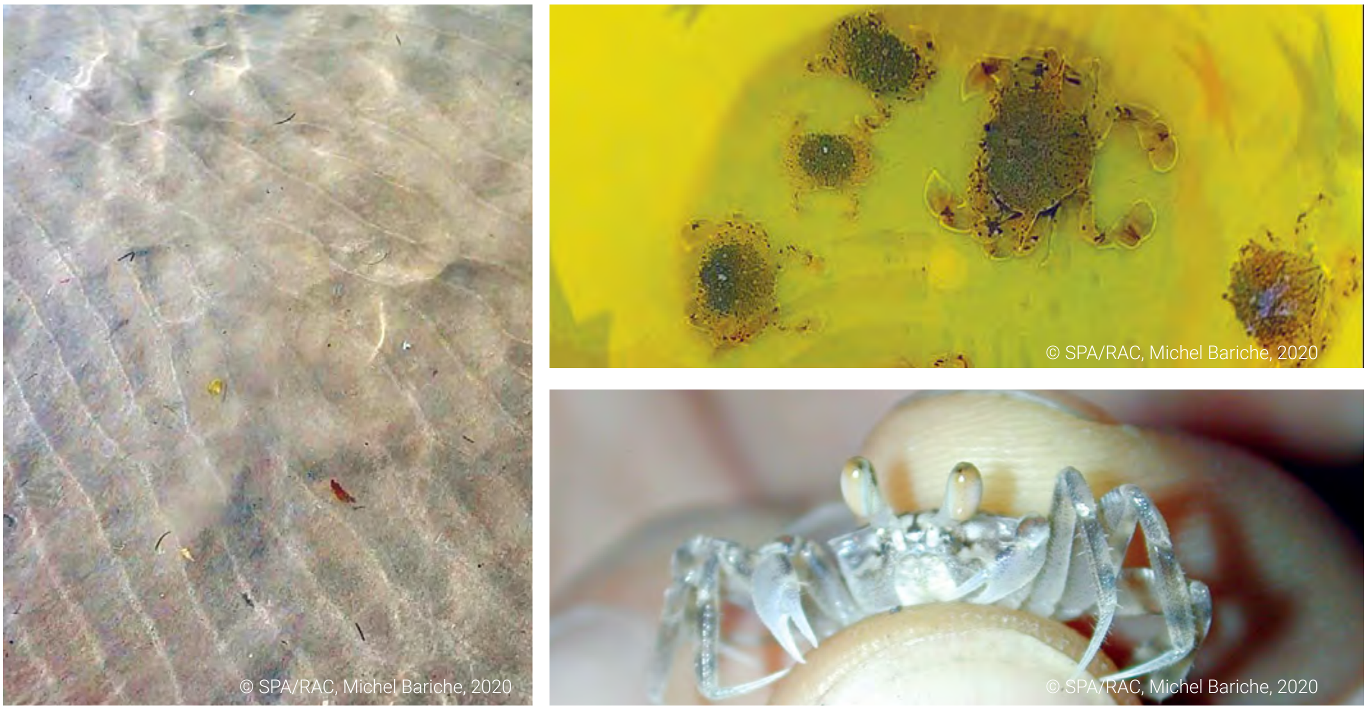


Figure 11: Sandy habitat of the midittoral zone showing
the invasive moon crab *Matuta victor* and a juvenile ghost crab (*Ocypode cursor*).

2. Soft bottom communities of the infralittoral and circalittoral

a) Biocenosis of coarse sand and gravels

This zone is under the influence of waves and local currents (Figure 12). It is a relatively large area that may extend down to the circalittoral in some places (6-45 m depth). Marine organisms are not very diverse and are mainly constituted of shells such as the non-indigenous snail *Conomurex persicus*, as well as bivalves (e.g. *Venus verrucosa*), the serpulid (*Ditrupa arietina*), the hermit crab (*Diogenes pugilator*) and sea urchins (*Brissus unicolor*). Among the fish species, the Pearly razorfish (*Xyrichthys novacula*) and some species of unidentified gobies (*Gobius bucchichi, Gobius* spp.) are common. Among other organisms that may be encountered are stingrays (*Taeniurops grabata, Dasyatis pastinaca*), the Yellowspotted puffer *Torquigener flavimaculosus* and empty shells of various snails and bivalves (e.g. *Acanthocardia tuberculata*) washed onshore.

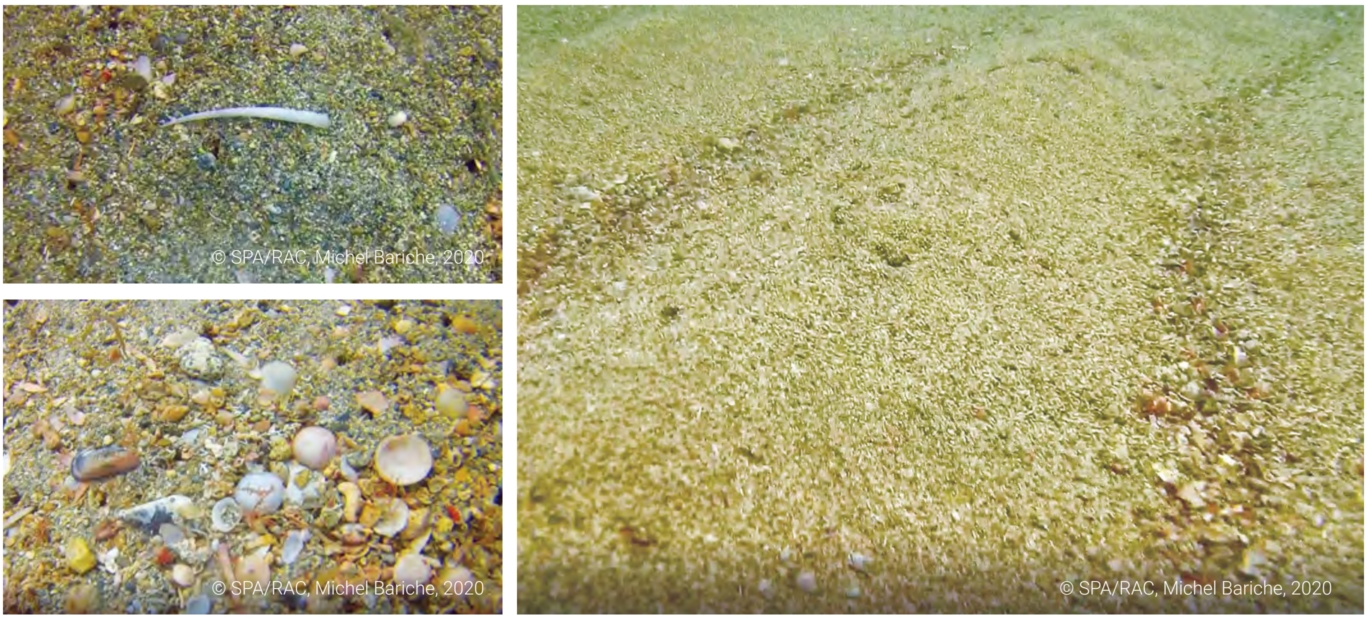


Figure 12: Coarse sand and gravel habitat of the infralittoral zone showing shells of various snails and bivalves,
and the serpulid *Ditrupa arietina*.

b) Biocenosis of the muddy sand with *Cymodocea nodosa*

A small zone has been spotted with irregular patches of the Little Neptune grass *C. nodosa* and seems to be highly disturbed. Marine organisms are not very diverse and are mainly composed of shells of the exotic snail *Conomurex persicus*, as well as bivalves (*Glycimeris insubrica, Mactra stultorum*) and the heart urchin *Brissus unicolor*. Among the fish species, *Pteragogus trispilus*, *Xyrichthys novacula* and *Gobius* spp. were observed (Figure 13). Other organisms encountered were the non-indigenous *Halophila stipulacea, Acanthocardia tuberculata, Glycymeris insubrica, Bursatella leachi* and empty shells of various snails and bivalves. It has been noted that the presence of *C. nodosa* seems to be very rare in the area, as a single small patch has been previously observed in the middle of the TCNR, off the Rachidieh camp at 31 m depth.

Figure 13: Muddy sand habitat of the infralittoral zone showing a Pearly razorfish *Xyrichthys novacula* and the test of the heart urchin *Brissus unicolor.*

c) Biocenosis of the maërl beds

The community present in this relatively rare habitat in the Mediterranean Sea is part of the biocenosis of coarse sands and gravels, also under the influence of currents, but is treated separately because of its originality (Figure 14). The bottom is easily recognized due to the presence of free living rhodoliths, mainly of the coralline algae *Neogoniolithon brassica-florida*. The rhodoliths are of various sizes, found lying on coarse sediment with shell gravel and other coarse materials. The maërl bed constitutes a significant part of the TCNR soft bottom, between 6 and 10 m depth. The most prominent marine organisms present there are seaweeds (e.g. *Cystoseira, Lithophyllum*, *Dictyota*, *Amphiroa, Lobophora*), sponges (*Crambe crambe*), hydroids (*Pennaria disticha, Macrorhynchia philippina*), and scattered bivalves (e.g. *Pinctada imbricata radiata, Spondylus spinosus, Chama pacifica, Malleus regula*). Among the fish species encountered, *Siganus rivulatus*, *Torquigener flavimaculosus*, and *Gobius* spp. were common. Other organisms that may be encountered are *Caulerpa scalpelliformis*, *Conomurex persicus, Pinna nobilis* (dead), *Synaptula reciprocans* and empty shells of various snails and bivalves (e.g. *Acanthocardia tuberculata*). The region also represents a nursery area for some fish of commercial importance such as groupers (*Mycteroperca rubra, Epinephelus costae*).

In the circalittoral, a deep rhodolith bed (circalittoral maërl beds) has also been reported between 32-45 m depth. The bottom is composed by coarse sand loaded with shell gravel. The most common rhodoliths present are *Lithothamnion corallioides* and *Mesophyllum* sp.. The non-indigenous seaweed *Caulerpa scapelliformis* has also been reported. Epifauna is scarce in this region, as very few species have been reported (e.g. *Conomurex persicus*, *Synaptula reciprocans*).

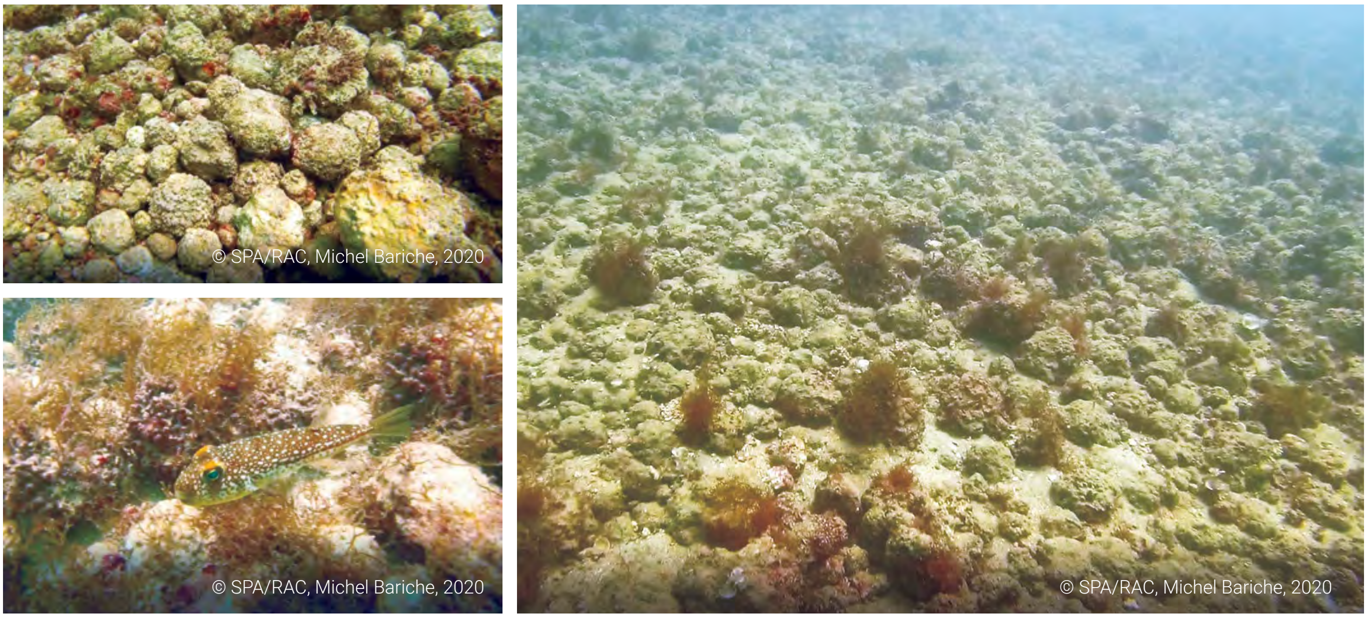


Figure 14: Maërl bed habitat with free living rhodoliths of various sizes and the invasive Yellowspotted puffer *Torquigener flavimaculosus*.

3. Hard bottom communities of the supralittoral and midittoral

a) Biocenosis of the supralittoral rock

This community is characterized by the presence of specialized endolithic cyanobacteria (*Entophysalis deusta*) living in cracks inside the rocks, as well as the lichen *Verrucaria amphibia* found in sporadic patches. The Rock lice (*Ligia italica*) and two periwinckles (*Melarhaphe neritoides, Echinolittorina punctata*) are relatively common on the rocks (Figure 15). The rock crabs *Pachygrapsus marmoratus* and *P. transversus* may also be visible at this level. Among the other organisms that may be encountered is the relatively rare barnacle *Euraphia depressa*. Small patches of crystallized salt, resulting from evaporated seawater that was trapped in small crevices, is sometimes found in this zone as well. This biocenosis has been referred to as **Association with *Entophysalis deusta* and *Verrucaria* spp.**, due to the prevalence of those species.

