Scientia Marina 82(1)
March 2018, 55-66, Barcelona (Spain)
ISSN-L: 0214-8358
https://doi.org/10.3989/scimar.04675.07A

Overview on the distribution of gorgonian species in Tunisian marine coastal waters (central Mediterranean)

Raouia Ghanem [1], Emna Soufi Kechaou [2], Jamila Ben Souissi [1,2], Joaquim Garrabou [3]

[1] Université de Tunis El Manar, Faculté des Sciences de Tunis, Laboratoire de Biodiversité, Biotechnologie et Changement Climatique LR11ES09, 1002 Tunis, Tunisie.
(RG) E-mail: raouia-ghanem@hotmail.fr. ORCID-iD: https://orcid.org/0000-0001-6947-582X
(JBS) (Corresponding autor) E-mail: jbensouissi@yahoo.com. ORCID-iD: https://orcid.org/0000-0003-1761-4204
[2] Université de Carthage, Institut National Agronomique de Tunisie (INAT), 1082 Tunis, Tunisie.
(ESK) E-mail: esoufi@gmail.com. ORCID-iD: https://orcid.org/0000-0003-2852-2727
[3] Institut de Ciències del Mar, CSIC, Passeig Marítim de la Barceloneta 37-49, 08003 Barcelona, Spain.
(JG) E-mail: garrabou@icm.csic.es. ORCID-iD: https://orcid.org/0000-0001-9900-7277

Summary: Gorgonian species play an important ecological role in the structure and function of marine communities. Human activities are negatively affecting the conservation status of gorgonian populations in the Mediterranean. Acquiring knowledge of gorgonian distribution is therefore a key step required to promote efficient management and conservation actions. However, information on the distribution of gorgonian species is lacking in many Mediterranean areas. This study aimed to provide an overview of the geographic and bathymetric distributions of gorgonians in the coastal waters of the Tunisian coast (1136 km). The sampling design encompassed three sectors, 27 localities and 87 sites. Information was collected from scuba diving (26 sites) and local ecological knowledge surveys of fishermen and divers (132 interviews), as well as from a literature review. Overall, the occurrence of eight gorgonians was confirmed at 54 out of the 87 sites surveyed in Tunisian coastal waters (7-120 m depth). The species that were found were *Eunicella singularis, Eunicella cavolini, Paramuricea clavata, Paramuricea macrospina, Leptogorgia sarmentosa, Eunicella verrucosa, Corallium rubrum* and *Ellisella paraplexauroides*. The highest gorgonian species richness and abundance was recorded in northern, followed by eastern Tunisian waters. In the southern areas only one species was recorded. This pattern was related to the rocky substrate that characterizes the northern and eastern coasts of Tunisia. This study is the first to report the occurrence of *E. singularis, E. cavolini, E. verrucosa* and *Leptogorgia sarmentosa* in northern and eastern Tunisian waters. The results are discussed in the hope of guiding future conservation and management actions for gorgonian assemblages in Tunisia.

Keywords: sea fans; coralligenous; octocorals; scientific diving; Tunisia; local ecological knowledge; conservation.

Distribución de las especies de gorgonias en las aguas costeras marinas de Túnez (Mediterráneo Central)

Resumen: Las especies de gorgonias juegan un papel ecológico importante en la estructura y función de las comunidades marinas. Las perturbaciones asociadas a las actividades humanas están afectando negativamente el estado de conservación de las poblaciones de gorgonias en el Mediterráneo. Conocer la distribución de las especies de gorgonias es una etapa clave para promover planes de gestión y acciones de conservación eficaces. Sin embargo, en muchas áreas del Mediterráneo no disponemos de información sobre la distribución de las especies de gorgonias. Este estudio tiene como objetivo proporcionar una visión general de la distribución geográfica y batimétrica de las especies de gorgonias en las costas de Túnez (1136 km). El diseño del muestreo abarcó 3 sectores, 27 localidades y 87 estaciones de muestreo. Se recolectó información a través de muestreos con escafandra autónoma (26 estaciones), entrevistas a pescadores y buceadores (132 entrevistas) aplicando las técnicas de Local Ecological Knowledge (LEK), así como de una revisión de la literatura disponible. En general, la presencia de ocho gorgonias se confirmó en 54 de las 87 estaciones de muestreo en la costa de Túnez (7-120 m de profundidad). Las especies encontradas fueron *Eunicella singularis, Eunicella cavolini, Paramuricea clavata, Paramuricea macrospina, Leptogorgia sarmentosa, Eunicella verrucosa, Corallium rubrum* y *Ellisella paraplexauroides*. La riqueza y abundancia de especies de gorgonias fueron más elevadas en la costa del Norte de Túnez seguida por la costa Este. En la costa del Sur solo se encontró una única especie de gorgonia. Este resultado se ha relacionado con la mayor proporción de sustrato rocoso presente a las costas del norte y este de Túnez. Este estudio permitió citar la presencia por primera vez de las especies de gorgonias *Eunicella singularis, E. cavolini, E. verrucosa* y *Leptogorgia sarmentosa* en la costa del norte y este de Túnez. Los resultados obtenidos pretenden contribuir a la adopción de acciones de gestión y conservación de las poblaciones de gorgonias en Túnez.

Palabras clave: gorgonias; coralígeno; octocorales; buceo científico; Túnez; conocimiento ecológico local; conservación.

Citation/Como citar este artículo: Ghanem R., Soufi Kechaou E., Ben Souissi J., Garrabou J. 2018. Overview on the distribution of gorgonian species in Tunisian marine coastal waters (central Mediterranean). Sci. Mar. 82(1): 55-66. https://doi.org/10.3989/scimar.04675.07A

Editor: M.J. Uriz.

Received: June 12, 2017. **Accepted:** December 22, 2017. **Published:** February 14, 2018.

INTRODUCTION

Mediterranean gorgonian species play an important ecological role in the structure and function of marine benthic communities (Ballesteros 2006, Kipson et al. 2014, Ponti et al. 2014). In general, they are long-lived species that display slow population dynamics, making them vulnerable to strong disturbance events (Garrabou and Harmelin 2002, Cerrano et al. 2013, Teixido et al. 2013). Indeed, gorgonian forests are especially vulnerable to the combined effects of multiple stressors associated with human activities such as direct and indirect fishing activities, pollution, habitat destruction and, more recently, climate warming (Bavestrello et al. 1997, Cerrano and Bavestrello 2008, Cerrano et al. 2013). Dramatic decreases in the abundance of gorgonian populations have been reported in many areas of the Mediterranean Sea (Garrabou et al. 2009, Bo et al. 2014, Garrabou et al. 2017). For instance, mass mortalities associated with temperature anomalies have affected populations of several species in different Mediterranean areas over the last several decades (Garrabou et al. 2009, Rivetti et al. 2014, Marbà et al. 2015). The observed decline supported the inclusion of several gorgonian species in different conservation frameworks at national and international levels (Otero et al. 2017). In addition to measures at the species level, the Action Plan for coralligenous assemblages by the Barcelona Convention has been adopted and includes some gorgonian species that are key species of these high-diversity Mediterranean assemblages with high ecological, socio-economic and heritage values (UN Environment/MAP 2017, Linares et al. 2008, Bouafif et al. 2014).

Mapping the gorgonian populations is a basic step required to implement effective management and conservation measures. In general, there is a knowledge gap in the geographic and bathymetric distribution of gorgonian species in the Mediterranean. However, information on the distribution of gorgonian species along the southern Mediterranean coasts is very scarce. The information available in Tunisian marine waters was compiled over four decades ago by Azouz (1973) during investigations of dredged bottoms in northern Tunisia and by an extensive Mediterranean study conducted by Carpine and Grasshoff (1975).

The main goal of this work was to provide an updated overview of the gorgonian species found in Tunisian marine waters. Geo-referenced observations on the presence of gorgonian species were obtained from a literature review and field work including a participatory monitoring method, the local ecological knowledge (LEK) approach, and scuba diving surveys. The study was intended to cover all gorgonian species. However, since the analysis of the available data revealed that the information available for deep gorgonians (>200 m depth) could not be updated, we decided to focus in gorgonian species dwelling in coastal waters (0-120 m depth). The ultimate goal of this study is to guide the design of management and conservation strategies for gorgonian species and the habitat that they characterize in Tunisian waters.

MATERIALS AND METHODS

Study sites and sampling effort

The study was carried out along Tunisian coasts including the main islands. To present the information on the distribution of gorgonian species along Tunisian coasts, three sectors were considered on the basis of the hydrographic and geomorphological features of the bottoms (Fig. 1). In addition, to compile the information on the distribution, in each sector we screened the presence of gorgonian species in different localities, in which several sites were surveyed by different methods. Thus, the information encompassed different spatial scales: sector (10^2 km), locality (10 km) and site (1 km). A total of 27 localities and 87 sites were investigated (Table 1).

