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Eleventh Meeting of Focal Points for SPAs

Rabat, Morocco, 2-5 July 2013

DESCRIPTION OF THE ECOLOGY OF THE GULF OF LIONS SHELF AND SLOPE AREA AND IDENTIFICATION OF THE AREAS THAT MAY DESERVE TO BE PROTECTED

Delegates are kindly requested to bring their documents to the meeting

UNEP
RAC/SPA - Tunis, 2013

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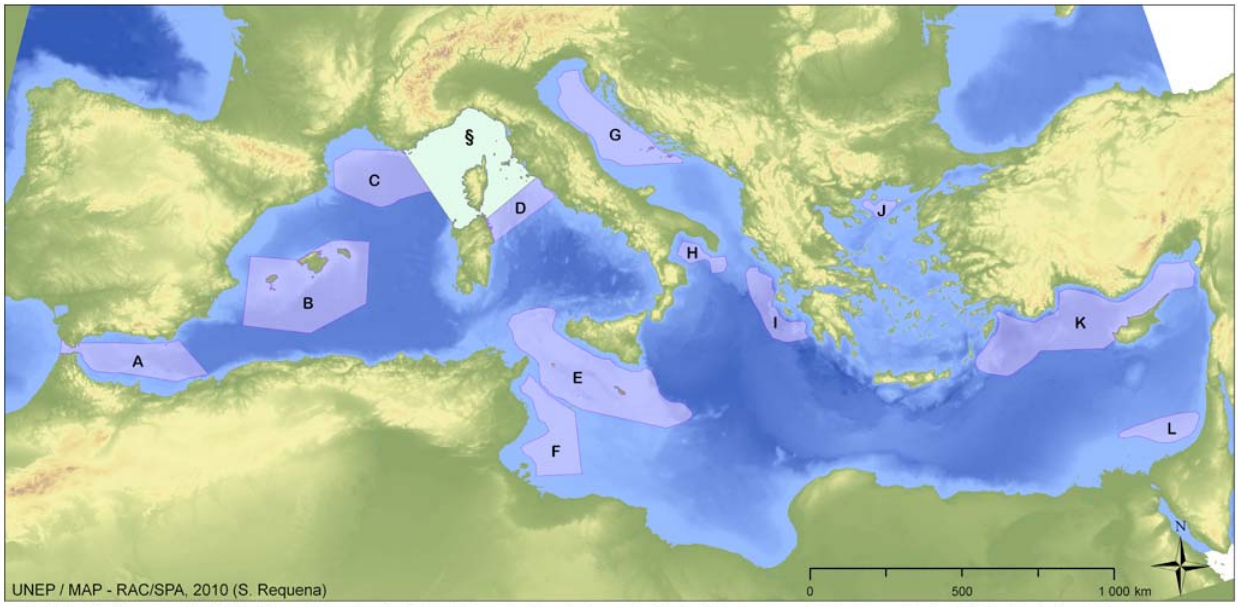
1. Introduction

1.1 Context of this report

The Regional Activity Centre for Specially Protected Areas (UNEP-MAP-RAC/SPA), with support from the European Commission and the Mediterranean Trust Funds, started in 2008 an ambitious project to identify and establish Marine Protected Areas in the open seas, including the deep seas, in order to promote the establishment of a representative ecological network of protected areas in the Mediterranean. The first phase of the project was based on the provisions of the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD Protocol) and was completed at the end of 2009. Its main result was the identification of twelve areas as priority conservation areas in the open seas, including the deep seas, likely to include sites that could be candidates for inclusion in the SPAMI list. One of these areas is the so-called 'Gulf of Lions shelf and slope' area (Figure 1).



A: Alborán Seamounts; B: Southern Balearic; C: Gulf of Lions shelf and slope; D: Central Tyrrhenian; E: Northern Strait of Sicily (including Adventure and nearby banks); F: Southern Strait of Sicily; G: Northern and Central Adriatic; H: Santa Maria di Leuca; I: Northeastern Ionian; J: Thracian Sea; K: Northeastern Levantine Sea and Rhodes Gyre; L: Nile Delta Region

§: Pelagos Sanctuary declared as SPAMI in 2001

Figure 1. Priority Conservation Areas in the open seas, includig the deep sea, likely to contain sites that could be candidates for the SPAMIs list.