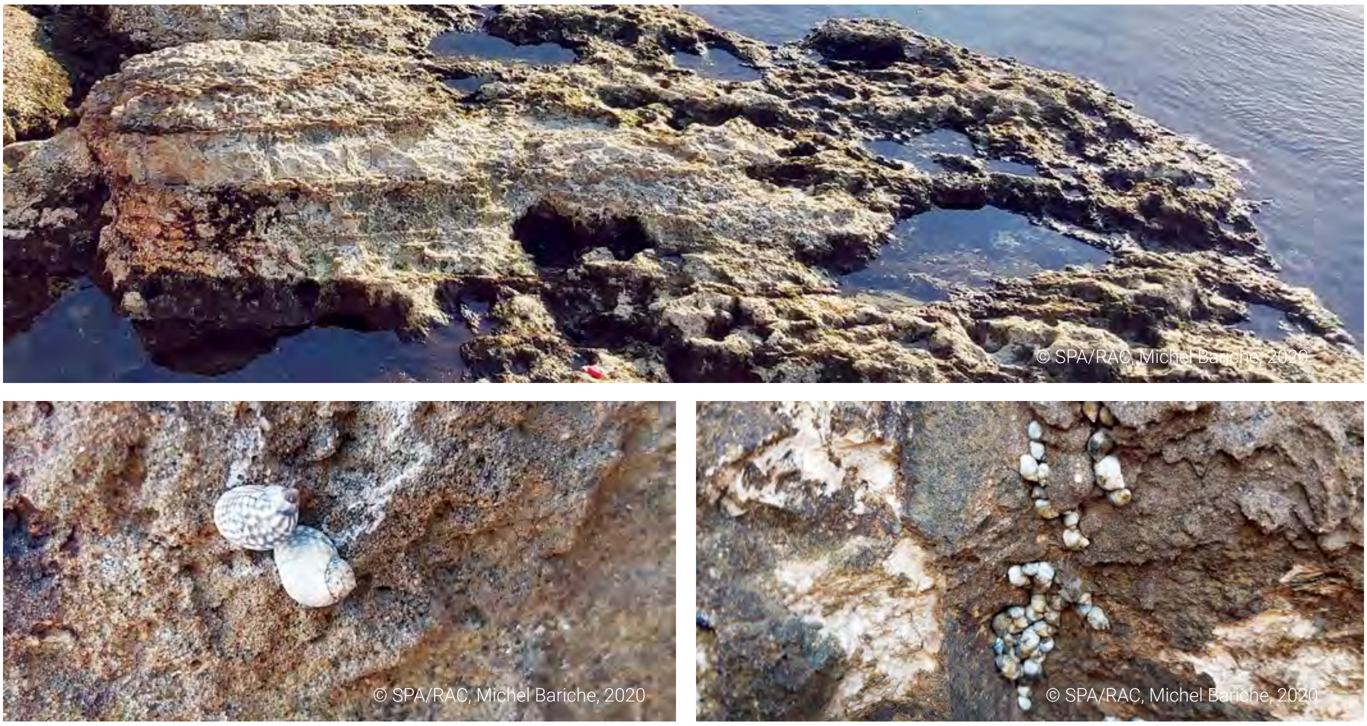


Figure 15: Supralittoral habitat showing the two characteristic periwinkles *Melarhaphe neritoides* and *Echinolittorina punctata.*

b) Biocenoses of the midlittoral rock

The upper parts of vermetid reefs constitute the rocky midlittoral. These reefs are widespread along the Lebanese coast and are situated in the northern part of the TCNR. This midlittoral zone may be divided into two entities:

The upper midlittoral rock is a habitat with a restricted period of immersion (Figure 16). It is characterized by the presence of the two barnacles *Microeuraphia depressa* and *C. montagui*, forming visible belts along the zone. Limpets (*Patella rustica*) and the shore crabs *Pachygrapsus marmoratus* and *P. transversus* are also relatively common. The two periwinkles, *Melarhaphe neritoides* and *Echinolittorina punctata*, may also be found here but are less common. Other organisms that may be encountered are: *Lithophyllum papillosum, Nemalion helmintoides, Patella ulyssiponensis* and *Ligia italica*. This biocenosis has been earlier referred to as **Facies with *Microeuraphia depressa*** because of the prevalence of the barnacle.

Figure 16: Upper midlittoral habitat characterized by the presence of barnacles, limpets, as well as the shore crab *Pachygrapsus transversus.*

The lower midlittoral rock is a habitat that is characterized by a higher period of immersion in seawater (Figure 17). The most common species are the vermetid snails, *Vermetus triquetrus* and *Dendropoma anguliferum*. While *V. triquetrus* is mainly present in small patches on the inner side of the reef, probably tolerating a higher emersion time, *D. anguliferum* is mainly found on the outer side, exposed to wave action. This habitat is also often associated with the calcareous encrusting red algae *Neogoniolithon brassica-marina*. Another calcareous red alga *Lithophyllum papillosum* can also be widely present over wide patches of the reef. Snails (e.g. *Phorcus turbinatus, Patella ulyssiponensis*), the chiton (*Rhyssoplax olicacea*), the barnacle *Microeuraphia depressa* and shore crabs (*Pachygrapsus marmoratus* and *P. transversus*) are also relatively common. The sea tomato *Actinia mediterranea* can be found in sheltered areas within this zone as well. Other species that may be encountered are *Palisada perforata, Jania rubens, Parablennius incognitus, Coryphoblennius galerita, Gobius cobitis*. It has been noted that many patches of vermetids were dead.

Figure 17: Lower midlittoral habitat characterized by the presence of vermetid snails (mainly *Dendropoma anguliferum*) and the calcareous red alga *Neogoniolithhon brassica-marina*. The relatively common sea tomato *Actinia mediterranea*. The non-indigenous seaweed *Palisada perforata* and the native snail *Phorcus turbinatus*.

The most recognizable associations and facies within the lower midlittoral rock community are the following: ***Dendropoma* and *Neogoniolithon* concretions; Association with *Lithophyllum papillosum***, as well as the shallow **tidal pools (cuvettes)** found on the vermetid reefs, which constitute an infralittoral enclave. They are usually dominated by macroalgae found in the infralittoral such as *Dictyota fasciola, Padina boergesenii, Jania rubens, Hypnea* spp., *Ulva* spp. *Chaetomorpha* spp., and other coralline algae.

c) Biocenoses of infralittoral macroalgae

The infralittoral hard bottom harbours several macroalgae communities and numerous associations, mainly characterized by light intensity and wave exposure. The area may reach a depth of up to 40 m.

(1) Exposed photophilic macroalgae community

This zone extends down to 6-8 m depth, where different associations and facies are found (Figure 18). Among the most characteristic species are macroalgae (*Jania rubens, Cystoseira compressa, Sargassum vulgare*), sponges (*Cliona parenzani, Crambe crambe, Chondrilla nucula, Chondrosia reniformis*), hydrozoans (*Pennaria disticha, Macrorhynchia philippina*), ascidian *Phallusia nigra*, bryozoan *Schizoporella errata*, snails (*Cerithium scabridum, Conomurex persicus*), barnacles (*Perforatus perforatus, Balanus trigonus*), the crab *Eriphia verrucosa*, hermit crab *Clibanarius erythropus*, sea cucumber *Holothuria forskali*, and several teleosts (*Thalassoma pavo, Siganus rivulatus, Diplodus vulgaris, Mullus surmuletus*, blennies and gobies). The two sea urchins *Paracentrotus lividus* and *Arbacia lixula*, which are characteristic of this habitat, have almost completely disappeared from this community.

The most recognizable associations and facies within this community are the following: **Associations with *Jania rubens***, where the species is very common in some shallow areas (<1m) and is mixed with *Ellisolandia elongata, Palisada perforata, Cladophora* spp. and *Laurencia obtusa*. **Associations with *Sargassum vulgare* and *Cystoseira compressa***, where the two species can be found in large patches in some calm areas (<2m) along with other common species, such as *Palisada perforata* and *Jania rubens*. **Facies with hydroids** show a clear dominance of the two hydroids *Pennaria disticha* and the non-indigenous *Macrorhynchia philippina*. **Facies with *Brachidontes pharaonis*** where the non-indigenous mussel is very abundant and forms a belt starting from the lower midlittoral, may constitute a wide patch. It is found with the green algae *Chaetomorpha* spp. and *Ulva* spp.

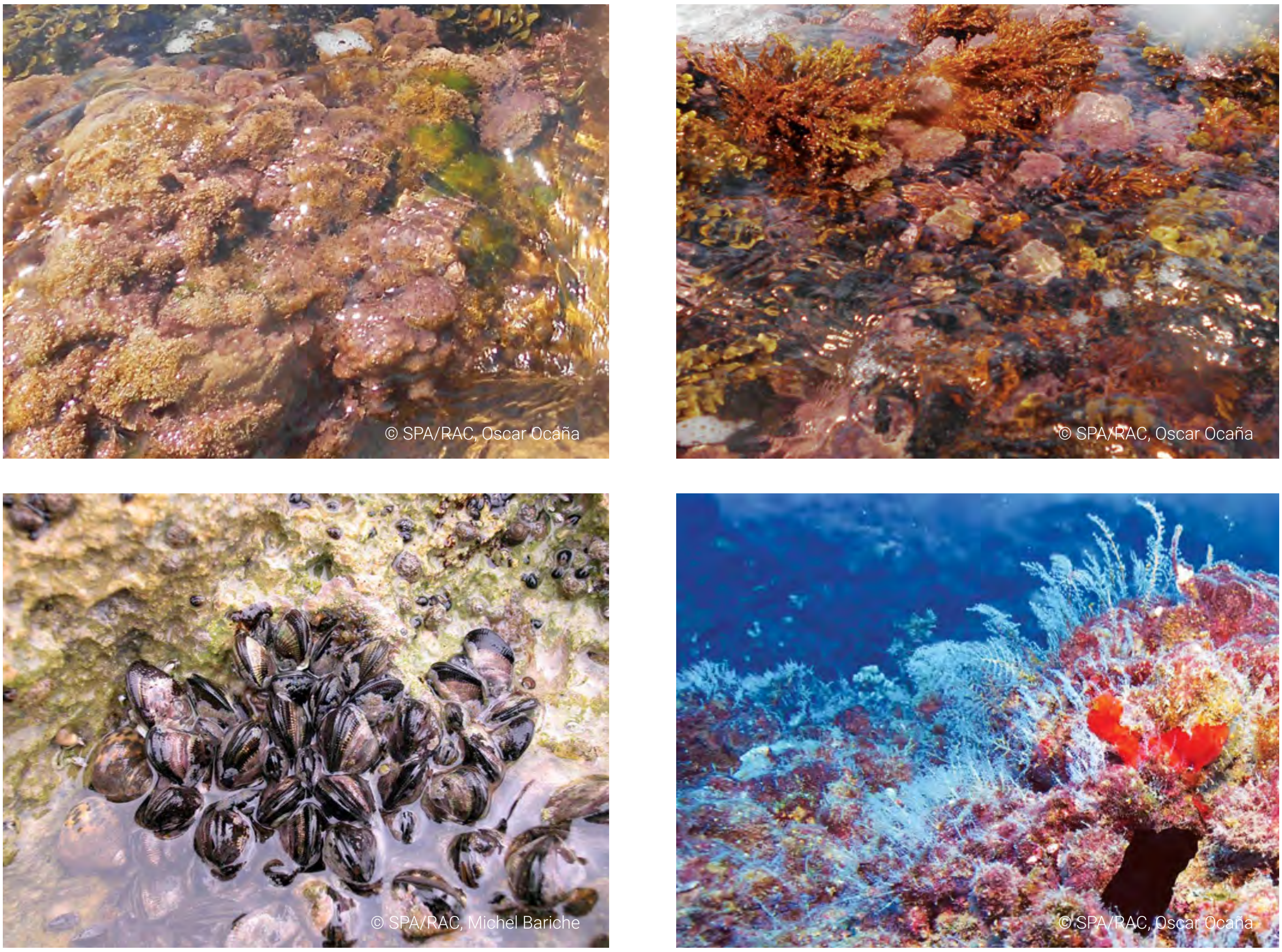


Figure 18: Infralittoral habitats with exposed photophilic macroalgae communities: *Jania rubens* with *Cladophora sp*.; Association with *Sargassum vulgare* and *Cystoseira compressa*, with *J. rubens*; Cluster of non-indigenous mussel (*Brachidontes pharaonis*) in the lower midlittoral; Facies with hydroid (*Pennaria disticha*).

(2) Exposed sciaphilic macroalgae community

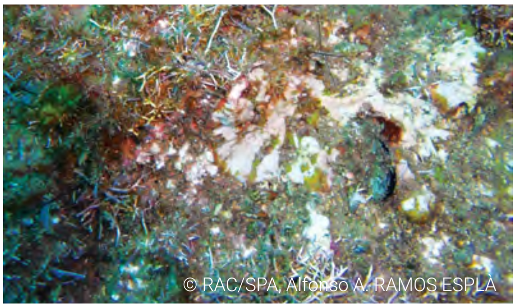
The community of sciaphilic macroalgae is present on vertical rocks, down to 6-8 m depth (Figure 19). Among the most characteristic species are macroalgae (e.g. *Ellisolandia elongata, Plocamium cartilagineum*), sponges (*Crambe crambe, Chondrosia reniformis, Phorbas topsenti, Chondrilla nucula*), hydrozoans (*Pennaria disticha, Macrorhynchia philippina*), ascidians (*Herdmania momus, Phallusia nigra*), colonial tunicates (*Didemnidae*), bryozoans (*Schizoporella sanguinea, Schizoporella errata*), the snail *Ergalatax junionae*, bivalves (*Chama pacifica, Spondylus spinosus, Malleus regula*), the polychaete *Hermodice carunculata*, crabs (*Charybdis helleri, Atergatis roseus*), the hermit crab *Calcinus tubularis* and teleosts (*Scorpaena maderensis, Sargocentron rubrum, Pterois miles, Mycteroperca rubra*). This biocenosis has been referred to as an **Association with *Ellisolandia elongata***, due to the prevalence of the species. No other association or facies within this community has been identified in the region.