Sector 1 stretches from the Algerian border to Kélibia, which covers 393 km of coastline and is part of the western basin of the Mediterranean Sea (WMED). In sector 1, data from 11 localities and 49 sites were obtained (Table 1).

Sector 2 comprises the area between Kélibia and Ras Kapudia (261 km of coastline). In sector 2, data from 9 localities and 21 sites were obtained (Table 1).

Sector 3 extends from Ras Kapudia to the Libyan border, including the Gulf of Gabès (482 km coastline). In sector 3, data from 7 localities and 17 sites were obtained (Table 1).

Sector 1 in northern Tunisia is under the influence of Atlantic currents and is characterized by a unique morphology and a heterogeneous bottom type, making its benthic habitats diverse and patchy with a dominance of coralligenous assemblages (Azouz 1973). Accordingly, around Galite Island, the hard bottoms are rich, and there are coralligenous assemblages up to a depth of 100 m. At Zembra Island, the bottom is characterized by a series of parallel recesses bordered by rocks and coastal detrital bottoms (Lubet and Azouz 1969, Andromède 2010a, b). Like those of the Banc des Esquerquis and Banc Rezgui, the bottoms around Cani Island, which is situated in northern Tunisia, are dominated by rocky substrates (Azouz 1973).

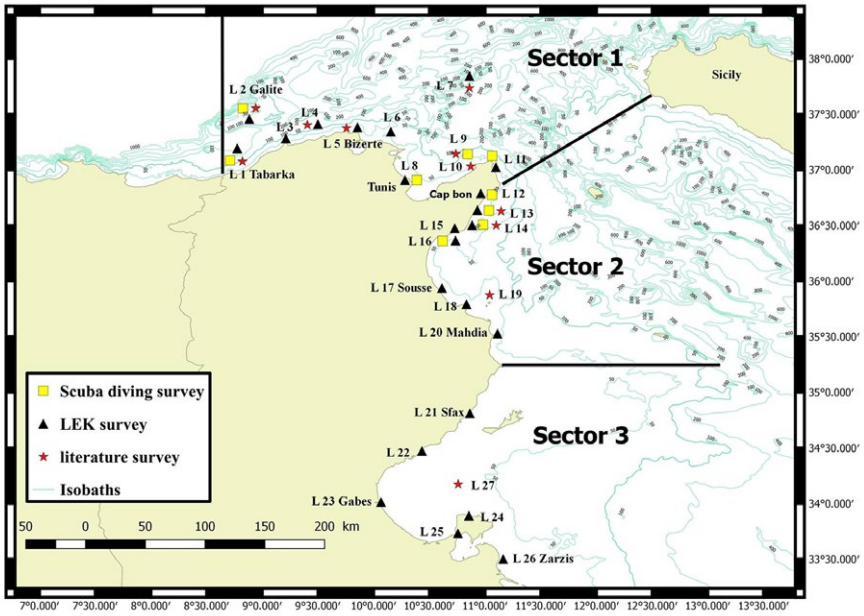


Fig. 1. – Sectors and localities along Tunisian marine waters and source of information to obtain distribution data on gorgonian species records.

Sectors 2 and 3 belong to the central Mediterranean. These sectors are dominated by sandy and muddy bottoms and harbour communities with subtropical species that are characteristic of the eastern basin of the Mediterranean Sea. Along the east coast, the sea bottom is fairly homogeneous, and the shelf is very wide, especially in the Gulf of Gabès (Bradai et al. 2004).

Literature survey

A literature survey was carried out using several bibliographic databases for the period from 1950 to the present. The research was done using different combinations of keywords, such as Mediterranean, gorgonians(s), cnidarian(s) species, coralligenous or benthic biocenoses, and Tunisia. In addition, informa-

Table 1. – Sampling effort and literature sources investigated in Tunisian waters per sector, locality and sites. Ref. 1, Anomyme 2011; Ref. 2, Andromède 2010a; Ref. 3, Jaziri et al. 2016; Ref. 4, Andromède 2010b; Ref. 5, Ben Mustapha et al. 2004; Ref. 6, Ben Mustapha and Afli 2007. For full references, see the reference list.

Locality ID	Locality name	Diving surveys (number of sites)	LEK (number of interviews-number of sites)	Literature survey (number of sites with information available, Ref. number)	Total investigated sites	Total sites with gorgonian species
Sector 1						
L1	Tabarka	2	10-1	Yes (2 sites; Ref. 1)	3	3
L2	Galite MPA	7	3-1	Yes (9 sites; Ref. 2)	17	15
L3	Cap Serrat	No	6-1	No	1	1
L4	Fratelli Island	No	3-1	Yes (2 sites; Ref. 3)	3	3
L5	Bizerte	No	10-2	Yes (3 sites; Ref. 3)	5	5
L6	Cani Island	No	2-1	No	1	1
L7	Banc des Esquerquis	No	5-1	Yes (1 site; Ref. 3)	2	2
L8	La Marsa	2	7-2	No	2	2
L9	Zembra MPA	5	No	Yes (5 sites; Ref. 4)	10	7
L10	Sidi Daoud	No	No	Yes (1 site; Ref. 5)	1	1
L11	Haouaria	4	8-3	No	4	4
Sector 2						
L12	Menzel Tmim	1	3-1	No	1	1
L13	Banc Korba	2	1-1	Yes (1 site; Ref. 5)	2	2
L14	Banc Maamoura	1	1-1	Yes (1 site; Ref. 5)	1	1
L15	Nabeul	No	5-3	No	3	0
L16	Hammamet	2	6-4	No	4	2
L17	Sousse	No	8-3	No	3	0
L18	Monastir	No	6-3	No	3	0
L19	Banc Hallouf	No	0	Yes (1 site; Ref. 6)	1	1
L20	Mahdia	No	3-3	No	3	2
Sector 3						
L21	Sfax	No	10-4	No	4	0
L22	Skhira	No	5-3	No	3	0
L23	Gabes	No	10-3	No	3	0
L24	Houmet Souk	No	7-2	No	2	0
L25	Ajim	No	5-1	No	1	0
L26	Zarzis	No	8-3	No	3	0
L27	Fora Mostafa	No	No	Yes (1 site; Ref. 5)	1	1
	TOTAL	26	132 interviews		87	54

tion was obtained from technical reports published by Tunisian national institutions. Only seven references were retained from the more than 50 reports and scientific publications that were evaluated. The site coordinates were taken from either the references or the maps included in the publications. The literature survey noted that the white sea fan, *Eunicella singularis*, was recorded by Azouz (1973) in Northern Tunisia, as was *Eunicella stricta* (Bertoloni, 1810), which is generally regarded as a junior synonym of *E. singularis*, as reported by Weinberg (1976, 1978).

Local ecological knowledge surveys

Species occurrences were also obtained from the LEK approach via interviews with local divers and fishermen. The LEK survey was applied at 23 localities along the Tunisian coasts: nine localities in sector 1, eight localities in sector 2 and six localities in sector 3 (Fig. 1 and Table 1). A total of 132 interviews were conducted, 19 diver interviews and 113 fishermen interviews. To ensure the quality of the information acquired, the interviews were conducted by showing samples and photographs of the gorgonian species. When the species were recorded by the interviews, the respondents sent photos with the corresponding coordinates. Nevertheless, when necessary the samples collected by divers and fishermen were identified in the laboratory. The LEK approach was successfully applied to compile information on the distribution and to track temporal changes of the presence and abundance of different marine species (Azzurro et al. 2011, Boughedir et al. 2015).

Scuba diving surveys

A total of 9 localities and 26 sites were surveyed for the presence of gorgonian species using scuba diving from May 2013 to December 2015. The sites were selected after analysing the literature and the results of the LEK surveys of fishermen and divers, and were based on information on the nature of the bottom. The surveys were conducted mainly in coastal areas but also included two insular areas (Fig. 1 and Table 1). A total of 20 and 6 sites were explored with scuba diving in sector 1 and sector, 2 respectively. Diving surveys were not conducted in sector 3 because the results from the interviews of both fishermen and divers indicated the absence of gorgonians in this sector (Fig. 1 and Table 1).

Diving surveys were carried out to a maximum depth of 40 m, and the surveys utilized a combination of both bathymetric transects and transects at fixed depths. The data collection was based on the presence or absence of gorgonian species. Species were identified in situ or after examining a sample in the laboratory when necessary. For each site, GPS coordinates were recorded. When gorgonians were present, semi-quantitative estimations of the abundance and the upper and lower depth limits were conducted when possible, and the estimations were specified for each species at each study site.