The listing of Specially Protected Areas of Mediterranean Importance (SPAMIs) in the open seas, including the deep seas within the Barcelona Convention framework will allow the protection of a new set of habitat types, as well as the creation of new partnerships through a cooperative approach to conservation and management. Additionally, the full implementation of the provisions of the Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD Protocol) will improve the capacity to manage sites and the recovery of marine biodiversity in the open seas, including the deep seas.

RAC/SPA organised an Extraordinary Meeting of the Focal Points for Specially Protected Areas on 1 June 2010, in order to present the results of this first phase. The representatives of France and Spain informed the meeting of their countries' intention to pursue their cooperation with regard to the Gulf of Lions and to consider the possibility of preparing a joint proposal for the declaration of a SPAMİ in this open-sea area, including the deep seas. In this context, a second phase of the project was initiated with the objective to support France and Spain in a process of consultation and coordination geared to the identification of the potential site/s in the 'Gulf of Lions shelf and slope' (Figure 2) area that could be candidate(s) for inclusion in the SPAMI list. As these data are spread over several national research institutes, it was proposed that RAC/SPA assisted by several experts compiled in a report all the information available. The report should accomplish the required goal of: i) establishing a state of knowledge on the ecology of the area under consideration, and ii) facilitating the work of the countries to prepare as appropriate the presentation report for the site(s) of the 'Gulf of Lions shelf and slope' area likely to be candidate(s) for inclusion in the SPAMI List.