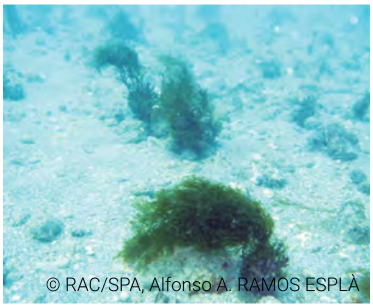
Figure 19: Infralittoral habitats with exposed sciaphilic macroalgae communities:
Association with *Ellisolandia elongata*, with the sponges (*Crambe crambe, Phorbas topsenti*) and some hydroids.

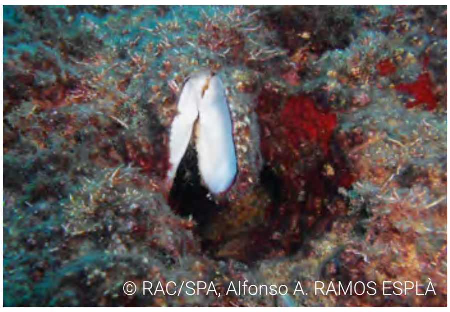
(3) Sheltered photophilic macroalgae

The depth range of the community living in this zone is mainly related to the light intensity and water circulation (Figure 20). This area may extend from 5 m down to 25 m or more. The upper part is characterized by the presence of erect macroalgae (e.g. *Galaxaura rugosa, Jania rubens, Jania longifurca, Halopteris scoparia, Padina* spp., *Colpomenia sinuosa, Dictyota dichotoma, Codium parvulum*) and encrusting seaweeds (*Lithophyllum incrustans* and *Neogoniolithon mamillosum*) in the deeper areas. Sponges (*Petrosia ficiformis, Aplysina aerophoba, Niphates toxifera, Ircinia* spp. *Sarcotragus* spp., *Crambe crambe, Phorbas topsenti, P. tenacior, Cliona* spp.), sea anemones (*Anemonia viridis, Aiptasia mutabilis*), polychaetes (*Hermodice carunculata*), snails (*Ergalatax junionae, Cerithium scabridum, Conomurex persicus, Marmorofusus verrucosus*), bivalves (*Chama pacifica, Spondylus spinosus, Pinctada imbricata, Malleus regula*), barnacles (*Perforatus perforatus, Balanus trigonus*), bryozoans (*Schizoporella errata*), the sea cucumber *Synaptula reciprocans* and ascidians (*Phallusia nigra, Herdmania momus, Didemnidae* spp.) and fishes (*Chromis chromis, Diplodus* spp., *Serranus* spp., *Coris julis, Scorpaena maderensis,* various gobies) are common.

The most recognizable associations and facies within this community are the following: **Association with *Halopteris scoparia*** found exclusively in the islets situated in the north of the TCNR. **Associations with erect Corallinales**, comprising a large area situated in the rocky areas down to 15 m. **Facies with *Chama pacifica* and *Spondylus spinosus***, where the two bivalves are very common between 5 and 25 m. In these dense areas, their shells constitute a hard substratum on which various organisms grow such as seaweeds, serpulids, worms, barnacles, hydrozoans, and bryozoans. **Associations with *Cystoseira* spp.** or **Associations with *Galaxaura rugosa* and *Laurencia* spp.** are found in some shallow water areas. **Associations with *Codium parvulum*** are present in shallow degraded areas where there are sediment deposits on rocky bottoms. Usually, the seaweed *Amphiroa rigida* and ascidian *Phallusia nigra* are also present in this association. **Naked rocks** are barren rocky areas that lack erected macroalgae because of overgrazing, most likely by the non-indigenous herbivorous fish *Siganus rivulatus*. Although rare, the macrofauna comprises some encrusting corallinales (*Lithophyllum incrustans* and *Neogoniolithon* spp.), as well as sponges (e.g. *Crambe crambe, Cliona* spp.), bryozoans (e.g. *Schizoporella errata*), barnacles (e.g. *Perforatus perforatus, Balanus trigonus*), in addition to the ascidian *Phallusia nigra*.







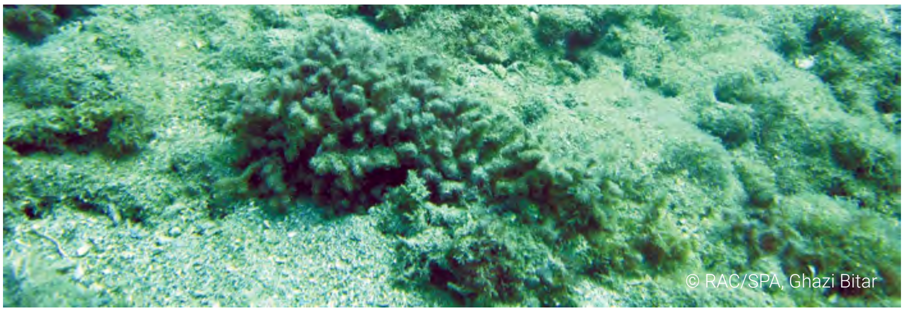


Figure 20: Infralittoral habitats with sheltred photophilic macroalgae communities:
Association with *Codium parvulum*; Association with erect Corallinales; Association with *Cytoseira* sp.;
Facies with *Chama pacifica* and *Spondylus spinosus*; Association with *Galaxaura rugosa* and *Laurencia* spp.

(4) Sheltered sciaphilic macroalgae community

The sciaphilic macroalgae community, considered to be well developed, is found in shallow sheltered areas (crevices, overhangs), as well as in deeper areas (>25 m) of the rocky infralitoral (Figure 21). *Peysonnelia* spp. constitute its main component. The sheltered sciaphilic community is characterized by the presence of macroalgae (*Peyssonnelia squamaria, P. rubra, Mesophyllum* spp., *Neogoniolithon* spp.), sponges (e.g. *Crambe crambe, Chondrosia reniformis, Petrosia ficiformis, Ircinia* spp., *Axinella polypoides, Cymbaxinella* sp.) which are relatively common, ascidians (*Phallusia nigra, Herdmania momus, Didemnidae* spp.), the polychaete *Hermodice carunculata*, crabs (*Atergatis roseus, Charybdis helleri*), and the hermit crab *Calcinus tubularis*. This is also a habitat of sea cucumbers such as *Holothuria* (*Panningothuria*) *forskali* and *H. sanctori*. The fish fauna is mainly characterized by *Tripterygion tripteronotum, Sargocentron rubrum, Pempheris rhomboidea, Scorpaena maderensis*, and *Apogon imberbis*.

The most recognizable associations within this community are the following: **Association with *Peysonnelia* spp.**, found down to about 35 m in sheltered areas and the **Association with encrusting Corallinales**, found in the deepest part of the infralittoral (25-35 m).

Figure 21: Infralittoral habitats with sheltered sciaphilic macroalgae community:
Association with *Peysonnelia* spp.; Association with encrusting corallinales.

4. Hard bottom communities of the circalittoral

Two types of communities constitute the circalittoral rocky bottoms: the coralligenous and the semi-dark caves. They thrive better on vertical slopes and overhangs, mainly deeper than 30-35 m and can be found on horizontal bottoms starting from 40-45 m depth. The same communities exist in shallow waters (infralittoral) whenever significant crevices, caves and overhangs are present.

a) Biocenosis of the 'coralligenous'

This community is undoubtedly one of the most complex in the Mediterranean Sea. It is often divided into subzones or strata.

The **upper stratum** in Lebanon is characterized by the presence of the sponge *Axinella* spp. and some macroalgae from the lower infralittoral region, such as *Cystoseira dubia*, *Arthrocladia villosa* and *Sporochnus pedunculatus*. **The middle stratum** is characterized by macroalgae, such as rhodophytes (e.g. *Acrosorium sp., Rhodymenia ardissonei, Gigartina* spp., *Halymenia* spp.) and ochrophytes (e.g. *Dictyota dichotoma, Stypopodium schimperi*), as well as sponges (*Agelas oroides, Acanthella acuta, Corticium candelabrum, Cymbaxinella damicornis, Dysidea avara, Haliclona mediterranea, Petrosia ficiformis*), hydrozoans (e.g. *Aglaophenia* spp., *Eudendrium* spp.), anthozoans (*Madracis pharensis, Phyllangia americana mouchezii*), the polychaete *Filograna* sp., and the ascidian *Herdmania momus*. **The lower stratum** is mainly characterized by rhodophytes (e.g. *Lithophyllum stictaeforme, Peyssonnelia* spp.). Sponges are also omnipresent (*Crambe crambe, Haliclona fulva*), as well as some typical bryozoans (*Schizomavella* spp.) and ascidians (*Cystodytes dellechiajei, Didemnidae* spp.). Some mobile fauna of the infralittoral that can be found at any stratum are the polychaete *Hermodice carunculata*, the crab *Pilumnus hirtellus*, and the sea stars *Echinaster sepositus*, *Coscinasterias tenuispina*.

(1) Coralligenous in infralittoral enclaves

Infralittoral enclaves are characterized by the presence of encrusting calcareous algae (e.g. *Mesophyllum alternans, Neogoniolithon mamillosum, Peyssonnelia* spp.), in addition to the chlorophyte *Palmophyllum crassum*. Sponges (e.g. *Crambe crambe, Chondrosia reniformis, Clathrina* spp.), hydrozoans (*Aglaophenia* spp.), bryozoans (*Schizoporella* spp., *Reptadeonella* spp.), and ascidians (*Didemnidae* spp., *Herdmania momus*) are also present. Fishes are represented by *Sargocentrum rubrum, Pempheris rhomboidea, Apogon imberbis* and *Tripterygion melanurum* (Figure 22).

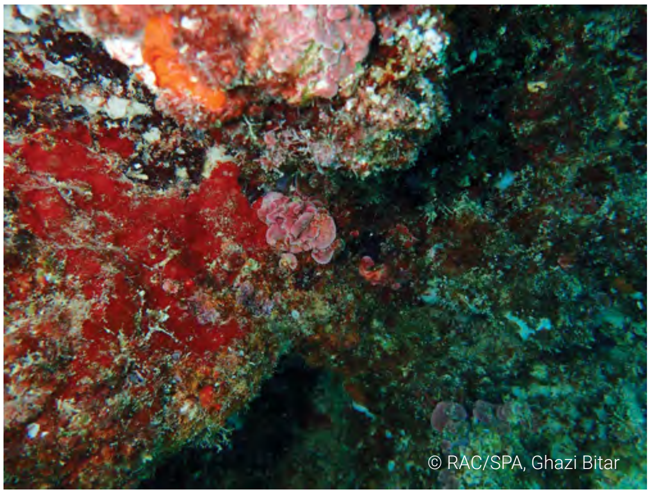


Figure 22: Coralligenous communities in infralittoral enclaves, with encrusting and erect organisms (e.g. sponges, hydroids) and coralline algae.

(2) Coralligenous in circalittoral bottoms

On the circalittoral bottom, commonly present organisms include macroalgae (*Lithophyllum stictiforme, Peyssonnelia* spp., *Mesophyllum alternans*), sponges (*Axinella* spp., *Crambe crambe*), the hydroid *Eudendrium glomeratum*, scleractinians (*Phyllangia americana mouchezii, Madracis pharensis*), and ascidians (*Cystodytes dellechiajei, Didemnidae* spp. and *Herdmania momus*) (Figure 23).