Species identification

Species identification followed the descriptions provided by Carpine and Grasshoff (1975) and Bayer et al. (1983), using the morphological characteristics of the colonies, and identifications were made to the lowest possible taxonomic level. The nomenclature adopted in this work follows the World Register of Marine Species (WoRMS).

RESULTS

Gorgonian species in Tunisian coastal waters

A total of eight gorgonian species were found in Tunisian coastal waters (Table 2). The reported species belong to four families and eight genera. The Gorgoniidae family is the most diverse in Tunisian waters with four species, followed by Plexauridae with two species and Coralliidae and Ellisellidae, both with a single species (Table 2). Only *Paramuricea macrospina* is considered endemic to the Mediterranean (Otero et al. 2017).

Geographic distribution

In this study, a total of 87 sites were investigated for the presence of gorgonian species, and the sites covered approximately 1300 km of coastline (Fig. 2). The presence of gorgonian species was confirmed at 54 sites (Table 1 and Fig. 2). At most sites, only one species was found (Table 3). Sector 1 constituted most of the observations of gorgonians in terms of both presence (11 localities and 44 sites) and the number of gorgonian species recorded (8 species) (Table 2, Figs 2 and 3). In sector 2, six localities encompassing nine sites were found to shelter populations of three gorgonian species: *E. singularis*, *E. cavolini* and *Leptogorgia sarmentosa.* In sector 3, only *E. singularis* was reported at only one site of the seven localities and 17 sites surveyed (Tables 1 and 3, Figs 2 and 3).

Table 2. – Gorgonian species, taxonomy and distribution (sector and depth range) in Tunisian waters.

Species	Taxonomy Class, Subclass, Family	Sectors / depth range Sector 1	Sector 2	Sector 3
Eunicella singularis (Esper, 1791)	Anthozoa, Octocorallia, Gorgoniidae	7-60 m	25-50 m	40-55 m
Eunicella cavolini (Koch, 1887)	Anthozoa, Octocorallia, Gorgoniidae	15-40 m	25-50 m	Absence
Corallium rubrum (Linnaeus, 1758)	Anthozoa, Octocorallia, Coralliidae	43-120 m	Absence	Absence
Leptogorgia sarmentosa (Esper, 1789)	Anthozoa, Octocorallia, Gorgoniidae	5	25-45 m	Absence
Eunicella verrucosa (Pallas, 1766)	Anthozoa, Octocorallia, Gorgoniidae	28-40 m	Absence	Absence
Paramuricea clavata (Risso, 1826)	Anthozoa, Octocorallia, Plexauridae	60 m	Absence	Absence
Paramuricea macrospina (Koch, 1882)	Anthozoa, Octocorallia, Plexauridae	80 m	Absence	Absence
Ellisella paraplexauroides Stiasny, 1936	Anthozoa, Octocorallia, Ellisellidae	47 m	Absence	Absence

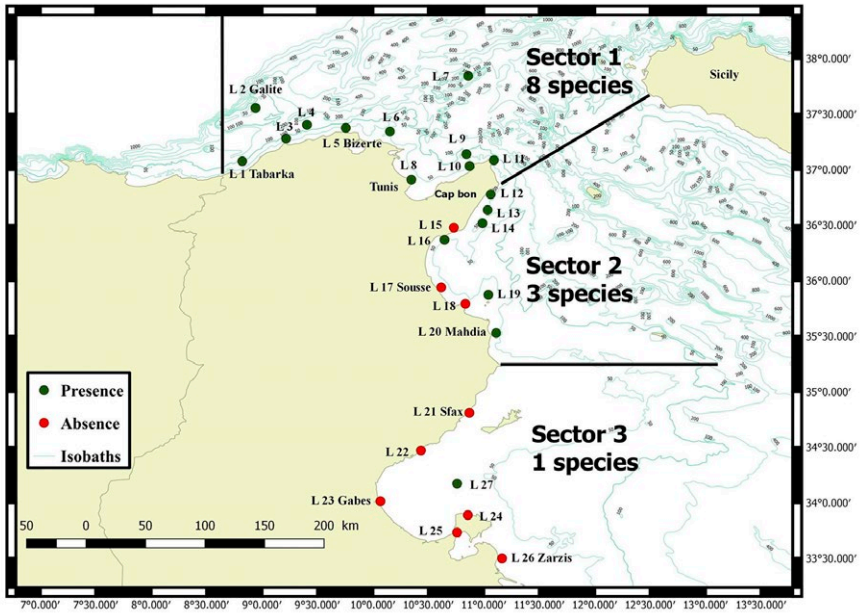


Fig. 2. – Presence and absence of gorgonian species in sectors and localities investigated in Tunisian marine waters.

In general, the direct observations and the information reported by the LEK and literature surveys indicate that the substrate types on which gorgonian populations dwelt were rocky boulders, shoals, vertical walls or plunging cliffs. However, the white gorgonian *E. singularis* was observed on a sandy bottom at one site in the marine protected area (MPA) of Zembra locality (L9), but the colonies were settled and developed over small stones.

Distribution and abundance of gorgonian species recorded in Tunisian coastal waters

E. singularis, was the only species reported in all three sectors covering the Tunisian coast (Table 2, Fig. 3). Its populations displayed low to moderate abundance according to the LEK interviews with divers and scuba diving surveys. The bathymetric distribution of the populations ranged from 7 to 60 m depth.

In sector 1, *E. singularis* was present at most of the localities surveyed where the bottoms were characterized by rocky bottoms and coralligenous assemblages. For instance, in the western part of sector 1, the diving surveys in the Tabarka area reported populations developing at depths between 15 and 26 m with moderate abundances. Similar observations were reported around Galite Island, which is 60 km from the continental coast, where *E. singularis* was recorded at depths ranging from 23 to 48 m (Table 3). Likewise, in the eastern areas of sector 1, the information available from local divers and fishermen obtained in Cap Serrat (L3), Bizerte (L5), Fratelli Island (L4) and Cani Island (L6) indicated that *E. singularis* populations were abundant at depths between 20 and 40 m. The local divers and red coral fishermen further east in Banc des Esquerquis (L7) noted that the species was abundant at 40 to 60 m depth.

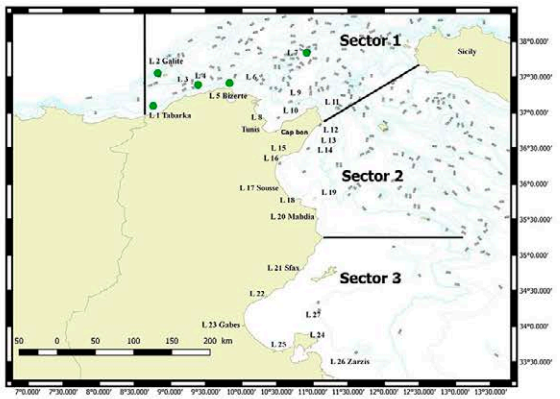
The dives conducted at two sites in the locality of La Marsa (L8) on rocky bottoms in the southeastern part of sector 1 indicated that *E. singularis* was also present in shallow waters (7-20 m depth). However, the colonies at these sites did not display dense patches. Further south, in Zembra Island National Park, *E. singularis* colonies were found at depths ranging from 30 to 40 m, according to the literature and diving surveys (Table 3). However, the presence of *E. singularis* at this locality is not widespread, because the diving surveys reported the presence of the species in only two of the five sites surveyed, though the dives were carried out on similar depth ranges and rocky substrata. The populations displayed low colony abundances at the two sites where *E. singularis* was observed. At the locality Haouaria (L11), at the limit with sector 2, scuba diving surveys at three sites recorded *E. singularis* at 18 to 26 m depth on rocky bottoms with relatively high abundances (Fig. 4A and Table 3).

In sector 2: Populations of *E. singularis* were reported at 6 of the 21 surveyed sites, and most of the populations corresponded to rocky banks (Table 3). At the Menzel Tmim locality (L12) in the northern part of sector 2, *E. singularis* populations were found between 25 and 35 m. At the Banc Korba (L13) and the Banc Maamoura (L14) localities, populations of *E. singularis* were reported between 25 and 35 m, while the populations were deeper (45 m) in Banc Hallouf (L19) (54 km from the coast) (Table 3). Finally, in the southern part of sector 2, *E. singularis* was reported to be present in the locality of Mahdia (L20) at 40-50 m depth (Table 3).