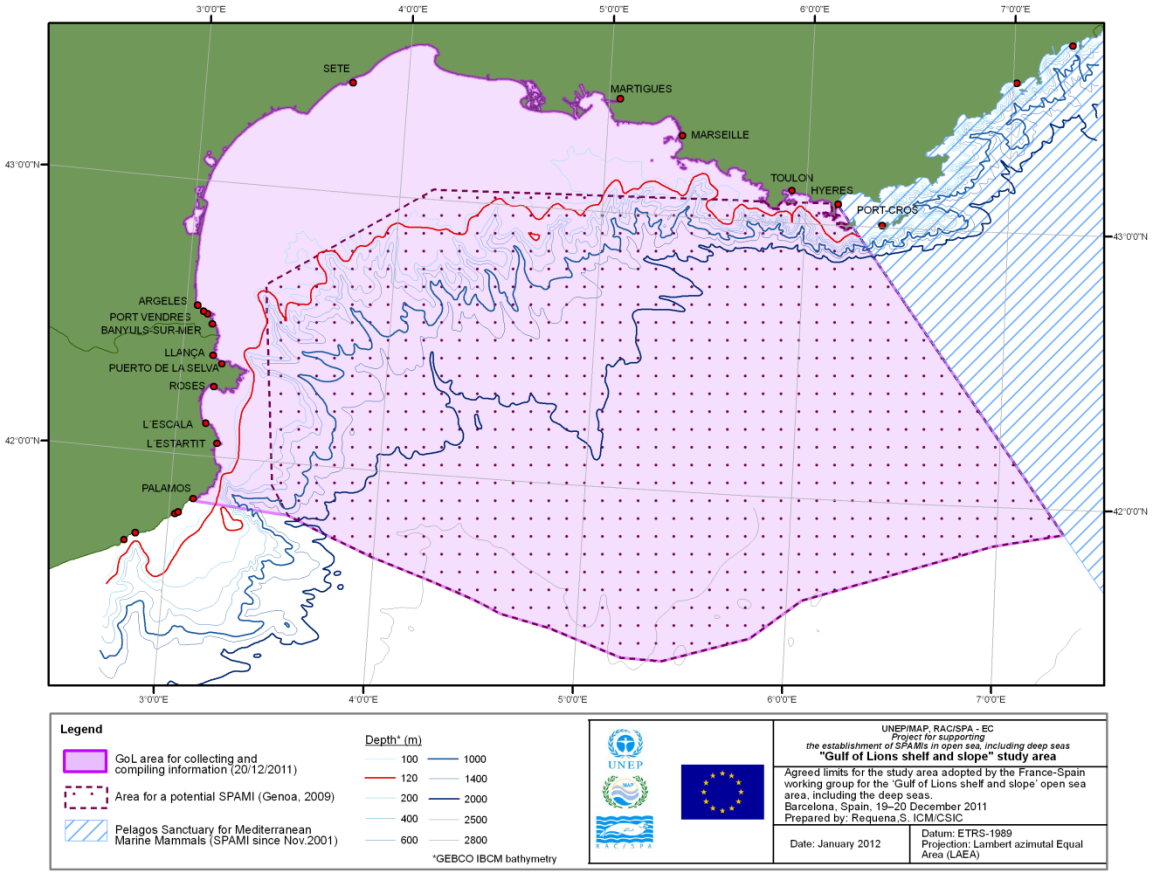


Figure 2. Area of study. Limits agreed for the study area adopted by the France-Spain working group for the Gulf of Lions shelf and slope open sea area. This area modifies the boundaries of the adopted area in the Genoa meeting in order to attend for the requeriments of seabirds and cetaceans.

1.2 Sources of information

France and Spain have carried out considerable research and exploration work in the Gulf of Lions area. Additionally, France (through the *Agence des aires marines protégées*) has been developing and implementing different surveys for improving its knowledge on the Gulf of

Lions within the Natura 2000 framework. Some surveys are ongoing (exploration of the canyons) and others are being launched (surveys of seabirds and marine mammals). However the conclusion of projects MEDSEACAN fom the *Agence des aires marines protégées* (France) and LIFE+INDEMARES from the *Ministerio de Agricultura, Alimentación y Medio Ambiente* (Spain) represent an important step forward in our understanding of the ecology of this system.

The "Mediterranean Sea Canyons" (MEDSeaCAN) programme was carried out from November 2008 to August 2010 and, probably one of the most ambitious ever undertaken to improve the understanding of submarine valleys in this area. Fullfilling an important need to address the lack of knowledge of these remarkable marine areas, it allowed data acquisition for a first inventory of habitats and species. The study area stretches from the Spanish border to the border of Monaco at depths between 150 and 700 meters.

One of the areas selected for the LIFE+ Project conducted on the Gulf of Lions "Inventory and designation of marine Natura 2000 areas in the Spanish sea" (INDEMARES Project) is the "Cap de Creus", which is the southernmost canyon of the Gulf of Lions oceanographic system. The project will be finished in December 2013 but some of the results were already published and at this moment is waiting for the implementation of the corresponding actions.

To achieve the project goals all relevant information on the geology, oceanography and ecology of the area was compiled at several scales of resolution and was combined in this report. The French and Spanish projects cited above have provided exhaustive information. The chief information for seabirds, cetaceans and fisheries was provided by "ad-hoc" tailored documents completed by specialists Carles Carboneras (seabirds), Lea David (cetaceans) and Henry Farrugio (fisheries), and complemented with reference publications (e.g. UNEP-MAP-RAC/SPA 2010a).

Most of the information compiled for this project is freely available. This includes a wide range of data, from software to raw and processed information from non-profit and public software and information providers: the Quantum GIS Project, the Open Source Geospatial Foundation Project, the SeaWiFS and the MODIS Projects, the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC), the GEBCO team and the British Oceanographic Data Centre (BODC), the IFREMER, the French *Agence des aires marines protégées*, the European Environment Agency (EEA), the European Environment Information and Observation Network (EIONET), the European Commission: Life+ Financial Instrument, the Communication and Information Resource Centre Administrator (CIRCA) and the European Marine Observation Data Network (EMODnet), the GoogleEarth™ community etc.

1.3 GIS work

The importance of Geographical Information Systems (GIS) in the marine environment has become increasingly evident in recent years. Information on oceanographic geology, environmental parameters, biota, human activities, risks, hazards, etc. is essential both for the development of new economic activities and for assessing the impact of those activities on the marine environment. Management policies and actions, including marine spatial

planning, need to be informed by the best-available data if they are to achieve long-term sustainable use and management of the marine environment and its resources.

Several actions geared at the compilation of such information and modelling are currently being developed in Europe. One of the most ambitious and relevant to our purpose is EUSeaMap, a broad-scale modelled habitats map of European seabed under the EUNIS classification, as well as undertaking broad-scale mapping of the western Mediterranean for the first time. The Regional Activity Centre for Specially Protected Areas (UNEP-MAP-RAC/SPA) considered the importance of the marine georeferenced information for the project to the identification of possible SPAMIs in the Mediterranean areas beyond national jurisdiction (ABNJ) and promoted a geodatabase covering all the Mediterranean which is being updated and completed progressively (UNEP-MAP-RAC/SPA 2010c and d).