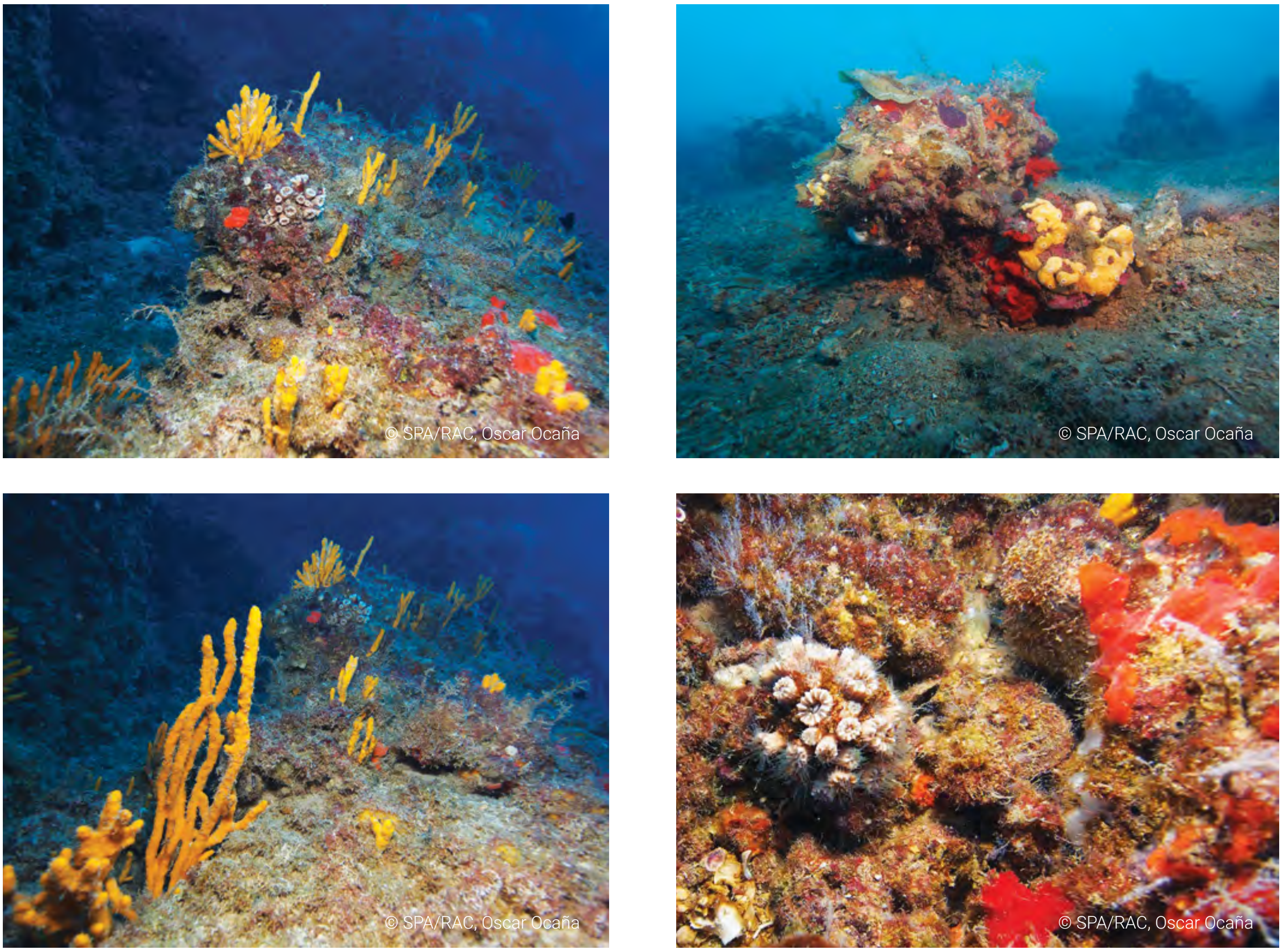


Figure 23: Coralligenous communities in the hard bottoms of the circalittoral characterized by some sponges such as *Axinella polyloides* and *Crambe crambe*, the anthozoan *Phyllangia americana mouchezii* and various ascidians.

b) Biocenosis of the semi-dark caves

When present, marine caves are colonized by a coralligenous community with encrusting algae (e.g. *Peyssonnelia* spp., *Mesophyllum* sp., *Lithophyllum stictiforme*). In more shady areas, sponges (e.g. *Aplysilla* sp., *Chondrosia reniformis, Crambe crambe*), the anthozoan (*Phyllangia americana mouchezii*); and various ascidians (e.g. *Didemnidae* spp., *Cystodytes dellechiajei*) are usually common. Among the fishes, typical species are *Sargocentrum rubrum*, *Pempheris rhomboidea*, *Mycteroperca rubra* and *Epinephelus* spp. (Figure 24).

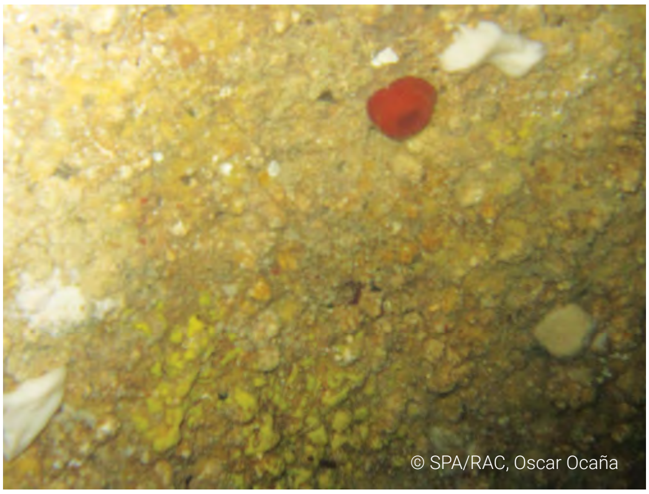


Figure 24: Example of a community found in semi-dark caves, with sponges (*Haliclona fulva, Crambe crambe, Borojevia* cf. *cerebrum, Chondrosia reniformis*), the anthozoan *Phyllangia americana mouchezii* and sea anemone *Actinia mediterranea*.

5. Submarine cold and hot freshwater springs

Some cold and hot underwater freshwater springs are present around the city of Tyre, outside the TCNR. They are regularly mentioned due to their rarity and the specific biota they constitute.

a. Cold water springs: These are located off Ras El Bayada, south of the Tyre region, at 12-15 m depth. Around the springs, red Cyanobacteria dominate, as well as encrusting rhodophytes (mainly *Peyssonnelia* spp. and *Lithophyllum* spp.). Sponges (e.g. *Crambe crambe, Chondrilla nucula, Phorbas topsenti*) are abundant, as well as well as two hydroids (*Macrorhynchia philippina, Pennaria disticha*) and the ascidian *Phallusia fumigata* (Figure 25).

b. Hot water springs: These are located north of the city of Tyre, at 38-42 m depth. They are characterized by the presence of colonies of bacteria (*Beggiatoa* spp.) which are concentrated near the springs' origins. Although dominated by encrusting rhodophytes, very few organisms occur around these zones (Figure 26).

Figure 25: Example of a community found in cold water springs in ras El Bayada, showing *Pennaria disticha, Crambe crambe, Chama pacifica, Phallusia nigra* and *Pannaria* sp.

Figure 26: Example of a community found in hot springs south of the Tyre region, showing bacterial colonies (*Beggiatoa* sp.) and encrusting red algae.

B. Fish assemblages found in the TCNR region

In the April 2017 study, fish assemblages within managed and control locations were updated and compared based on the 2013 inventory (RAC/SPA-UNEP/MAP, 2013; 2014). The data on fish assemblages between the 2013 and 2017 studies are not similar, yet their comparison allows for some general conclusions.

The diversity of fish seems to be high in the Tyre region, as more than 70 fish species have been recorded from the underwater survey, among which about 23% are non-indigenous invasive to the Mediterranean (Figure 27).

The highest species richness (number of species observed) and fish biomass (estimated wet weight per observed species) in the community were found in *Jamal* deep, while the highest fish abundance (number of observed individuals per species) was found in Turtle Reef and *Zire*. The highest economic value was found close to the *Qasmieh* Springs (Figure 3, Table 5). Sea breams (Sparidae) and wrasses (Labridae) were the most observed species and the damselfish *Chromis chromis*, rabbitfish *Siganus rivulatus* and sweeper *Pempheris rhomboidea* were the most abundant. Goatfishes (Mullidae) and Groupers (Serranidae) dominate and have the highest commercial value (Tables 6, 7). It should be noted that the abundance and biomass of the two non-indigenous species, the goatfish *Parupeneus forskali* and Lionfish *Pterois miles*, have significantly increased since the study of 2017. The two species have acquired a significant commercial importance because of their palatability. They add to the 12 highest economically valuable species found in the region.

Table 5: Mean species richness (species/125 m^2), mean total abundance (individuals/125 m^2), mean total biomass (kg/125 m^2) and mean economic value ($/125 m2) (±s.e.) of the fish assemblages observed in the eight sampled localities in the 2017 census.

	Managed areas			Non-Managed areas				
	Jamal	Zire	Jamal Deep	Bayada	Bakbouk	East Zire	Qasmieh	Turtle Reef
Species richness	4.3±0.4	5.5±0.5	7.7±0.7	4.6±0.3	5.3±0.3	2.9±0.5	2.8±0.3	6.1±0.6
Total abundance	65.6±17.7	106.7±22.4	71.5±26.6	87.8±24.3	21.3±3.3	27.5±16.4	11.7±2.2	106.3±34.4
Total biomass	1.3±0.5	1.4±0.2	3.6±2.4	2.9±2.0	1.6±1.2	0.4±0.2	2.2±1.4	0.9±0.2
Economic value	6.5±2.7	6.0±1.0	6.3±1.7	12.9±10.0	1.9±0.4	4.7±2.6	24.4±23.8	9.0±2.6

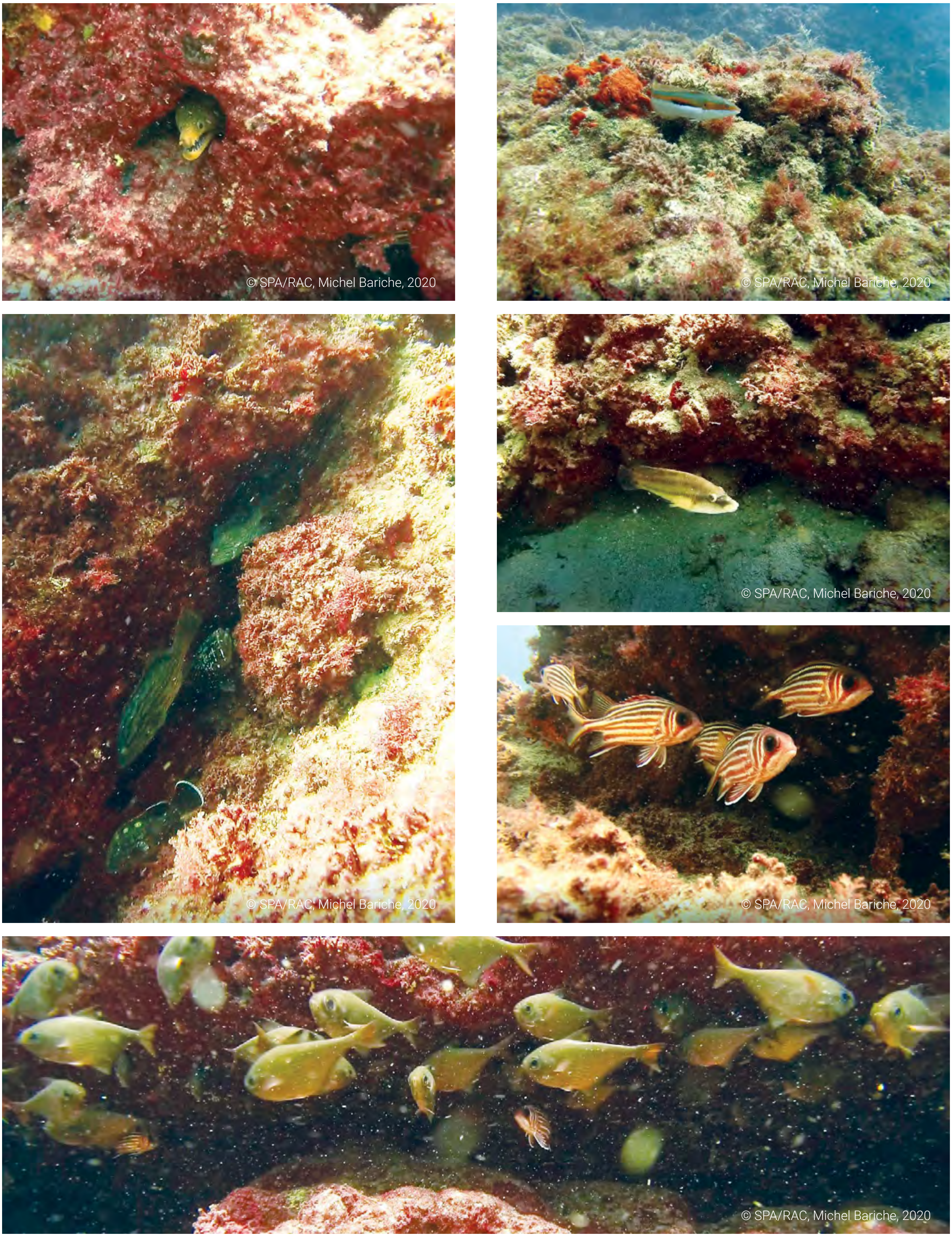


Figure 27: Some of the fish species encountered in the TCNR. The moray eel *Enchelycore anatina*, wrasses (*Coris julis, Symphodus tinca*), groupers (*Mycteroperca rubra, Epinephelus marginatus*), and the invasive fishes *Sargocentron rubrum* and *Pempheris rhomboidea.*

Table 6: Families and fish species observed during the survey of 2017.