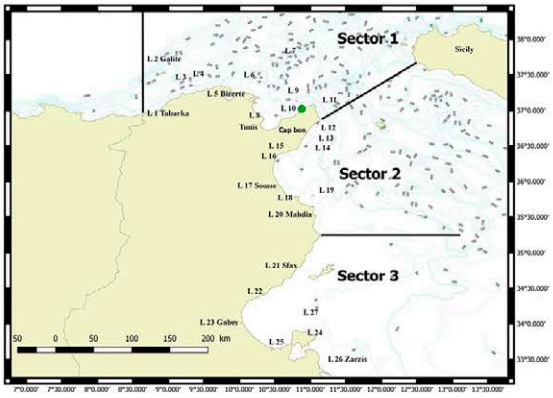
In sector 3, *E. singularis* was observed at only 1 site out of the 17 investigated (Fig. 3 and Table 3). In the central part of the Gulf of Gabès, its presence was reported at 40-55 m depth at the Fora locality (L27) (Table 3).

Table 3. – Gorgonian species distribution in Tunisian water geographic position, depth range and source of information of gorgonians.

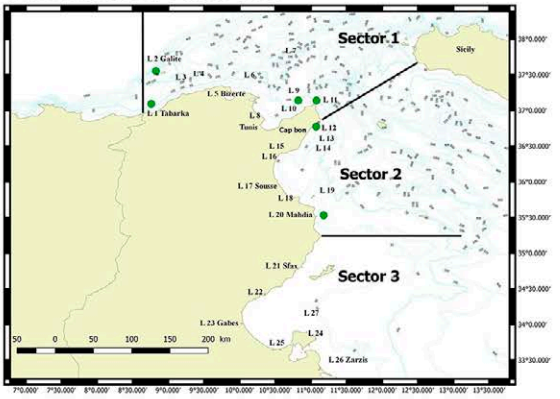
Species	Sector	Locality	ID Locality	GPS Coordinates	Depth	Source
Eunicella singularis (Esper, 1791)	1	Tabarka	L1	36°58’505”N 008°45’216”E	15-18 m	Anonyme 2011 + this study
				36°58’646”N 008°44’499”E	20-26 m	Anonyme 2011 + this study
				36°58.758’N 008°45.588’E	18-25	LEK survey
				37°33’718”N 8°57’538”E	44 m	Andromède 2010a
				37°34’099”N 8°57’488”E	45 m	Andromède 2010a
				37°30’790”N 8°54’266”E	23 m	Andromède 2010a
				37°29’563”N 8°53’252”E	24-48 m	Andromède 2010a
	1	Galite Island	L2	37°32’35”N 8°56’41”E	24-26 m	This study
				37°33’45”N 8°57’55”E	20-27 m	This study
				37°31’18”N 8°56’29”E	15-30 m	This study
				37°30’52”N 8°54’02”E	20-24 m	This study
				37°33’14”N 8°57’07”E	19-21 m	This study
	1	Cap Serrat	L3	37°08’16”N 9°01’20”E	15-30 m	LEK survey
	1	Fratelli Island	L4	37°18’300”N 09°24’520”E	35-40 m	LEK survey
	1	Bizerte	L5	37°26’391”N 10°06’743”E	20-25 m	LEK survey
	1	Cani Island	L6	37°21’220”N 10°07’450”E	35-40 m	LEK survey
	1	Banc des Esquerquis	L7	37°45’200”N 10°48’620”E	40-60 m	LEK survey
	1	La Marsa	L8	36°54’45”N 10°20’50”E	7-15 m	LEK survey + this study
				36°55’14”N 10°21’23”E	10-20 m	LEK survey + this study
				37°08’28”N* 010°48’22”E	30-40 m	Andromède 2010b
				37°08’28”N* 010°47’42”E	52 m	Andromède 2010b
				37°07’23”N* 010°47’20”E	25-40 m	Andromède 2010b
		Zembra Island	L9	37°06’58”N* 010°47’28”E	45 m	Andromède 2010b
				37°08’28”N* 010°48’47”E	30-50 m	Andromède 2010b
				37°08’291”N 010°48’117”E	35-40 m	This study
	1			37°07’139”N 010°47’315”E	30-35 m	This study
				37°02’607”N 11°04’650”E	18-24 m	LEK survey + this study
		Haouaria	L11	37°03’383”N 11°04’739”E	20-26 m	LEK survey + this study
	1			37°03’360”N 11°04’767”E	20-25 m	LEK survey + this study
	2	Menzel Tmim	L12	36°47’368”N 11°01’19”E	25-35 m	LEK survey + this study
	2	Banc Korba	L13	36°31’870”N 11°05’810”E	25-35 m	Ben Mustapha et al. 2004 + LEK survey + this study
	2	Banc Maamoura	L14	36°17’400”N 10°50’800”E	26-33 m	Ben Mustapha et al. 2004 + LEK survey + this study
	2	Banc Hallouf	L19	35°34’650”N 11°32’050”E	45 m	Ben Mustapha and Afli 2007
	2	Mahdia	L20	35°50’853”N 11°08’430”E	40-50 m	LEK survey
				35°50’509”N 11°08’852”E	40-50 m	LEK survey
	3	Fora Mostafa	L27	34°09’470”N 11°34’100”E	40-55 m	Ben Mustapha et al. 2004
Eunicella cavolini (Koch, 1887)	1	Tabarka	L1	36°58’646”N 008°44’499”E	15-25 m	This study
	1	Galite Island	L2	37°29’563”N 8°53’252”E	38 m	Andromède 2010a + this study
	1	Zembra Island	L9	37°08’29.1”N 010°48’11.7”E	30-40 m	This study
	1	Haouaria	L11	37°02’607”N 11°04’650”E	18-24 m	This study
	2	Menzel Tmim	L12	36°47’368”N 11°01’193”E	25-35 m	This study
	2	Mahdia	L20	35°50’853”N 11°08’430”E	40-50 m	LEK survey
				35°50’509”N 11°08’852”E	40-50 m	LEK survey
Corallium rubrum (Linnaeus, 1758)	1	Tabarka	L1	36°58’01”N 008°45’24”E	60-120 m	LEK survey + Jaziri. 2017
				37°32.09’N 8°57.38’E	60-120 m	LEK survey
	1	Galite Island	L2	36°38’35”N 008°57’29”E	71 m	Jaziri et al. 2016, Jaziri 2017
				37°38’28”N 008°57’36”E	75 m	Jaziri et al. 2016, Jaziri 2017
				37°38’49”N 008°57’25”E	75 m	Jaziri et al. 2016, Jaziri 2017
	1	Fratelli Island	L4	37°20’10”N 009°27’40”E	83 m	Jaziri et al. 2016, Jaziri 2017
				37°20’10”N 009°27’43”E	80 m	Jaziri et al. 2016, Jaziri 2017
				---------	60-120 m	LEK survey
	1	Bizerte	L5	37°21’54”N 009°59’38”E	54 m	Jaziri et al. 2016, Jaziri 2017
				37°23’10”N 009°59’38”E	60 m	Jaziri et al. 2016, Jaziri 2017
				37°17’28”N 009°57’43”E	43 m	Jaziri et al. 2016, Jaziri 2017
	1	Banc des Esquerquis	L7	37°51’47”N 10°55’19”E	55 m	Jaziri et al. 2016, Jaziri 2017
Leptogorgia sarmentosa (Esper, 1789)	1	Haouaria	L11	37°02’304”N 11°03’930”E	5 m	This study
	2	Banc Korba	L13	36°37’316”N 10°56’156”E	25-30 m	This study
				36°24’29”N 10°40’20”E	45 m	LEK survey + this study
	2	Hammamet	L16	36°19’07”N 10°31’26”E	32-35 m	This study
	2	Banc Hallouf	L19	35°34’650”N 11°32’050”E	45 m	Ben Mustapha and Afli 2007
Eunicella verrucosa (Pallas, 1766)	1	Galite Island	L2	37°33’718”N 8°57’538”E	35-40 m	Andromède 2010a + this study
	1	Zembra Island	L9	37°08’291”N 10°48’117”E	28 m	This study
Paramuricea clavata (Risso, 1826)	1	Banc des Esquerquis	L7	37°45’200”N 10°48’620”E	60 m	LEK survey
Paramuricea macrospina (Koch, 1882)	1	Banc des Esquerquis	L7	37°45’200”N 10°48’620”E	80 m	LEK survey
Ellisella paraplexauroides Stiasny, 1936	1	Sidi Daoud	L10	36°59’30”N 10°52’15”E	47 m	Ben Mustapha et al. 2004