This report will provide additional information to this database as well as an update of previous information on the Gulf of Lions area in the form of georeferenced files (shapefiles format (.shp) and .kmz files for GoogleEarth™ display) and map layouts in editable Adobe™ portable document file (pdf) high-resolution format and portable network graphics (.png) and extended (enhanced) Windows metafile format (.emf).

1.4 Further considerations

This report reflects the current knowledge at a suitable resolution to achieve the goals mentioned above. Survey methods and technologies have improved dramatically in the fields of remote sensing and imaging and advances such as multi-beam echo sounding, side-scan sonar, manned submersibles and ROVs (remote operated vehicle) able to provide new and revealing high detailed data on the seafloor going beyond the bathymetric ranges never reached before. The Gulf of Lions has been studied intensively in a Mediterranean context; however, a gap in knowledge of deep-sea ecosystems continues to persist, especially beyond the 600 m depth.

New faunal communities and species are being described that are actually not listed in the official catalogues of marine habitats and communities such as the reference list of marine habitat types (UNEP-MAP-RAC/SPA 2006), the European Nature Information System (EUNIS) and the Habitats Directive annexes (Directive 92/43/EEC). The revision and updating of such tools is thus necessary, otherwise it will invalidate its use.

Overall, the information available to date is not comprehensive, particularly for the deep-sea. Thus the periodical revision and updating of this report is recommended in order to facilitate the listing of the biologically-significant areas in the Gulf of Lions as candidate(s) SPAMI site(s) under the SPA/BD Protocol.

2. International regulations and conservation framework

2.1. Natura 2000 network: Habitats Directive (92/43/EEC) and Birds Directive (79/409/CEE)

The European Directives 92/43/EEC and 79/409/CEE (today replaced by the Directive 2009/147/EC) are the base for the establishment of areas for the conservation of biodiversity in the territory of the European Union within the network Nature 2000. The European Commision considers Natura 2000 network is the “centrepiece of EU nature & biodiversity policy”. The aim of the network is to *assure the long-term survival of Europe's most valuable and threatened species and habitats*. Natura 2000 should not to be consireded as complex of nature reserves managed under restrictictons and prohibitions where all human activities are excluded. Whereas the network will certainly include nature reserves most of the protected areas (both terrestrial and marine, eg. Figure 3. the emphasis will be on ensuring that future management is sustainable, both ecologically and economically. The establishment of theis network of protected areas also fulfils a Community obligation under the UN Convention on Biological Diversity.

2.2. Sites of Community Importance (SCI), Special Protection Areas for birds (SPA). and and Special Areas of Conservation (SAC)

The Directive 92/43/EEC regarding the conservation of the natural habitats and the wild fauna and flora establishes the obligation to designate areas to guarantee or to restore in a state of favorable conservation the habitats and species in its area of natural distribution. Each Member State will have to present its proposal of areas that will have to include the geographic limits of each, the habitats and species of communitarian interest by which it is declared and the valuation of some elements of importance for the sites. The Directive 2009/147/EC on the conservation of wild birds establishes the obligation to designate the most suitable areas in number and surface for the conservation of species of communitarian interest and the migratory species including in its Annexes. The selection of sites must be driven by scientific criteria. These sites automatically become part of the Natura 2000 network. The listing process for SPAs will be the same used for SIC areas.

Once the lists of “Sites of Community Importance” have been adopted, it is for the Member States to designate all of these sites as “Special Areas of Conservation”, as required by the Habitats Directive. They should give priority to those sites that are most threatened and/or that are of most importance in conservation terms. During this period, Member States must take the necessary management or restoration measures to ensure the favourable conservation status of those sites.

2.3. Conservation of the network Nature 2000, monitoring and surveillance

The responsible administrations in each Member State will adopt, in the areas included in Nature 2000 network, suitable management plans and statutory, administrative or contractual measures to fulfill the conservation purposes. States must take appropriate steps to avoid, in the special areas of conservation, the deterioration of natural habitats and the habitats of species as well as disturbance of the species for which the areas have been designated. They will also have to guard so that the accomplishment of plans, programs and projects outside SIC, SAC or SPA areas that can have an effect on them are put under evaluation and, where appropriate, compensatory measures applied to revert the possible negative effects.