Family	Species	Status	SC	TC	Commercial value		Total abundance
					Juvenile	Adult	
Haemulidae	*Pomadasys incisus*	NIS	4	MEC	NC	NC	2
Dasyatidae	*Dasyatis centroura*	N	6	MAC	NC	NC	1
	Dasyatis marmorata	N	6	MAC	NC	NC	1
	Dasyatis pastinaca	N	6	MAC	NC	NC	3
Gobiidae	*Gobius bucchichi*	N	6	MEC	NC	NC	7
Holocentridae	*Sargocentron rubrum*	NIS	6	MEC	NC	NC	146
Labridae	*Coris julis*	N	5	MEC	NC	NC	548
	Labrus viridis	N	5	MEC	NC	NC	1
	Pteragogus pelycus	N	5	MEC	NC	NC	1
	Symphodus doderleini	N	5	MEC	NC	NC	5
	Symphodus mediterraneus	N	5	MEC	NC	NC	1
	Symphodus roissali	N	5	MEC	NC	NC	2
	Symphodus tinca	N	5	MEC	NC	NC	22
	Thalassoma pavo	N	5	MEC	NC	NC	1764
	Xyrichtys novacula	N	5	MEC	9.9	13.2	1
Monacanthidae	*Stephanolepis diaspros*	NIS	5	MEC	NC	NC	20
Mullidae	*Upeneus pori*	NIS	4	MEC	23.1	39.6	1
Muraenidae	*Muraena helena*	N	6	MAC	NC	NC	6
Pempheridae	*Pempheris rhomboidea*	NIS	6	MEC	NC	NC	106
Pomacentridae	*Chromis chromis*	N	2	MIC	NC	NC	6782
Scaridae	*Sparisoma cretense*	N	5	MEC	4.62	9.9	77
Scorpaenidae	*Pterois miles*	NIS	6	MAC	NC	NC	1
	Scorpaena maderensis	N	6	MAC	9.9	16.5	1
	Scorpaena porcus	N	6	MAC	9.9	16.5	2
Serranidae	*Epinephelus costae*	N	5	MAC	17.82	23.1	9
	Mycteroperca rubra	N	5	MAC	17.82	23.1	50
	Serranus cabrilla	N	5	MAC	NC	NC	50
	Serranus scriba	N	5	MAC	NC	NC	14
Siganidae	*Siganus luridus*	NIS	3	HBV	3.3	6.6	75
	Siganus rivulatus	NIS	3	HBV	3.3	6.6	6335

Sparidae	*Boops boops*	N	1	MIC	5.28	9.9	800
	Diplodus annularis	N	3	MEC	4.62	9.9	1
	Diplodus cervinus	N	3	MEC	4.62	9.9	2
	Diplodus puntazzo	N	3	MEC	4.62	9.9	1
	Diplodus sargus	N	3	MEC	4.62	9.9	79
	Diplodus vulgaris	N	3	MEC	4.62	9.9	5
	Oblada melanura	N	1	MIC	3.96	7.92	69
	Spicara smaris	N	3	MIC	NC	NC	18
	Spondyliosoma cantharus	N	3	MIC	NC	NC	1
Tetraodontidae	*Lagocephalus sceleratus*	NIS	2	MAC	NC	NC	4
	Torquigener flavimaculosus	NIS	4	MIC	NC	NC	21

Status (N: Native Mediterranean species, NIS: Non-Indigenous Species); spatial category (SC):
1- highly mobile gregarious, pelagic erratic species, 2- planktophagous and relatively sedentary species, living throughout the water column,
3- demersal mesophagic species, with medium-amplitude vertical movements and relatively broad horizontal movements,
4- demersal species, with slight vertical and high lateral movements,
5- sedentary demersal mesophagic species,
6- highly sedentary cryptic benthic species); trophic category (TC: HBV: herbivores, MIC: microphagic carnivores, MEC: mesophagic carnivores, MAC: macrophagic carnivores); commercial value ($/Kg, NC: No commercial value) and total abundance.

All calculated indices (i.e. species richness, abundance, biomass, economic values) were statistically similar between managed and control areas within the region. This may be due to the fact that illegal fishing may be occurring within the managed area, or that habitat degradation due to human impact (city, refugee camp, tourism) is deeply affecting the TCNR region (Figure 29).

The abundance and biomass of the most representative fish species showed that *S. rivulatus*, *M. rubra* and *D. sargus* displayed a high relative abundance and relative biomass, while being economically valuable species. Other species such as *D. sargus*, *D. cervinus*, *D. vulgaris*, *O. melanura*, *S. porcus*, *U. pori*, *P. rhomboides*, *S. rivulatus*, *S. diaspros* and *T. pavo* were more abundant with a higher biomass in managed sites. *Epinephelus costae*, *D. annularis*, *D. puntazzo*, *S. cretense*, *S. maderensis*, *C. chromis*, *C. julis*, *M. rubra* and *S. cabrilla* were mostly abundant and displayed a higher biomass in control sites. On the other hand, *S. luridus*, *S. rubrum* and *S. tinca* showed similar abundances and biomasses in managed and control localities, as opposed to *M. rubra*, *S. cretense* and *S. rivulatus*, which only showed similar biomasses. Additionally, the abundances and biomasses of *C. chromis*, *S. luridus*, *S. rivulatus* and *T. pavo* showed significant spatial variability among sites, while the abundances of *M. rubra* and *S. tinca* varied among localities. Similarly, the biomasses of *M. rubra*, *S. rubrum* and *S. tinca* also varied among localities (IUCN-SPA/RAC, 2017 unpublished). Comparison between the estimated indices for fish assemblages between the two studies of 2013 and 2017 showed little differences, mainly due to the highest census effort focused on fish assemblages made in 2017 (RAC/SPA-UNEP/MAP, 2014; IUCN-SPA/RAC, 2017 unpublished). The relative high abundance and biomass reported for *D. annularis* in 2017 seems to be doubtful, as the species is relatively rare in the region and the difference in both abundance and biomasses for *P. forskali* and *P. miles* cannot be estimated.

Finally, a comparison with fishery landings in the local fish market of Tyre, shows the presence of many species that are rarely encountered in underwater censuses, and thus are underestimated or absent from diversity assessments of fish communities. Among those species are the highly commercial goatfish *Upeneus moluccensis*, some seabreams (*Lithognathus mormyrus*, *Pagellus* spp., *Pagrus* spp.) and some midwater species (e.g. Carangidae, Scombridae). The same could be said about fishes and invertebrates living in the infauna or simply being cryptic.

Table 7: Species inventory from the surveys of 2013, 2017 and 2020.

Species
Proteobacteria
Beggiatoa sp.
Cyanobacteria
Entophysalis deusta
Oscillatoria sp.
Phormidium autumnale
Fungi
Verrucaria amphibia
MACROPHYTA
Chlorophyta
Bryopsis plumosa
Caulerpa scalpelliformis
Chaetomorpha spp.
Cladophora sp.
Codium parvulum
Palmophyllum crassum
Ulva spp.
Ochrophyta
Arthrocladia villosa
Colpomenia sinuosa
Cystoseira compressa
Cystoseira dubia
Cystoseira foeniculacea
Dictyota dichotoma
Dictyota fasciola
Dictyota linearis
Halopteris scoparia
Lobophora variegata
Padina boergesenii
Padina pavonica
Padina spp.
Ralfsia verrucosa
Sargassum vulgare
Sporochnus pedunculatus
Stypopodium schimperi
Rhodophyta
Acrosorium sp.
Amphiroa beauvoisii
Amphiroa rigida
Corallina elongata
Ellisolandia elongata
Galaxaura rugosa
Ganonema farinosum
Gigartina spp.
Haliptilon virgatum
Halymenia spp.
Hildenbrandia rubra
Hypnea spinella
Hypnea spp.
Jania longifurca
Jania rubens
Jania rubens var. corniculata
Laurencia obtusa
Laurencia sp.
Lithophyllum incrustans
Lithothamnion corallioides
Lithophyllum papillosum
Lithophyllum stictiforme
Lophocladia lallemandii
Mesophyllum alternans
Mesophyllum spp.
Neogoniolithon brassica-florida
Neogoniolithon mamillosum
Neogoniolithon spp.
Palisada perforata
Peyssonnelia coriacea ?
Peyssonnelia rosa-marina
Peyssonnelia rubra
Peyssonnelia spp.
Peyssonnelia squamaria
Plocamium cartilagineum
Rhodymenia ardissonei
Spongites fruticulosa
Tricleocarpa fragilis
Tracheophyta
Cymodocea nodosa
Halophila stipulacea
Echium angustifolium
Eryngium maritimum
Pancratium maritimum
INVERTEBRATA
Porifera
Calcarea
Clathrina spp.
Sycon sp.

Homoscleromorpha
Oscarella lobularis
Demospongiae
Acanthella acuta
Agelas oroides
Aplysilla spp.
Aplysina aerophoba
Axinella polypoides
Axinella sp.
Chondrilla nucula
Chondrosia reniformis
Cinachyrella levantinensis
Ciocalypta carballoi
Cliona viridis
Cliona parenzani
Cliona spp.
Corticium candelabrum
Crambe crambe
Cymbaxinella damicornis
Cymbaxinella sp.
Dictyonella sp.
Dysidea avara
Dysidea tupha?
Haliclona fulva
Haliclona mediterranea
Ircinia variabilis
Ircinia spp.
Lyosina blastifera
Niphates toxifera
Petrosia ficiformis
Phorbas tenacior
Phorbas topsenti
Sarcotragus cf. foetidus
Sarcotragus spinosulus
Sarcotragus spp.
Spirastrella cunctatrix
Spongia officinalis

Cnidaria
Hydrozoa
Aglaophenia sp.
Eudendrium carneum
Eudendrium glomeratum
Eudendrium cf. merulum
Eudendrium spp.
Hydrozoa sp.
Macrorhynchia philippina
Pennaria disticha

Anthozoa
Actinia mediterranea
Aiptasia mutabilis
Anemonia viridis
Asterosmilia sp.
Cladocora caespitosa
Madracis pharensis
Oculina patagonica
Phyllangia americana mouchezii
Telmatactis cricoides

Polychaeta
Filograna sp.
Hermodice carunculata
Sabellidae sp.
Serpulidae spp.

Sipuncula
Phascolosoma stephensoni
Sipunculus nudus

Crustacea
Cirripedia
Balanus trigonus
Chthmalus montagui
Chthamalus stellatus
Microeuraphia depressa
Perforatus perforatus
Decapoda
Alpheus edwardsii (as *Alpheus audouini*)
Atergatis roseus
Calcinus tubularis
Callinectes sapidus
Charybdis hellerii
Clibanarius erythropus
Diogenes pugilator
Eriphia verrucosa
Matuta victor
Ocypode cursor
Pachygrapsus marmoratus
Pachygrapsus transversus
Pagurus anachoretus
Palaemon serratus
Pilumnus hirtellus
Portumnus latipes
Upogebia pusilla
Malacostraca
Ligia italica

Mollusca

Gastropoda

Bittium sp.
Bulla striata
Bursatella leachi
Cerithium scabridum
Cerithium vulgatum
Conomurex persicus
Dendropoma anguliferum
Echinolittorina punctata
Elysia grandifolia
Elysia timida
Ergalatax junionae
Erosaria spurca
Euthria cornea
Goniobranchus annulatus
Hexaplex trunculus
Hypselodoris infucata
Trochus erithreus (as Infundibulops erithreus)
Marmorofusus verrucosus (as Fusinus verrucosus)
Melarhaphe neritoides
Nassarius reticulatus
Patella rustica
Patella ulyssiponensis
Phorcus turbinatus
Purpuradusta gracilis notata
Rhinoclavis kochi
Serpulorbis arenarius
Tonna galea
Vermetus triquetrus

Bivalvia

Acanthocardia tuberculata
Arca noae
Brachidontes pharaonis
Chama pacifica
Dendostrea folium
Donax trunculus
Gafrarium pectinatum
Gafrarium savignyi
Glycymeris glycymeris
Glycymeris nummaria
Glycymeris insubrica
Lima lima
Lioberus agglutinans
Lioberus sp.
Mactra stultorum
Malleus regula
Mimachlamys varia
Ostreidae sp.
Peronaea planata
Pinctada imbricata radiata
Pinna nobillis
Polititapes aureus
Spondylus spinosus
Venerupis corrugata
Venus casina
Venus verrucosa

Sabellida

Ditrupa arietina

Bryozoa

Caberea sp.
Reptadeonella spp.
Schizoporella errata
Schizomavella spp.
Schizoporella sanguinea
Schizoporella spp.

Echinodermata

Asteroidea

Coscinasterias tenuispina
Echinaster sepositus

Echinoidea

Arbacia lixula
Brissus unicolor
Echinocardium mediterraneum
Echinocyamus pusillus
Paracentrotus lividus

Holothuroidea

Holothuria (Panningothuria) forskali
Holothuria (Thymiosycia) impatiens
Holothuria (Platyperona) sanctori
Holothuria (Holothuria) tubulosa
Synaptula reciprocans

Ascidiacea

Botrylloides cf. leachii
Cystodytes dellechiajei
Didemnidae spp.
Herdmania momus
Phallusia fumigata
Phallusia nigra
Polyclinidae sp.
Rhodosoma turcicum
Styelidae sp.

VERTEBRATA

Chondrichthyes

Dasyatis pastinaca
Dasyatis centroura
Dasyatis marmorata
Glaucostegus cemiculus
Taeniurops grabata

Osteichthyes

Apogon imberbis
Apogonichthyoides pharaonis (as *A. nigripinnis*)
Atherinomorus forskalii (as *A. lacunosus*)
Belone belone
Boops boops
Bothus podas
Caranx crysos
Chromis chromis
Coris julis
Coryphoblennius galerita
Diplodus annularis
Diplodus cervinus
Diplodus puntazzo
Diplodus sargus
Diplodus vulgaris
Epinephelus costae
Epinephelus marginatus
Epinephelus spp.
Gobius bucchichi
Gobius cobitis
Gobius spp.
Labrus viridis
Lagocephalus sceleratus
Lithognathus mormyrus
Lipophrys trigloides
Mugilidae spp.
Mullus surmuletus
Mycteroperca rubra
Oblada melanura
Pagellus spp.
Pagrus spp.
Parablennius incognitus
Parablennius rouxi
Parablennius sanguinolentus
Parupeneus forsskali
Pempheris rhomboidea (as *P. vanicolensis*)
Plotosus lineatus
Pempheris rhomboidea
Pomadasys incisus
Pteragogus trispilus (as *P. pelycus*)
Pterois miles
Sargocentron rubrum
Scorpaena maderensis
Scorpaena porcus
Serranus cabrilla
Serranus scriba
Siganus luridus
Siganus rivulatus
Sillago suezensis
Sparisoma cretense
Spicara smaris
Spondyliosoma cantharus
Stephanolepis diaspros
Symphodus doderleini
Symphodus mediterraneus
Symphodus roissali
Symphodus tinca
Saurida undosquamis (as *Synodus saurus* ?)
Thalassoma pavo
Torquigener flavimaculosus
Trachurus sp.
Tripterygion melanurum
Tripterygion tripteronotum
Upeneus moluccensis
Upeneus pori
Xyrichthys novacula

REPTILIA

Caretta caretta
Chelonia mydas

AVES

Larus michahellis

C. Species of heritage and interest value

Among the species that have been reported from the aforementioned missions, several are considered threatened and are thus protected under various international conventions and directives, the most significant being:

1. The Barcelona Convention: The SPA/BD protocol of the Barcelona Convention provides, in its annexes, a list of endangered or threatened species (Annex II) and a list of species whose exploitation is regulated (Annex III).
2. The Bern Convention: This convention provides, in its appendices, a list of strictly protected flora species (Appendix I), a list of strictly protected fauna species (Appendix II) and a list of protected fauna species (Appendix III).
3. The Directive 92/43 CE on the conservation of natural habitats and of wild fauna and flora of the European Commission lists the natural habitat types whose conservation requires the designation of special areas of conservation (Annex I), species requiring designation of Special Areas of Conservation (Annex II), species in need of strict protection (Annex IV), and the restricted species to be taken from the wild (Annex V).
4. The Washington Convention or CITES, for international trade of endangered animals and plants: CITES lists species that are the most endangered and threatened with extinction (Appendix I), species that are not necessarily threatened with extinction but may become so unless trade is closely controlled (Appendix II), and species included at the request of a Party that already regulates trade of the species and needs the cooperation of other countries to prevent unsustainable or illegal exploitation (Appendix III).
5. The Mediterranean Flora 'Red Book' (UNEP/IUCN/GIS Posidonie, 1990), for endangered and rare marine macrophytes.
6. IUCN's Red List of Threatened Species has categories and criteria that are intended to highlight species at risk of extinction. Each species is grouped under a category (Not Evaluated, Data Deficient, Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered, Extinct in the Wild and Extinct) showing its conservation status. It provides critical information that can be used for biodiversity conservation.