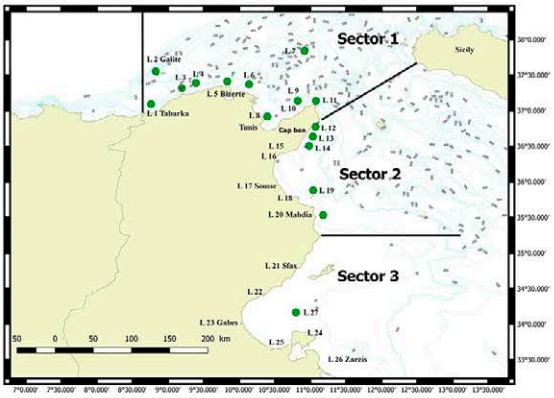
Corallium rubrum



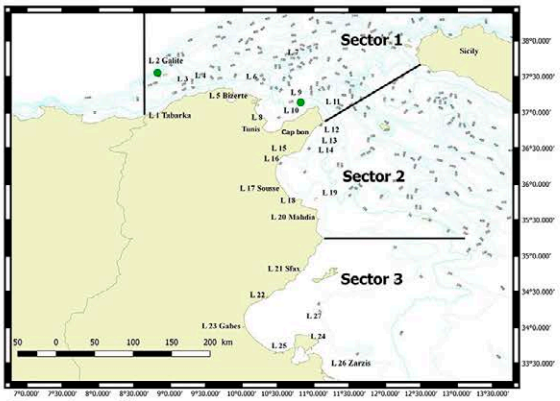
Ellisella paraplexauroides



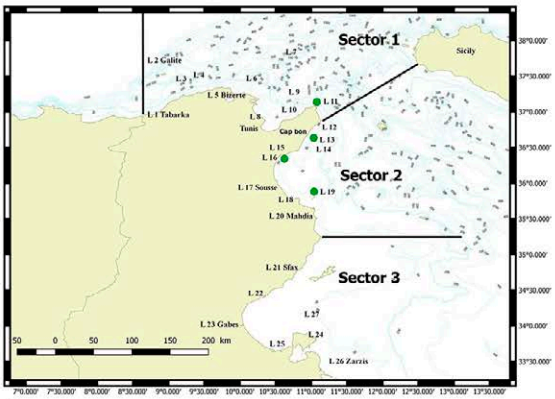
Eunicella cavolini



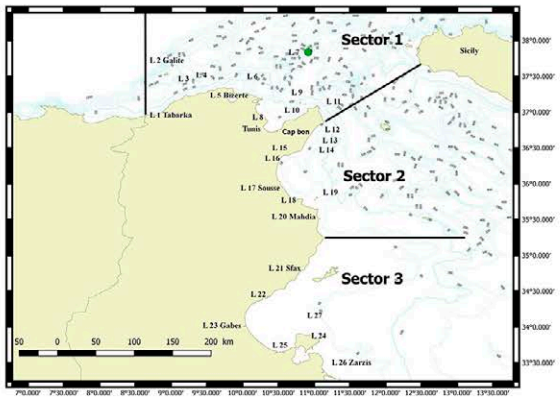
Eunicella singularis



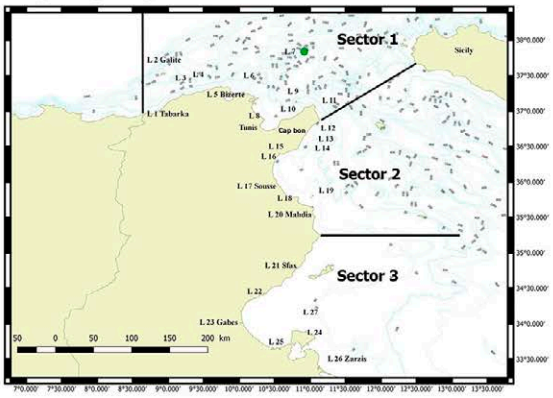
Eunicella verrucosa



Leptogorgia sarmentosa



Paramuricea clavata



Paramuricea macrospina

Fig. 3. – Distribution map of gorgonian species found in shallow Tunisian waters.

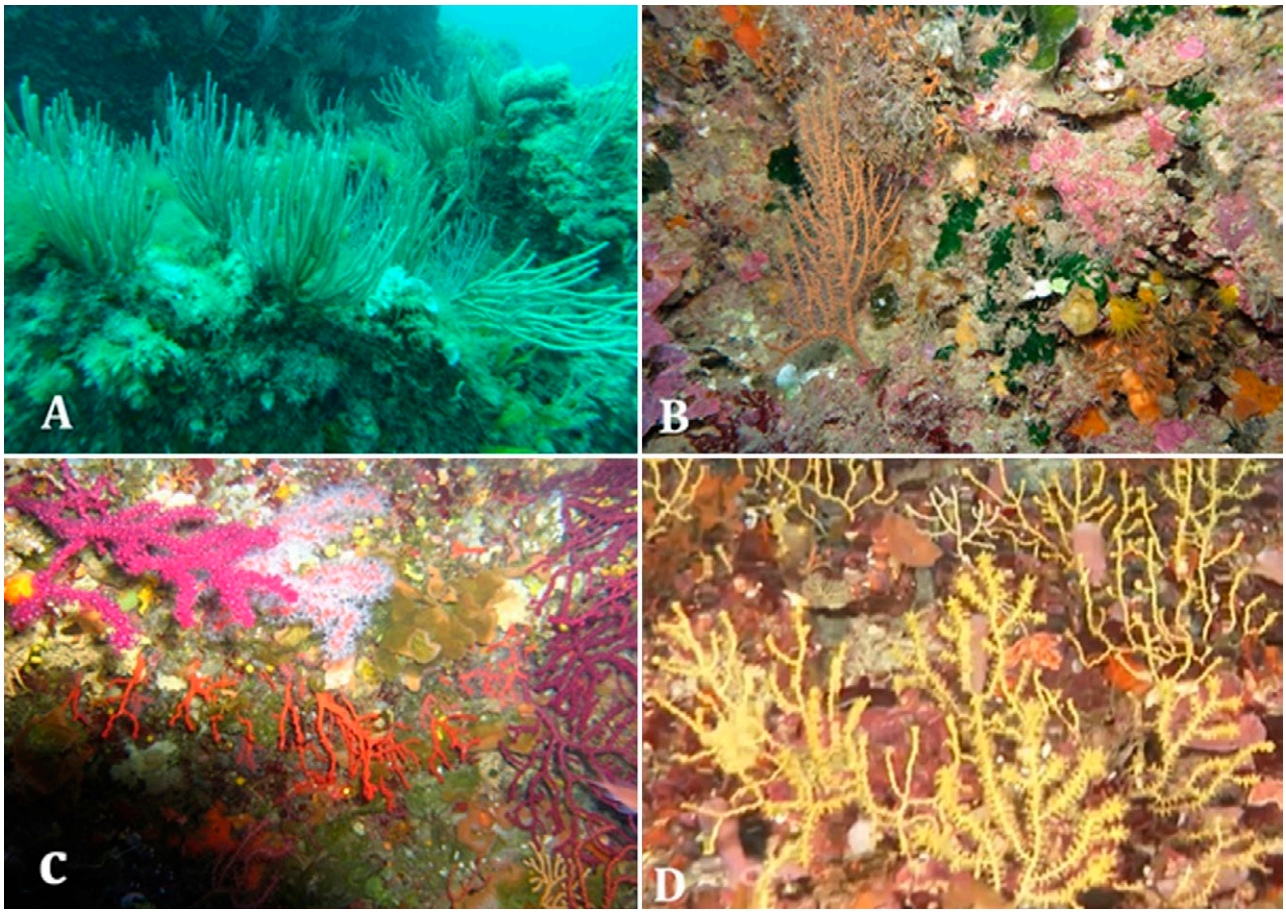


Fig. 4. – **A**, *Eunicella singularis* recorded at Haouaria; **B**, *Leptogorgia sarmentosa* observed at Banc Korba; **C**, association of *Paramuricea clavata* and *Corallium rubrum* at Banc des Esquerquis; **D**, records of *Eunicella cavolini* at Galite Island.

The yellow gorgonian, *Eunicella cavolini* (Fig. 4D), was observed at four localities in sector 1 and two localities in sector 2; however, its populations displayed moderate to low abundances at all observed sites. In the northern part of sector 1, the diving survey highlighted the presence of *E. cavolini* Tabarka (L1) at depths ranging from 15 to 25 m, while at Galite Island (L2), the species was observed at 31 to 44 m depth (Fig. 3). Populations were present at 30 to 40 m in the southeastern part of sector 1 in Zembra National Park (L9) and at 18 to 24 m in Haouaria (L11) (Table 3).

In sector 2, *E. cavolini* was reported at two localities in Menzel Tmim (L12), where the populations were reported to be between 25 and 35 m depth, and in Mahdia (L20), where the LEK survey indicated that its distribution could reach a depth of 50 m.

Eunicella verrucosa was reported at only two localities of sector 1 (Fig. 3). The diving surveys conducted in this study confirmed the presence of the species at 30 to 35 m depth on rocky bottoms around Galite Island (L2) and provided the first observation in Zembra National Park (L9) at 30 m depth. In both cases, a few colonies were observed on rocky boulders.

Leptogorgia sarmentosa was observed in the southeastern parts of sectors 1 and 2 (Fig. 3). However, this species was observed at only one locality in sector 1 and two localities in sector 2. The observation in sector 1 was from a scuba diving survey near the harbour of Haouaria (L11) at 5 m depth. The observations in sector 2 correspond to scuba diving surveys near the harbour of Hammamet (L16) at 32 to 45 m depth and on coralligenous falls in Banc Korba (L13) at 25 to 30 m depth (Fig. 4B). Moreover, in sector 2, technical reports indicated the presence of *Leptogorgia sarmentosa* in Banc Hallouf bank (L19) (approximately 54 km from Monastir), which is constituted by rocky zones formed by very extensive blocks and surrounded by coarse elements.

The LEK surveys in the Banc des Esquerquis (L7) indicated that both *Paramuricea clavata* and *P. macrospina* were present on rocky bottoms between depths of 60 and 80 m (Fig. 3). The diving surveys carried out up to a depth of 40 m on rocky cliffs and coralligenous formations in sectors 1 and 2 did not report the presence of these species.

Ellisella paraplexauroides is an Atlantic-Mediterranean gorgonian species that was reported at only one locality Sidi Daoud (L10) from sector 1 at a depth of 47 m (Table 3)

The precious red coral, *Corallium rubrum,* was present in only sector 1 (Fig. 4C). However, the species was observed at five localities in this sector, and the populations were still abundant despite the fact that they are still exploited by fishermen according to the LEK surveys. The populations of the red coral *Corallium rubrum* were mainly observed between 60 and 120 m at most of the localities (Table 3).

DISCUSSION

In this study, we have provided comprehensive geo-referenced data on the geographic distribution and bathymetric ranges of gorgonians in the Tunisian coastal waters by conducting field work and gathering all published information. This effort provided a compilation of information and new records for Tunisian waters for several species in different areas. In particular, the presence of *E. singularis, Eunicella cavolini*, *Paramuricea clavata* and *Eunicella verrucosa* was detected in northern Tunisian waters (sector 1) and new records of *Leptogorgia sarmentosa* were obtained in the eastern part of the study area (sector 2).

A total of 8 species (about one third) of the 26 Mediterranean gorgonian species were found in Tunisian waters (Aguilar 2004, Aguilar and Sànchez 2007). In general, the mono-specific characteristics of the gorgonian assemblages reported in this study are in agreement with those found in other areas of the Mediterranean Sea (Topçu and Öztürk 2015, Grinyó et al. 2016, Molina et al. 2016). In fact, the co-dominance of two or more species was rarely observed in Tunisian assemblages (Fig. 4C). The analysis of the literature allowed us to add three additional species that dwell in deep waters (200-650 m depth). The gorgonians *Bebryce mollis* and *Villogorgia bebrycoides* were collected once before in Banc des Esquerquis (sector 1 L7/WMED) at 230 to 400 m depth (Carpine and Grasshoff 1975). The bamboo coral, *Isidella elongata*, was previously sampled in Banc Rezgui (sector 1) and Cape Negro (sector 1 L3) at 550 to 650 m depth and was found to colonize muddy bottoms (Maurin 1962). Unfortunately, these species were reported several decades ago, and we could not confirm their presence with recent observations. Bearing in mind the intense trawling fishing activities in the northern sector of Tunisian waters (DGPA 2016), it is likely that the populations of these deep gorgonian species have suffered severe declines, as reported in other Mediterranean areas (Fabria et al. 2014).

Gorgonian distribution and abundance are largely influenced by the availability of hard bottoms, as well as by other environmental conditions required by the species for their development, such as the amount of irradiance reaching the sea floor, temperature, exposure to flow and food availability (nutrient and particulate organic matter concentration) (Weinberg 1979, 1980, Zabala and Ballesteros 1989). Indeed, the large differences in the presence and number of gorgonian species from north to south Tunisia (Fig. 3) could be associated with the geomorphological features of the bottoms and hydrological conditions. The northern coast from the Algerian border to Kélibia (sector 1) is characterized by the dominance of rocky bottoms and is under the influence of strong currents (Sammari et al. 1999, Anonyme 2002, Ben Ismail et al. 2014), while the coverage of hard bottom decreases along the eastern coast from Kélibia to Ras Kapudia (sector 2), and hard bottom is almost absent in southern Tunisia (Gulf of Gabès) (sector 3) (Ktari-Chakroun and Azouz 1971, Azouz 1973, Azouz and Ben Othman 1975).

The dominant gorgonian species in Tunisian marine waters are *E. singularis, E. cavolini* and *Corallium rubrum*, a finding which is consistent with the observations in other Mediterranean areas, with the exception of *Paramuricea clavata*, which is another species that is widely distributed in the mainly western basin of the Mediterranean and the Adriatic (Harmelin and Marinopoulos 1994, Linares et al. 2008, Aguilar et al. 2015). *E singularis* is the most common species, and it was the only species present in all three study sectors. According to Linares et al. (2008), this species can tolerate an extensive range of abiotic factors and can dwell in shallow infralittoral and coralligenous habitats. This wide tolerance was proven in Tunisian waters, as *E. singularis* was observed in the Fora Mostafa zone at 40 to 55 m depth (Ben Mustapha et al. 2004) (central part of the Gulf of Gabès, sector 3) despite the fact that this area is characterized by muddy bottoms and subject to intense shrimp trawling (Hattour 1991, El Abed and Hattour 1997). The other two gorgonian species that were most common in Tunisia were the yellow gorgonian *Eunicella cavolini* and the red coral *Corallium rubrum*. The yellow gorgonian was found on rocky bottoms between depths of 15 and 50 m, as reported in other areas of the Mediterranean Sea (Sini et al. 2015). The results of this study indicate that the current red coral populations are found only at depths deeper than 40 to 60 m (Table 2). However, this species was recorded at a depth of 20 m in Tunisia several decades ago (Anonyme 2016a,b). This shift in the depth distribution can be attributed to the overexploitation of the red coral populations at shallow depths (Anonyme 2016a,b, Garrabou et al. 2017).

The information obtained on gorgonian distribution in Tunisian waters from this study should be considered as baseline data. Despite the research conducted, it is clear that our sampling strategy underestimated the presence of some species, such as *Paramuricea clavata* and *Leptogorgia sarmentosa*. Increasing the number of sampling sites with scuba diving and remotely operated vehicles will provide a more accurate view on the gorgonian distribution, especially in the northern and eastern sections of the study area (sectors 1 and 2).

Since gorgonians are in general long-lived organisms that display slow population dynamics, they are particularly vulnerable to anthropogenic disturbances, especially the direct and indirect impacts of fishing and climate change (e.g. Garrabou and Harmelin 2002, Bo et al. 2014, Garrabou et al. 2009). Fishing activities can cause severe damage to the habitats dominated by gorgonian species. Trawling nets and other fishing gear have been found entangled in gorgonian forests, causing lesions and breakages of a few branches up to complete colonies (Bavestrello et al. 1997, Bo et al. 2014, Giusti et al. 2015). In Tunisia, divers in the Tabarka (L1) and La Marsa (L8) localities reported much more dense gorgonian populations in the past, and they noted that trawling and fishing activities might be the primary causes of the observed decline. In fact, the gorgonian records provided in this study from the LEK surveys of fishermen were from gorgonians caught in trawling nets or long lines. Regarding the effects of climate

Table 4. – Conservation frameworks of Tunisian gorgonian species.

Species	Endemic species	IUCN category	Other conservation frameworks
Eunicella singularis (Esper, 1791)	No	Near-threatened	Action Plan for the Conservation of the Coralligenous and Other Calcareous Bio-Concretions in the Mediterranean Sea
Eunicella cavolini (Koch, 1887)	No	Near-threatened	Action Plan for the Conservation of the Coralligenous and Other Calcareous Bio-Concretions in the Mediterranean Sea
Corallium rubrum (Linnaeus, 1758)	No	Endangered	- Protocol SPA/BD Annex III - Bern Convention Annex III - EU Habitats Directive Annex V - REC.CMGFCM/ 36/2012/1 On further measures for the exploitation of red coral in the GFCM area. REC.CMGFCM/ 35/2011/2 On the exploitation of red coral in the GFCM Competence Area. - Action Plan for the Conservation of the Coralligenous and Other Calcareous Bio-Concretions in the Mediterranean Sea
Leptogorgia sarmentosa (Esper, 1789)	No	Least concern	-----
Eunicella verrucosa (Pallas, 1766)	No	Near-threatened	-----
Paramuricea clavata (Risso, 1826)	No	Vulnerable	Action Plan for the Conservation of the Coralligenous and Other Calcareous Bio-Concretions in the Mediterranean Sea
Paramuricea macrospina (Koch, 1882)	Mediterranean endemic species	Data deficient	-----
Ellisella paraplexauroides Stiasny, 1936	No	Vulnerable	Protocol SPA/BD Annex II
Bebryce mollis Philippi, 1842	No	Data deficient	-----
Villogorgia bebrycoides (Koch, 1887)	No	Data deficient	-----
Isidella elongata (Esper, 1788)	No	Critically endangered	-----

change, over the last several decades mass mortality events associated with warming have affected several sessile benthic macroinvertebrate organisms, including gorgonian species such as *Paramuricea clavata, Corallium rubrum, E. singularis* and *E. cavolini*, which were among the most affected species (Garrabou et al. 2009). In Tunisia, only one mass mortality in the northern gorgonian populations was reported in 1999 (Cerrano et al. 2000). However, the lack of systematic monitoring schemes and the recurrence of these events in other areas of the Mediterranean Sea make it very likely that other events have affected Tunisian populations.