Table 8 highlights those species that are under protection or at risk and that have been reported from the region of Tyre (Figures 28, 29). Other species of conservation interest are known to be present or have been reported in other studies from the region of Tyre or from the Lebanese waters in general (Table 9). Since the Lebanese coastline does not exceed 200 km in length and is thus relatively small, the eventual presence of some additional species within the region of the TCNR would not be exceptional and can even be expected.

Table 8: Marine organisms of conservation interest observed from the region of Tyre and related international conventions or directives.

Species	MRB	EU	BaC	BeC	WC	IUCN	Reference
MACROPHYTA							
Cystoseira foeniculacea	+		II		NE	NE	RAC/SPA-UNEP/MAP, 2013
Lithothamnion corallioides	+	V					RAC/SPA-UNEP/MAP, 2013
Cymodocea nodosa	+		II	I	NE	LC	RAC/SPA-UNEP/MAP, 2013
PORIFERA							
Aplysina aerophoba			II				RAC/SPA-UNEP/MAP, 2013
Axinella polypoides			II	II	NE	NE	RAC/SPA-UNEP/MAP, 2013
Sarcotragus foetidus			II		NE	NE	RAC/SPA-UNEP/MAP, 2013
Spongia officinalis			III	III	NE	NE	RAC/SPA-UNEP/MAP, 2013

CNIDARIA							
Cladocora caespitosa			II		II	EN	RAC/SPA-UNEP/MAP, 2013
Phyllangia americana mouchezii					II	NE	RAC/SPA-UNEP/MAP, 2013
MOLLUSCA							
Dendropoma anguliferum (as Dendropoma petraeum)			II	II		NE	RAC/SPA-UNEP/MAP, 2013
Erosaria spurca			II	II		NE	RAC/SPA-UNEP/MAP, 2013
Tonna galea			II	II	NE	NE	RAC/SPA-UNEP/MAP, 2013
Pinna nobilis		IV	II		NE	NE	RAC/SPA-UNEP/MAP, 2013
CRUSTACEA							
Ocypode cursor			II	II	NE	NE	2020
ECHINODERMATA							
Paracentrotus lividus			III	III	NE	NE	2020
VERTEBRATA							
Glaucostegus cemiculus			II		NE	CR	RAC/SPA-UNEP/MAP, 2013, Bariche and Fricke, 2020
Rhinobatos rhinobatos			II		NE	EN	Bariche and Fricke, 2020
Mobula mobular			II	II	II	EN	Bariche and Fricke, 2020
Squatina oculata			II		NE	CR	Bariche and Fricke, 2020
Heptranchias perlo			III		NE	NT	Bariche and Fricke, 2020
Cetorhinus maximus			II	II	II	EN	Bariche and Fricke, 2020
Epinephelus marginatus			III	III	NE	VU	RAC/SPA-UNEP/MAP, 2013
Umbrina cirrosa			III	III	NE	NE	Bariche and Fricke, 2020
Sciaena umbra			III	III	NE	NT	Bariche and Fricke, 2020
Xiphias gladius			III		NE	EN	Bariche and Fricke, 2020
Thunnus thynnus			III		NE	EN	Bariche, pers. obs.
Caretta caretta		II,IV		II	I	VU	RAC/SPA-UNEP/MAP, 2020
Chelonia mydas		II,IV	II	II	I	EN	RAC/SPA-UNEP/MAP, 2013
Trionyx triunguis			II	II	II	VU	Bariche, pers. obs.

(MRB) Mediterranean Flora Red Book; (EU) Habitat Directive European Union (1992); (BaC) Barcelona Convention (1995); (BeC) Bern Convention (1996-98);(WC) CITES (2013).

Table 9 Marine organisms of conservation interest observed from other regions and related international conventions or directives.

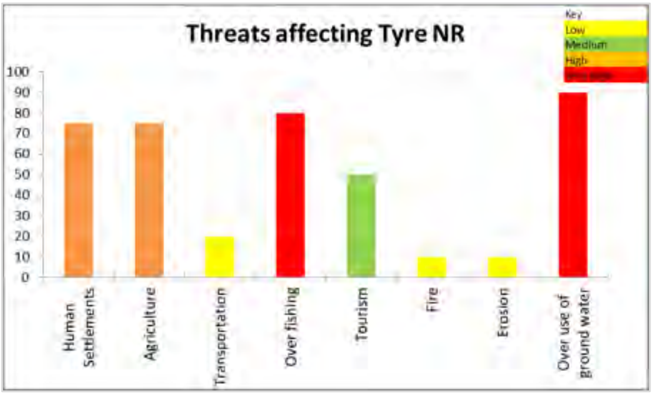
Species	MRB	EU	BaC	BeC	WC	IUCN	Reference
MACROPHYTA							
Ochrophyta							
Cystoseira dubia			II		NE	NE	RAC/SPA-UNEP/MAP, 2014
Cystoseira amentacea			II	I	NE	NE	RAC/SPA-UNEP/MAP, 2014
Sargassum trichocarpum			II		NE	NE	RAC/SPA-UNEP/MAP, 2014
Rhodophyta							
Phymatolithon calcareum	+	V			NE	NE	RAC/SPA-UNEP/MAP, 2014
Titanoderma trochanter			II		NE	NE	RAC/SPA-UNEP/MAP, 2014
Tracheophyta							
Zostera noltii			II		NE	LC	RAC/SPA-UNEP/MAP, 2014
PORIFERA							
Aplysina sp.			II	II			RAC/SPA-UNEP/MAP, 2014
Hippospongia communis			III	III	NE	NE	RAC/SPA-UNEP/MAP, 2014
MOLLUSCA							
Luria lurida			II	II	NE	NE	RAC/SPA-UNEP/MAP, 2014
Lithophaga lithophaga		IV	II	II	II	NE	RAC/SPA-UNEP/MAP, 2014
Charonia lampas			II		NE	NE	RAC/SPA-UNEP/MAP, 2014
Charonia variegata (as C. tritonis)			II		NE	NE	RAC/SPA-UNEP/MAP, 2014
CRUSTACEA							
Scyllarides latus		V	III	III	NE	DD	RAC/SPA-UNEP/MAP, 2014
ECHINODERMATA							
Centrostephanus longispinus		IV	II	II	NE	NE	RAC/SPA-UNEP/MAP, 2014
VERTEBRATA							
Gymnura altavela			II		NE	VU	RAC/SPA-UNEP/MAP, 2014

Mustelus mustelus			III		NE	VU	Bariche and Fricke, 2020
Alopias vulpinus			III		II	VU	Bariche and Fricke, 2020
Carcharhinus plumbeus			III		NE	VU	Bariche and Fricke, 2020
Squalus acanthias			III		NE	LC	Bariche and Fricke, 2020
Pristis pectinata			II		I	CR	Bariche and Fricke, 2020
Sphyrna zygaena			II		II	VU	Bariche and Fricke, 2020
Squatina aculeata			II		NE	CR	Bariche and Fricke, 2020
Squatina squatina			II	III	NE	CR	Bariche and Fricke, 2020
Centrophorus granulosus			III		NE	DD	Bariche and Fricke, 2020
Hippocampus guttulatus			II	II	II	DD	Bariche and Fricke, 2020
Hippocampus hippocampus			II	II	II	DD	Bariche and Fricke, 2020
Syngnathus abaster				III	NE	DD	Bariche and Fricke, 2020
Isurus oxyrinchus			II	III	NE	NT	Bariche and Fricke, 2020
Odontaspis ferox			II		NE	VU	Bariche and Fricke, 2020
Oxynotus centrina			II		NE	VU	Bariche and Fricke, 2020
Dermochelys coriacea		IV	II	II	I	VU	Bariche, pers. obs.
Tursiops truncatus		II	II	II	II	LC	RAC/SPA-UNEP/MAP, 2014
Delphinus delphis			II	II	II	LC	Bariche, pers. obs.
Stenella coeruleoalba			II	II	II	LC	Bariche, pers. obs.

(MRB) Mediterranean Flora Red Book; (EU) Habitat Directive European Union (1992);
(BaC) Barcelona Convention (1995); (BeC) Bern Convention (1996-98); (WC) CITES (2013).

ANTHROPOGENIC PRESSURES AND OTHER THREATS

The city of Tyre is a relatively populated area and an important touristic zone during the summer season. In addition, the presence of the highly populated refugee camp within its boundaries constitutes a significantly additional anthropogenic pressure (Figures 3, 31). The existence of a touristic section in its northern part and agriculture activities in its southern part are also significant in terms of threats to the terrestrial and marine environments (RAC/SPA-UNEP/MAP, 2013). Furthermore, the thriving non-indigenous species in the eastern Mediterranean, as well as the global problem of climate change and its effect on the biodiversity, habitats and ecosystems, constitute additional problems. The following threats and key values for Tyre have been identified (Figure 28).



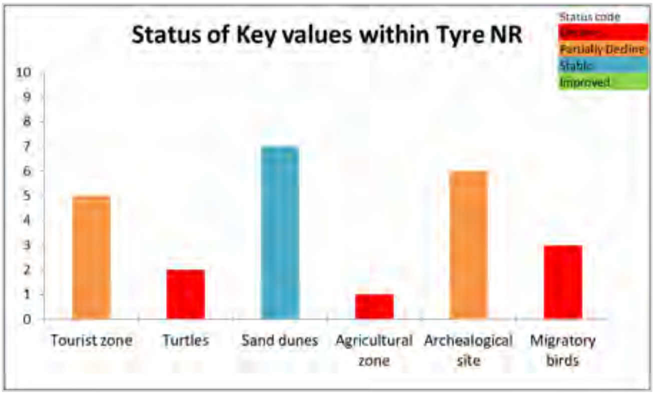


Figure 28: Threats and status of key values for the Tyre Nature Reserve identified by METT (Harhash and El Shaer, 2011).

A. Human pressure

The region of Tyre is being subjected to increased human pressures that may threaten or have a significant impact on its marine and coastal environment. In fact, the most important anthropogenic pressures that contribute directly or indirectly to the marine environment, resources and biodiversity of the area can be summarized as follows:

1. Pollution

Pollution is among the most serious threats for the marine environment. It can be divided into three types: industrial, agricultural and domestic pollution. The region of Tyre does not have major industries and is mainly affected by the last two types.

In fact, agriculture activities end up releasing pesticides, herbicides and some heavy metals into the marine environment. They are mainly referred to as agricultural runoffs.

Domestic pollution is mainly composed of solid waste, which results from discarded garbage dumped along the coast or carried to the marine environment by sewers or temporary water flows. The main component of this waste is plastic bags and other plastic debris which may entangle or suffocate marine organisms that consume them (fishes, sea turtles, seabirds, mammals). Lost fishing nets or fishing lines may keep catching organisms for a relatively long time and thus continue "fishing" (Figure 29). Several fishing debris have been encountered within the TCNR. Floating plastic rubbish breaks down under the effect of the sun, and toxic molecules end up in the sediment or get ingested by marine organisms, particularly sessile filter feeding species such as clams, tunicates and sponges. The toxic molecules may affect their biology or accumulate in other organisms that consume them. In 2013, significant sewage discharge was reported from this region whereas in 2017, the absence of discharge was clearly noted (RAC/SPA-UNEP/MAP, 2013; IUCN-SPA/RAC, 2017 unpublished).

2. Recreational fishing

Recreational fishing mainly consists of line fishing and spearfishing. They both occur in the vicinity of the protected area and probably within its boundaries. While fishing with hook-and-line has relatively little effect, spearfishing has evolved into a semi-professional activity with the development of modern gears (sonar, GPS, diving equipment) and techniques (e.g. compressor, SCUBA diving). Many recreational SCUBA divers and fishermen use SCUBA diving or a compressor to spear highly priced fishes (e.g. groupers and seabreams) that are later sold to the fish market and restaurants. These fishing methods are illegal in Lebanon and the use of compressors constitutes about 10% of the employed fishing methods (Halabi et al., 2016).

3. Professional fishing

Professional fishing that takes place in the region of Tyre is artisanal, as in most of the country. Most of the common fishing techniques used at a professional level comprise entangling nets, longlines and wire traps.