Implications for conservation of gorgonian populations

As a result of negative impacts of human activities on gorgonian species, 7 out of the 11 species reported in Tunisian shallow and deep-sea waters are included in different conservation measures (Table 4). According to the Mediterranean Anthozoan IUCN Red List, three species are considered near-threatened and four species are considered threatened (Otero et al. 2017, Table 4). Among the threatened species, the deep-sea gorgonian *Isidella elongata* is listed as a critically endangered species, and the leading cause of this status is the anthropogenic impact caused by trawling. This species has almost disappeared from the Mediterranean Sea (Fabria et al. 2014). Since the presence of *Isidella elongata* in Tunisia was reported more than 50 years ago (Maurin 1962), specific sampling campaigns on deep-sea bottoms are urgently needed to assess the presence of this species and other deep gorgonian species. The red coral, *Corallium rubrum*, is considered an endangered species, and the major and oldest source of disturbance to this species is intensive exploitation. In fact, *C. rubrum* is also included in Annex III of the Barcelona Convention, which also confers the need to establish management plans for this species (Garrabou et al. 2017, Table 4). Finally, *Paramuricea clavata* and *Ellisella paraplexauroides* are considered vulnerable species. In addition to these species, all gorgonians dwelling in the coralligenous assemblages, such as *E. singularis* and *E. cavolini*, benefit from conservation measures included at the habitat level (Table 4).

The overview of the species richness and distribution of gorgonians in Tunisian waters could be considered a basic step that will contribute to the implementation of management and conservation strategies for these emblematic Mediterranean species. The highest gorgonian species diversity was found in the northern and eastern parts of Tunisia and particularly in the MPAs of Zembra and Galite. This finding confirms the role of MPAs in preserving species. Therefore, there is a need to create more MPAs, as suggested by Anonyme (2011) within the framework of the MPAs created for Cap Tabarka and Rocher Mérous in the Tabarka locality. This work also supports the management measures proposed by Jaziri et al. (2016) for the conservation of the red coral, *Corallium rubrum*, beyond areas where harvesting is prohibited. More detailed studies of the habitats and species distribution, as well as the assessment of the conservation status of gorgonian populations, should be rapidly implemented to identify key areas for management and conservation that should include the designation of marine sanctuaries.

ACKNOWLEDGEMENTS

We warmly acknowledge fishermen and divers for their precious collaboration during the LEK interviews. This study was supported by the "Tropical signals program" of the Mediterranean Science Commission and was partially funded by the Prince Albert II of Monaco Foundation "MIMOSA project Are Mediterranean marine protected areas efficient against warming effects?" Joaquim Garrabou is part of the Marine Conservation Research Group (MedRecover, 2014 SGR 1297) from the Generalitat de Catalunya.

REFERENCES

Aguilar R. 2004. The corals of the Mediterranean. Oceana, Fundación Biodiversidad, Madrid, 86 pp.

Aguilar C., Sànchez J.A. 2007. Phylogenetic hypotheses of gorgoniid octocorals according to ITS2 and their predicted RNA secondary structures. Mol. Phylogenet. Evol. 43: 774-786. https://doi.org/10.1016/j.ympev.2006.11.005

Aguilar R., Goffredo S., Garcia S., et al. 2015. *Paramuricea macrospina*. The IUCN Red List of Threatened Species. http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T50012470A50609268.en

Andromède. 2010a. Etude et cartographie des biocénoses marines de l'archipel de la Galite, Tunisie. Initiative pour les petites îles de Méditerranée. Contrat OEil d'Andromède/Agence de l'eau. 132 pp.

Andromède. 2010b. Etude et cartographie des biocénoses marines de l'île de Zembra, Tunisie. Initiative pour les petites îles de Méditerranée. Contrat OEil d'Andromède/Agence de l'eau. 122 pp.

Anonyme. 2002. Rapport national sur la biodiversité marine et côtière en Tunisie programme d'action stratégique pour la conservation de la biodiversité en méditerranée (PAS/BIO). Centre d'Activites Régionales pour les Aires Spécialement Protégées CAR/ASP Boulevard de l'Environnement - Tunisie

Anonyme. 2011. Etude pour la réalisation du diagnostic et définition des mesures de protection, d'aménagement et de gestion pour les sites marins des Tunnels et du Rocher aux Mérous à Tabarka. 80 pp.

Anonyme. 2016a. Commissariat Régional de Développement Agricole (CRDA) de Jendouba, arrondissement de pêche de Tabarka, données sur la pêche dans la région Nord de la Tunisie.

Anonyme. 2016b. Commissariat Régional de Développement Agricole (CRDA) de Bizerte, arrondissement de pêche de Bizerte, données sur la pêche dans la région Nord de la Tunisie.

Azouz A. 1973. Les fonds chalutables de la région Nord de la Tunisie. 1: Cadre physique des côtes Nord de la Tunisie. Bull. Inst. Océanogr. Pêche Salammbô 2: 473-564.

Azouz A., Ben Othman S. 1975. Les fonds chalutables de la région est de la Tunisie (de Kélibia à Mahdia). Bull. Inst. Natl. Sci. Tech. Océanogr. Pêche Salammbô 4: 49-59.

Azzurro E., Moschella P., Maynou F. 2011. Tracking signals of change in Mediterranean fish diversity based on local ecological knowledge. PLoS ONE 6: e24885. https://doi.org/10.1371/journal.pone.0024885

Ballesteros E. 2006. Mediterranean coralligenous assemblages: a synthesis of present knowledge. Oceanogr. Mar. Biol. Ann. Rev. 44: 123-195. https://doi.org/10.1201/9781420006391.ch4

Bavestrello G., Cerrano C., Zanzi D., et al. 1997. Damage by fishing activities to the Gorgonian coral *Paramuricea clavata* in the Ligurian Sea. Aquat. Conserv. Mar. Freshw. Ecosyst. 7: 253-262. https://doi.org/10.1002/(SICI)1099-0755(199709)7:3<253::AID-AQC243>3.0.CO;2-1

Bayer F.M., Grasshoff M., Verseveldt J. 1983. Illustrated trilingual glossary of morphological terms applied to Octocorallia. E.J. Brill, Leiden, 74 pp.

Ben Ismail S., Schroeder K., Sammari C., et al. 2014. Interannual variability of water mass properties in the Tunisia-Sicily Channel. J. Mar. Syst. 135: 14-28. https://doi.org/10.1016/j.jmarsys.2013.06.010

Ben Mustapha K., Afli A. 2007. Quelques traits de la biodiversité marine de Tunisie: Proposition d'aires de conservation et de gestion. Report of the MedSudMed Expert Consultation on Marine Protected Areas and Fisheries Management. MedSudMed Technical Documents. Rome (Italy), pp. 32-55.

Ben Mustapha K.B., Afli A., Hattour A., et al. 2004. Sessile megabenthic species from Tunisian littoral sites. MedSudMed Technical Documents, pp. 1-16.

Bo M., Bava S., Canese S., et al. 2014. Fishing impact on deep Mediterranean rocky habitats as revealed by ROV investigation. Biol. Conserv. 171: 167-176. https://doi.org/10.1016/j.biocon.2014.01.011

Bouafif C., Langar H., Ouerghi A. 2014. Proceedings of the 2nd Mediterranean Symposium on the conservation of coralligenous and other calcareous bio-concretions (Portorož, Slovenia, October 29-30). UNEP-MAP-RAC/SPA, pp. 235-236.

Boughedir W., Rifi M., Shakman E., et al. 2015. Tracking the invasion of *Hemiramphus far* and *Saurida undosquami* along the southern Mediterranean coasts: a local ecological knowledge study. Med. Mar. Sci. 16: 628-635. https://doi.org/10.12681/mms.1179

Bradai M.N., Quignard J.P., Bouain A., et al. 2004. Ichtyofaune autochtone et exotique des côtes tunisiennes: recensement et biogeography. Cybium 28: 315-328.