Fishing with entangling nets (trammel, gillnets) is widely used in Lebanon and around the Mediterranean Sea. This constitutes about 50% of the fishing methods employed in Tyre (Halabi et al., 2016). However, these methods are often misused when casting small mesh sizes, due to the low enforcement of the Lebanese fishing laws and the declining fishery catches. Furthermore, these nets seem to be used within the boundaries of the TCNR. Fishing with longlines and wire traps are also common, however they do not cause much damage.

Observations at the fish market show that Lampara nets are also used. This old fishing method involves catching fish larvae that aggregate under a source of light fixed on a boat. A net encircles the group of fish, mainly consisting of sardines and anchovies, known as *bizree*. However, this method is very destructive as it catches larvae and juveniles of other fishes with a high commercial value (Bariche et al., 2007).

Figure 29: Removal an encountered lost fishing net within the TCNR.

4. Blast fishing and fishing with poisons

Blast fishing is an illegal and highly destructive method that involves the use of explosives and indiscriminately stun or kill a wide variety of fish and nearby bottom-dwelling organisms. This method also causes significant physical damage to the sea bottom. The use of explosives was common in Tyre and has been reduced to the minimum (2%) due to awareness raising activities, law enforcement and conservation activities with fishermen (Halabi et al., 2016). As with sewage discharge, the absence of blast fishing in the region was noted in 2017 (RAC/SPA - UNEP/MAP, 2013; unpublished, 2017).

The use of chemicals that intoxicate fish occasionally occurs at relatively small levels (Bariche pers. obs.). The poacher may use pesticides available in the market known to be toxic to fish. The surrounding habitat would consequently be affected by the poison and consumers may be at risk of being poisoned from the fish illegally collected by this destructive method.

5. Habitat destruction

A natural habitat is considered degraded when human activities significantly affect it and its inhabitants. This habitat may irreversibly evolve into another one. Marine habitats in the region of Tyre are relatively well preserved compared to the rest of the country. However, some show a relatively high rate of destruction mainly due to coastal urbanization, fishing activity, and tourism. The presence of non-indigenous invasive species adds to the destruction of marine habitats, as they are known to have a significant impact on the inhabitants (Katsanevakis et al., 2014). While some of these habitats may recover, other changes are irreversible. This results in the reduction and sometimes the collapse of the fishery resource.

6. Other pressures

Other pressures related to anthropogenic origin, such as mooring, trampling, high sedimentation, bait and shellfish collecting, have been reported (RAC/SPA-UNEP/MAP, 2013). Anchors used to hold fishing vessels and recreational boats are known to damage the bottom, particularly when it comes to destroying the rooting system of seagrass meadows. Seagrass meadows were unexpectedly absent in the area in 2020 with one exception, despite active search. Only a few shoots of *Cymodocea nodosa* have been reported in 2013. Meadows are known to stabilize sandy bottoms and beaches, and increase productivity of the area, generating oxygen and maintaining high water quality where they occur. They are also used as breeding and feeding grounds and more importantly, as nursery areas for many marine species of interest. A worldwide decline has been reported, which is considerably caused by human activity and climate change. Once destroyed, seagrass meadows do not have the ability to easily recover and the meadow is often lost forever as environmental conditions often change. It is unclear whether meadows existed but disappeared due to the human impact, or were just naturally absent.

Trampling mainly occurs on vermetid reefs, which are biogenic platforms built by marine organisms, dominantly by the vermetid snail *Dendropoma anguliferum*, as well as the associated calcareous encrusting algae *Neogoniolithon brassica-florida*. Vermetid platforms are affected by various types of pollution, non-indigenous species and coastal development, but more so by human trampling and recreational harvesting, which results in crushing the skeleton and shells of various inhabitants of the platforms. The damage of trampling is more significant in sites regularly used by anglers or other users. The effect reported on shellfish collecting and high sedimentation seemed to be minor, as no significant bivalve beds or source of sediment were present in 2020, at least within the boundaries of the TCNR.

B. Non-Indigenous Species

The presence of Non-Indigenous Species (NIS) in the Lebanese waters in general, and the coast of Tyre in particular, can be considered as an additional significant problem that affects biodiversity. NIS presence in the eastern Mediterranean is mainly due to the Suez Canal, which allowed the introduction of countless tropical marine organisms from the Red Sea into the eastern Mediterranean Sea (Lessepsian migration). Some NIS arrived in ballast waters, as fouling organisms or as aquarium escapees. Introduction rates and population expansion are currently increasing significantly in the Mediterranean (e.g. Samaha et al., 2016) and this has been generally attributed to the expansion of the Suez Canal and to climate change.

Figure 30: The Nile softshell turtle *Trionyx triunguis*,
a rare species of conservation interest that has been reported in the TCNR.

The coastal waters of Lebanon are highly prone to the establishment of NIS, mainly because of the country's geographical position on the route of Lessepsian migration and the status of degradation of the coast. Recently a National Action Plan on species introductions and invasive species for Lebanon has been published by SPA/RAC (SPA/RAC-UNEP/MAP, 2019), since the SPA/BD Protocol considers NIS as one of the major problems requiring special attention at the regional level. The region of Tyre is evidently affected, reflected by the relatively large number of NIS reported (Table 10). A national monitoring programme related to biodiversity and NIS in Lebanon was also developed in 2018 (SPA/RAC–UN Environment/MAP, 2018).

C. Climate change

The Middle East and Lebanon are also under the influences of climate change. The effects of climate change are different between regions worldwide and may impact ecosystems, livelihoods, or water security. Among the most important impacts are those associated with an increase in temperature, reduced precipitation and scarcity of freshwater. A continuous warming of about 3.5-7°C has been occurring since the 1960s and is likely to continue until 2099 (Lelieveld et al., 2012).

In 2018, Lebanon ranked as high as 110 in ND-GAIN out of a total of 181 countries; the ND-GAIN being a calculated index that summarizes a country's vulnerability to climate change and other global challenges in combination with its readiness to improve resilience. It also ranked 86/181 in climate Vulnerability and 147/181 in Readiness (ND-GAIN, 2018).

Given the size of the country, the effects of climate change are equally similar along its coast, including the TCNR. Among the most direct effects are the sea level rise and the associated problems of saltwater intrusion into the coastal aquifers. The reduced rainfall and the expected increase of temperature at the regional level will have an effect on the amount of precipitation (40% decrease in snow), which in turn will have a significant impact on Lebanon's freshwater supply. The country's freshwater resources are increasingly affected by the high population growth, increased agricultural demand, inefficient utilization and inadequate storage, as well as pollution. An assessment made in 2018 estimated that the total economic cost of climate change in Lebanon in the year 2020 would be equivalent to about USD 4,000 per household, which constitutes a third of the average household annual earnings (about USD 12,000), and will result in household impoverishment (MFA, 2018). The average surface temperature of the Mediterranean Sea is expected to increase by 3.1°C in 2070-2099. According to this scenario, many fish species would be listed on the IUCN Red List of endangered species. This is particularly significant in the context of endemic fish species (25 fish IUCN Red listed and six extinct by 2041-2060; 45 IUCN Red listed and 14 extinct by 2070–2099). Lebanon, which is situated in the easternmost part of the Mediterranean, is expected to experience a full change in species composition, where all endemic fish species would disappear or move towards different areas by the mid-21st Century (Ben Rais Lasram et al., 2010). The disappearance of fish and marine invertebrates from the coast of the Levant and Lebanon, along with an increase in seawater temperature, would leave more space for NIS of tropical origin to establish and modify more habitats and species assemblages. This is particularly relevant since the rate of NIS introduction has been significantly increasing over recent decades with different temporal trends for various groups of fishes (Samaha et al., 2016). If this comes true, a similar scenario is likely to occur for marine invertebrates as well. The effects of climate change could increase the number and impact of NIS coming from tropical areas, eventually leading to the disappearance of some species from the coastal waters of Lebanon. This seems to have happened, for instance, to the Mediterranean mussel *Mytilus galloprovincialis* which was replaced by the non-indigenous *Brachidontes pharaonis* and also some gorgonians which were reported from the Lebano-Syrian coastal waters by Gruvel (1931). The native seabream *Sarpa salpa*, which was common in the early 1930, has almost completely disappeared, as it was gradually replaced by the invasive rabbitfishes *Siganus rivulatus* and *S. luridus* (Gruvel, 1931; Bariche et al., 2004). Other species could also have faced, or are currently facing, similar fates such as the native Little Neptune grass *Cymodocea nodosa*, snails (e.g. murex, tritons), crabs (e.g. *Pilumnus hirtellus*), and sea urchins (*Paracentrotus lividus, Arbacia lixula*). Such species have disappeared or are present in very small numbers. Vermetid platforms will also be threatened by the sea level rise, in case they are able to tolerate seawater temperature increase. The impact of climate change can be detected in several biocenoses, but it is difficult to quantify this impact.

Figure 31: Views of the freshwater pond, agriculture area and Rachidieh Refugee camp of *Ras el Ain*.

Table 10 List of non-indigenous marine organisms observed
from the region of Tyre, year of first observation and successful establishment in Lebanon.

Species (authority)	Family	Year of first record	Status
MACROPHYTA			
Codium parvulum (Bory de Saint Vincent ex Audouin) P.C. Silva, 2003	Codiaceae	2008	invasive
Padina boergesenii Allender & Kraft, 1983	Dictyotaceae	1992	established
Stypopodium schimperi (Kützing) M.Verlaque & Boudouresque, 1991	Dictyotaceae	1991	invasive
Galaxaura rugosa (J.Ellis & Solander) J.V.Lamouroux, 1816	Galaxauraceae	1995	invasive
Ganonema farinosum (J.V.Lamouroux) K.C.Fan & Yung C.Wang, 1974	Liagoraceae	1993	established
Hypnea spinella (C.Agardh) Kützing, 1847	Cystocloniaceae	1998	established
Laurencia sp.			
Cnidaria			
Hydrozoa			
Macrorhynchia philippina Kirchenpauer, 1872	Aglaopheniidae	1999	established
Anthozoa			
Oculina patagonica de Angelis, 1908	Oculinidae	1992	established
Crustacea			
Cirripedia			
Balanus trigonus Darwin, 1854	Balanidae		established
Decapoda			
Alpheus edwardsii (Audouin, 1826)	Alpheidae		established
Mollusca			
Gastropoda			
Cerithium scabridum Philippi, 1848	Cerithiidae	1999	established
Conomurex persicus (Swainson, 1821)	Strombidae		invasive
Elysia grandifolia Kelaart, 1858	Plakobranchidae	2002	established
Ergalatax junionae Houart, 2008	Muricidae		established
Goniobranchus annulatus (Eliot, 1904)	Chromodorididae		established

Hypselodoris infucata (Rüppell & Leuckart, 1830)	Chromodorididae	1999	established
Trochus erithreus Brocchi, 1821 (as *Infundibulops erithreus*)	Trochidae	1999	established
Purpuradusta gracilis notata (Gill, 1858)	Cypraeidae		established
Rhinoclavis kochi (Philippi, 1848) (shells)	Cerithiidae		established
Bivalvia			
Brachidontes pharaonis (P. Fischer, 1870)	Mytilidae	Before 1929	invasive
Chama pacifica Broderip, 1835	Chamidae	1999	invasive
Dendostrea folium (Linnaeus, 1758)	Ostreidae	2012	established
Gafrarium savignyi (Jonas, 1846)	Veneridae	Before 1998	established
Malleus regula (Forsskål in Niebuhr, 1775)	Malleidae	1929-1930	invasive
Pinctada imbricata radiata (Leach, 1814)	Margaritidae	Before 1911	established
Spondylus spinosus Schreibers, 1793	Spondylidae	1999	invasive
Holothuroidea			
Synaptula reciprocans (Forsskål, 1775)	Synaptidae	1999	established
Ascidiacea			
Herdmania momus (Savigny, 1816)	Pyuridae	1999	established
Phallusia nigra Savigny, 1816	Ascidiidae	1999	established
Rhodosoma turcicum (Savigny, 1816)	Corellidae		established
Actinopterygii			
Apogonichthyoides pharaonis (Bellotti, 1874)	Apogonidae	1977	established
Atherinomorus forskalii (Rüppell, 1838) (as *A. lacunosus*)	Atherinidae	1964	established
Pempheris rhomboidea Kossmann & Räuber, 1877	Pempheridae	1979	established
Plotosus lineatus (Thunberg, 1787)	Plotosidae	2015	invasive
Pteragogus trispilus Randall, 2013	Labridae	2005	established
Pterois miles (Bennett, 1828)	Scorpaenidae	2012	invasive
Sargocentron rubrum (Forsskål, 1775)	Holocentridae	1964	established
Siganus luridus (Rüppell, 1829)	Siganidae	1964	established
Siganus rivulatus Forsskål & Niebuhr, 1775	Siganidae	1931	established
Stephanolepis diaspros Fraser-Brunner, 1940	Monacanthidae	1964	established
Torquigener flavimaculosus Hardy & Randall, 1983	Tetraodontidae	2015	invasive
Upeneus pori Ben-Tuvia & Golani, 1989	Mullidae	1964	established

MONITORING

The National Monitoring Programme for marine biodiversity, following the IMAP requirements, has been developed for Lebanon. It has been prepared within the framework of the EcAp-Med II project with the assistance of the SPA/RAC. It included creating a list of species of importance for assessment, as well as selecting key areas for monitoring. This collaborative process involved the MoE, experts, MPA managers and national stakeholders.

Several individual monitoring programmes for marine benthic habitats, sea turtles, coastal and marine birds, marine mammals and NIS were developed. They tackled the Ecological Objectives EO1 related to biodiversity and EO2 related to NIS (SPA/RAC- UN Environment/ MAP, 2018).