Carpine C., Grasshoff M. 1975. Les gorgonaires de la Méditerranée. Bull. Inst. Océanogr. Monaco 71: 1-140.

Cerrano C., Bavestrello G. 2008. Medium-term effects of die-off of rocky benthos in the Ligurian Sea. What can we learn from gorgonians? Chemistry and Ecology 24: 73-82. https://doi.org/10.1080/02757540801979648

Cerrano C., Bavestrello G., Bianchi C.N., et al. 2000. A catastrophic mass-mortality episode of gorgonians and other organisms in the Ligurian Sea (North-western Mediterranean), summer 1999. Ecol. Lett. 3: 284-293. https://doi.org/10.1046/j.1461-0248.2000.00152.x

Cerrano C., Cardini U., Bianchelli S., et al. 2013. Red coral extinction risk enhanced by ocean acidification. Sci. Rep. 3: 1457. https://doi.org/10.1038/srep01457

Direction Générale de la Pêche et de l'Aquaculture (DGPA). 2016. Rapport Technique, Tunis: Minist. Agric. Ressour. Hydraul. Pêche. 26 pp.

El Abed A., Hattour A. 1997. Le Golfe de Gabès: une préoccupation méditerranéenne. Environnement littoral, Atelier CIESM, Marseille, France, 3 pp.

Fabria M.C., Pedela L., Beuckb L., et al. 2014. Megafauna of vulnerable marine ecosystems in French Mediterranean submarine canyons: Spatial distribution and anthropogenic impacts. Deep-Sea Res. Pt II 104: 184-207. https://doi.org/10.1016/j.dsr2.2013.06.016

Garrabou J., Harmelin J.G. 2002. A 20-year study on life-history traits of a harvested long-lived temperate coral in the NW Mediterranean: insights into conservation and management needs. J. Anim. Ecol. 71: 966-978. https://doi.org/10.1046/j.1365-2656.2002.00661.x

Garrabou J., Coma R., Benssoussan N., et al. 2009. Mass mortality in NW Mediterranean rocky benthic communities: effects of the 2003 heat wave. Glob. Change Biol. 15: 1090-1103. https://doi.org/10.1111/j.1365-2486.2008.01823.x

Garrabou J., Linares C., Montero-Serra I., et al. 2017. Informe sobre el estado de las poblaciones de coral rojo (*Corallium rubrum*) en las aguas de Cataluña. Departament d'Agricultura, Ramaderia, Pesca i Alimentació, Generalitat de Catalunya. 39 pp. http://agricultura.gencat.cat/web/.content/de_departament/de10_publicacions_dar/de10_a02_01_monografies_altres/documents/fitxers_estatics/2017_Informe-estado-poblaciones-coral-costa-catalana-20170117.pdf

Giusti M., Cerrano C., Angiolillo M., et al. 2015. An updated overview of the geographic and bathymetric distribution of *Savalia savaglia*. Mediterr. Mar. Sci. 16: 128-135. https://doi.org/10.12681/mms.890

Grinyó J., Gori A., Ambroso S., et al. 2016. Diversity, distribution and population size structure of deep Mediterranean gorgonian assemblages (Menorca Channel, Western Mediterranean Sea). Prog. Oceanogr. 145: 42-56. https://doi.org/10.1016/j.pocean.2016.05.001

Hattour A. 1991. Le chalutage dans les eaux tunisiennes, réalités et considérations législatives particulièrement dans les golfes de Tunis et de Gabès. Notes. Inst. Natn. Scient. Tech. Océanogr. Pêches Salammbô 1: 1-28.

Harmelin J.G., Marinopoulos J. 1994. Population structure and partial mortality of the gorgonian *Paramuricea clavata* (Risso) in the North-Western Mediterranean (France, Port-Cros Island). Mar Life 4: 5-13.

Jaziri S. 2017. Le corail rouge *Corallium rubrum* (Linnaeus, 1758) en Tunisie: discrimination des populations, structures démographiques et aménagement des pêcheries. Ph. D. thesis. 209 pp.

Jaziri S., Costantini F., Rugiu L., et al. 2016. Does historical harvesting affect colony size distributionand genetic diversity in *Corallium rubrum* (Linnaeus, 1758)? Evidences from the Southern Mediterranean commercial banks. Hydrobiologia 784: 211-224. https://doi.org/10.1007/s10750-016-2875-7

Ktari-Chakroun F., Azouz A. 1971. Les fonds chalutables de la région sud-est de la Tunisie (golfe de Gabès). Bull. Inst. Océanogr. Pêche Salammbô 2: 5-47.

Kipson S., Linares C., Čižmek H., et al. 2014. Population structure and conservation status of the red gorgonian *Paramuricea clavata* (Risso, 1826) in the Eastern Adriatic Sea. Mar. Ecol. 36: 982-993. https://doi.org/10.1111/maec.12195

Linares C., Coma R., Zabala M. 2008. Restoration of threatened red gorgonian populations: An experimental and modelling approach. Biol. Conserv. 141: 427-437. https://doi.org/10.1016/j.biocon.2007.10.012

Lubet P., Azouz A. 1969. Etude des fonds chalutables du golfe de Tunis. Bull. Inst. Océanogr. Pêche Salammbô 1: 87-111.

Marbà N., Jordà G., Agustí S., et al. 2015. Footprints of climate change on Mediterranean Sea biota. Front. Mar. Sci. 2: 56. https://doi.org/10.3389/fmars.2015.00056

Maurin C. 1962. Etude des fonds chalutables de la Méditerranée occidentale (Ecologie et Pèche). Résultats des campagnes des navires océanographiques «Président-Théodore-Tissier» 1957 et 1960 et «Thalassa» 1960 et 1961. Rev. Trav. Inst. Pêches marit. 26: 163-218.

Molina A.C., Montefalcone M., Vassallo P., et al. 2016. Combining literature review, acoustic mapping and in situ observations: an overview of coralligenous assemblages in Liguria (NW Mediterranean Sea). Sci. Mar. 80: 7-16. https://doi.org/10.3989/scimar.04235.23A

Otero M.M., Numa C., Bo M., et al. 2017. Overview of the conservation status of Mediterranean anthozoans. IUCN, Malaga, Spain. x + 73 pp.

Ponti M., Perlini R.A., Ventra V., et al. 2014. Ecological shifts in Mediterranean coralligenous assemblages related to gorgonian forest loss. PLoS ONE 9: e102782. https://doi.org/10.1371/journal.pone.0102782

Rivetti I., Fraschetti S., Lionello P., et al. 2014. Global warming and mass mortalities of benthic invertebrates in the Mediterranean Sea. PLoS ONE 9: e115655. https://doi.org/10.1371/journal.pone.0115655

Sammari C., Millot C., Taupier-Letage I., et al. 1999. Hydrological characteristics in the Tunisia-Sardinia-Sicily area. Deep-Sea Res. I 46: 1671-1703. https://doi.org/10.1016/S0967-0637(99)00026-6

Sini M., Kipson S., Linares C., et al. 2015. The yellow gorgonian *Eunicella cavolini*: demography and disturbance levels across the Mediterranean Sea. PLoS ONE 10: e0126253. https://doi.org/10.1371/journal.pone.0126253

Teixido N., Casas E., Cebrian E., et al. 2013. Impacts on coralligenous outcrop biodiversity of a dramatic coastal storm. PLoS ONE 8: e53742. https://doi.org/10.1371/journal.pone.0053742

Topçu E.N., Öztürk B. 2015. Composition and abundance of octocorals in the Sea of Marmara, where the Mediterranean meets the Black Sea. Sci. Mar. 79: 125-135. https://doi.org/10.3989/scimar.04120.09A

UN Environment/MAP. 2017. Action Plan for the Conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea. United Nations Environment Programme / Mediterranean Action Plan, Athens, Greece. http://www.rac-spa.org/sites/default/files/action_plans/pa_coral_en.pdf

Weinberg S. 1976. Revision of the common Octocorallia of the Mediterranean circalittoral. I. Gorgonacea. Beaufortia 24: 63-104.

Weinberg S. 1978. Revision of the common Octocorallia of the Mediterranean circalittoral. III. Stolonifera. Beaufortia 27: 139-176.

Weinberg S. 1979. Autoecology of shallow-water Octocorallia from Mediterranean rocky substrata. I. The Banyuls area. Bijdragen Tot Dierkunde 49: 1-15.

Weinberg S. 1980. Autoecology of shallow-water octocorallia from Mediterranean rocky substrata. II. Marseille, Cote d'Azur and Corsica. Bijdragen Tot Dierkunde 50: 73-86.

Zabala M., Ballesteros E. 1989. Surface-dependent strategies and energy flux in benthic marine communities or, why corals do not exist in the Mediterranean. Sci. Mar. 53: 3-17.