1. Marine benthic habitats

The objective of the monitoring programme is to assess the ecological statuses of various marine habitats (coastal to circalittoral), and their associated species. Three areas of monitoring are proposed, one of them being Tyre – *Ras El Bayada* sector. Special emphasis is made on species with a threatened or protected statuses, listed in the appendices of conventions related to the conservation of the marine environment.

2. Sea turtles

The objective of the monitoring programme for the Loggerhead sea turtle *Caretta caretta* and the Green sea turtle *Chelonia mydas* is to determine their distribution in the Lebanese waters and determine the size and density of their populations. It also deals with sea turtle stranding and their interactions with humans.

Detailed sea turtle monitoring started in 1998 in various sandy beaches along the Lebanese coast in search of sea turtle nesting sites (Hraoui-Bloquet and Sadek 2003). It was followed by several other surveys (e.g. Demirayak et al., 2002; Newbury et al., 2002; Aureggi et al., 2007; Khalil et al., 2009).

Individuals of a Loggerhead sea turtle (Figure 32) and a Green sea turtle have been monitored by a telemetric device since 2012 by the TCNR group and SPA/RAC. A long term monitoring programme covering several sandy beaches along the Lebanese coast is proposed and includes some beaches situated north (*Al-Abassieh, Al-Qasmieh*) and south (*Al-Mansoury, Al-Kleily*) of the TCNR region.

Furthermore, a recent survey was done in May-September 2019 along Lebanese sandy beaches which highlighted the importance of the TCNR region, *Al-Abbasieh, Al-Addousiyeh, Al-Mansouri*, in addition to the Palm Islands Nature Reserve in north Lebanon (SPA/ RAC-UNEP/MAP, 2020).

3. Coastal and marine birds

The objective of the monitoring programme is to assess the ecological statuses of all sea birds and collect key information, such as species richness, abundances, breeding sites and demographic characteristics. It consists of several sub-categories; namely birds of the foreshore, breeding sea birds, birds at sea, beaching of birds and interactions with humans. Some threatened bird species requiring monitoring and other interesting observations were recorded from the TCNR.

4. Marine mammals

The program suggests the monitoring of cetacean sightings from ships, cetacean stranding and monitoring of common indicators related to monk seals.

5. Non-Indigenous Species

The objective of the program is to assess the ecological status of various habitats and the impacts of NIS. Three areas of monitoring are proposed and include Tyre – *Ras El Bayada* sector.

Figure 32: The loggerhead sea turtle *Caretta caretta*, a common species in the TCNR.

MANAGEMENT

A. Evaluation and conservation activities

In 2013, an evaluation that took into consideration the variety of habitats, fishery interests, aesthetics and anthropogenic pressures showed that the Tyre region ranked high among other similar sites (RAC/SPA-UNEP/MAP, 2013).

A total of at least 26 different habitats with "associations" and "facies" were observed. Among the most significant were vermetid reefs and some important zones of the infralittoral and circalittoral. These include: Associations with *Sargassum vulgare* and *Cystoseira compressa*; Associations with *Cystoseira cf. foeniculacea*, the coralligenous community and the rhodoliths in the infralittoral, as well as communities present within semi-dark caves (RAC/SPA-UNEP/MAP, 2015). Similarly, among the most interesting animals, some sponges (e.g. *Aplysina aerophoba, Sarcotragus cf. foetidus, Spongia officinalis*), corals (e.g. *Cladocora caespitosa*), gastropods (e.g. *Dendropoma petraeum, Erosaria spurca, Tonna galea*), bivalves (e.g. *Pinna nobilis*), crabs (e.g. *Ocypode cursor*) and vertebrates (e.g. *Glaucostegus cemiculus, Chelonia mydas*), as well as some IUCN vulnerable fish species, such as *Epinephelus marginatus* (Table 8).

In the evaluation, it was also concluded that an integral protected area was not possible in Tyre, given that the city is highly populated. As a result, a buffer zone encircling the inlets around Tyre and the western region of the northern lagoon, which includes the maërl and *Cystoseira* habitat, was suggested. An additional buffer zone having a circle of 500 m radius was also suggested around the core zone and a multi-use zone around Tyre from the shore down to a 20 m depth, where recreational fishing is forbidden. Similarly, the presence of industry, spearfishing, aquaculture, sewage dumping or dredging were also forbidden. A core zone that includes the submarine freshwater springs at 30-50 m depth, where only research/education would be allowed, as well as SCUBA diving and tourists and visitors was also suggested (Figure 33).

To a certain extent, the Municipality of Tyre has achieved protection from intensive, illegal and destructive fishing in some areas along the coast. *Zire* and *Jamal* were protected from illegal fishing through the support of IUCN under the sustainable fisheries project. Other zones of ecological interest were also covered (*Qasmieh Springs* and *Turtle Reef*) and additional zones without protection (*Bayada* and *Bakbouk*) were used as control areas. It was suggested to extend the limits of the managed areas to also cover the two locations named *East Zire* and *Jamal Deep*, which would be added to *Zire* and *Jamal* (IUCN-SPA/RAC, 2017 unpublished). This aimed at protecting a wider depth range in order to ensure the protection of additional habitats which are useful for a wider group of marine organisms.

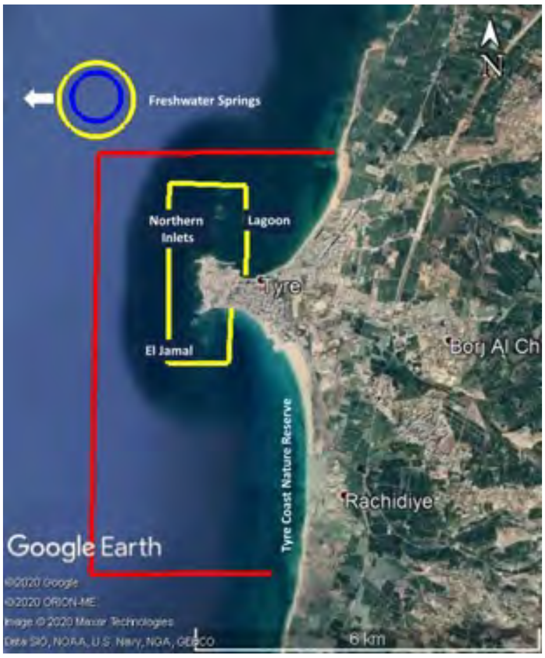


Figure 33: Proposed marine protected and/or managed area, and zoning: core zone (blue line), buffer zones (yellow lines) and multi-zone (red lines). Reproduced from: RAC/SPA-UNEP/MAP, 2013.

B. Challenges and recommendations for effective management

Marine reserves and other protected areas are considered as the best tools to preserve marine biodiversity and protect the habitats. However, effective management is required to achieve conservation and retaining the values that were once selected upon. This is particularly true, since many similar reserves in the Mediterranean and worldwide did not achieve the objectives for which they were established.

The management of a marine reserve should be tailored and specific to its geographic location, taking into account its biological and social characteristics, as well as potential challenges and particular needs. Management requires clear objectives and strategies, as well as suitable human and financial resources.

In 2007, the World Wildlife Foundation (WWF) and the World Bank launched a tool known as the METT (Management Effective Tracking Tool), giving a quick overview on management effectiveness. This powerful tool was applied to many protected areas in several countries to support decision-making. It is built around the IUCN-WCPA (World Commission on Protected Areas) management effectiveness evaluation framework, which provides a consistent basis for designing evaluation systems for protected areas. The management of the TCNR was assessed according to the Advanced Management Effectiveness Tracking Tool (Advanced METT), which was commissioned by the German Development Bank (KfW) and added questions to the original METT. The management was described as "basic with major deficiencies".

The most important deficiencies were related to financial and human resources. The TCNR relies mostly on a budget from local authorities, some unsustainable projects and summer activities in its touristic zones for funding. The MoE, through the department of ecosystem services, provides the TCNR with annual financial support. The Municipality of Tyre covers the staff time and operation cost of most seasonal rangers and security staff in peak season during the spring and summer peak season. According to the METT, the budget received is usually limited. Most of the delayed time results in inefficient management and limited human resources. The number of reported staff was also low with limited qualifications, which restricted them from fulfilling their tasks, writing reports and seeking funds. Furthermore, priorities in management planning were lacking and yearly work plans according to the available resources were not established. Community education and outreach activities were also absent, particularly since the TCNR is significantly affected by major anthropogenic pressures.

The TCNR has greatly benefited from the sustainable fisheries project, which was implemented between 2013 and 2017 in Tyre. The project created a link mainly between coastal communities, fishers, and the TCNR team. Despite its declaration in 1998, the reserve management team hadn't interacted with the local community until the 2013 survey, followed by the launch of the "Sustainable Fisheries Management for Improved Livelihoods of the Coastal Fishing Community in Tyre" project by IUCN and ADR (Association for the Development of Rural Capacities). This interaction between the TCNR and the local community was reinforced with the development of a Sustainable Fishing Platform, which allowed coordination and dialogue between stakeholders, including the fishers' cooperative and syndicate. Since its creation, the TCNR focused on coastal habitats (sandy beach and dunes) and sea turtles. The original approach was relatively hostile towards fishing communities, rather than being inclusive. Fishers were considered as a direct threat for sea turtles, and sea turtles were seen breaking into fishing nets and damaging them. Furthermore, sea turtles were also consumed locally. Multiple workshops for fishers helped bridging gaps and promoting conservation awareness. This assists the transition from species to ecosystem conservation.

Based on previous assessments and the current situation, the following actions are recommended:

1. Adequate management plan

A management plan with clear objectives will help in identifying priorities and developing an action plan and a yearly work plan specific to the area. Setting up an adequate and updated management plan is particularly significant since the current one dates back to 2006 and focuses on strict boundaries of the TCNR (Figure 3). It did not consider, for instance, the marine section of the reserve and its surroundings, or the coastal and terrestrial parts of the TCNR boundaries. It should be updated in consultation with APAC and some stakeholders. The most important natural values and ecosystems should be specified and key objectives should be prioritized in line with available financial resources.

2. Sustainable financing

Since the allocated budget is insufficient for proper management, the TCNR management team, along with key stakeholders, is requested to prepare a detailed business plan that includes a required budget and selected funding sources. The budget should highlight regular basic costs, including equipment maintenance. Other costs, such as those related to specific programmes, should also be specified with their funding. Funds should be secured to buy and maintain additional equipment.

3. Staff capacity

The capacity of the staff present at the TCNR should be assessed and the specific needs identified. Their tasks should be reviewed and prioritized, eventually adding new tasks. Current and newly recruited staff should receive proper training in order to acquire specific knowledge and skills to help achieve the objectives of the management plan. A training programme should be developed for the staff and management team. A training manual for volunteers was also suggested. Training could also include staff from other reserves, as part of national training.

4. Geographical boundaries

It is evident that the zoning within the TCNR should be reviewed and include the marine regions with clear boundaries and their regulations. More specifically:

- The various terrestrial coastal zones (Figure 3) are not properly delimited and may be accessible to outsiders. This is important in the context of the present species of conservation interest, such as ghost crabs or sea turtle nests and hatchlings.
- The protected region of the beach could be extended during the sea turtle nesting season to encompass a wider area temporarily.
- The proposed marine zones (Figure 33) are not adequate; new core and transition zones should be identified, based on available biocenoses and human activities (e.g. tourism, fisheries, scuba diving).

5. Enforcement

A well-staffed and funded marine reserve is essential, but the enforcement of restricted human activities within the multi-use adjacent zones is also crucial. Patrolling and closely monitoring anthropic activities is a very important step for population recovery, and this has been documented in well-protected marine areas around the Mediterranean Sea, where marine populations recovered fully or partially when enforcement and control are optimal.

6. Monitoring and creating an early detection system

The National Monitoring Programme for marine biodiversity adopted for Lebanon should be competently implemented in the TCNR. The monitoring of some important habitats or selected species, particularly those with an endangered status or with an invasive potential, is an important activity to be regularly undertaken within the TCNR. This could be done on a yearly, bi-annual or seasonal basis. The type of monitoring and its frequency should be done following standard methods and will depend on the habitat or species of concern. Similarly, it is recommended that the TCNR team should continue collecting information from fishers. This will result in the acquisition of time series data and will make it possible to estimate trends in abundances, temporal occurrences and spatial distributions.

An early detection system for newly arriving NIS could be implemented in selected hotspots within the TCNR. After the detection of a new NIS, a quick assessment can be done to generate a rapid response effort. This may help the scientific community in controlling or eradicating an eventual establishment of a new NIS in the country. The early detection system could be achieved with the help of volunteers, such as members of dive centers, NGOs, or passionate sea lovers that use the TCNR for their activities.

7. Communication and awareness raising activities

Clear policies, procedures and guidelines should be developed and available for the TCNR staff to follow at an internal level, as a lack of communication was detected. Furthermore, managers and staff from various nature reserves, local or international, should regularly meet for a constant exchange of information and experience.

At a wider level, the public using the TCNR reserve should be considered a major stakeholder and citizens should take part in its management. Therefore, public awareness and community engagement are essential for successful management, where they create a community identity. Information and data collected within the boundaries of the TCNR should be properly disseminated and ensured that involved stakeholders have easy and early access. As such, fishers are among the first stakeholders to be consulted before new decisions are taken or when conservation measures are applied. Awareness raising activities on endangered or noticeable species present in the TCNR may also be used to increase public engagement.

Finally, the development of clear policies and rules that promote scientific research and monitoring will add a significant component to the reserve. This may be helpful for various aspects in accreditation, funding and public awareness activities. Scientists may detect problems or anomalies and will highlight research gaps, raise significant questions and give advice.

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Co-funded by the European Union