Likewise, administrations will watch the conservation status of the habitats and the species of communitarian interest, by means of an annual report. They will also inform the European Commission on a regular basis of the results of the management plans and programs, and of those of newly proposed measures.

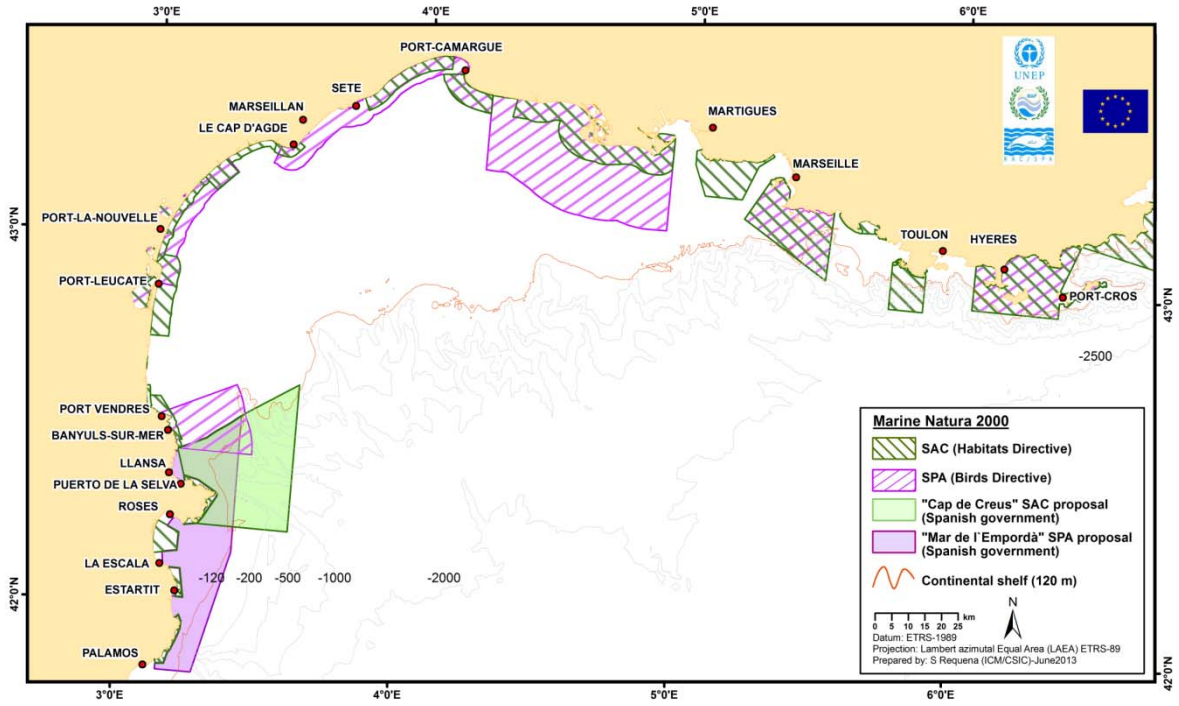


Figure 3. Proposed marine areas in the area in study under the Natura 2000 framework.

2.4 International agreements: the Barcelona Convention and other instruments for conservation

Different international instruments for the conservation of the biodiversity establish the possibility, or even the obligation, to declare protected areas to secure their objectives: among others, the Barcelona Convention on the protection of the environment in the Mediterranean Sea, the Ramsar Convention on the protection of wetlands as habitats for aquatic birds, the UNESCO World Heritage and the ACCOBAMS agreement on the conservation of cetaceans. The OSPAR convention for the protection of the marine environment of the NE Atlantic, is not applicable to the Mediterranean Sea per se, but it is

applicable to all species that move across the Strait of Gibraltar. It is possible thus, in the future, that other agreements regarding the conservation of the biodiversity establish the protection of areas as instruments to secure their objectives, or also that Spain and France together assign new specific commitments within the framework of the international legislation, to some of the present and future protected areas.

2.5 Other dispositions applicable to Nature 2000 network areas and SPAMIs

The Regulation (EC. number 1967/2006), regarding the measures of management for the sustainable operation of the fishing resources in the Mediterranean Sea, establishes the following regime of additional protection, common to all areas within the Nature 2000 network and the Specially Protected Areas of Mediterranean Importance (SPAMI) that have been designated for the conservation of these habitats:

- Fishing using dredges, trawls and seines is prohibited over seabeds of marine vegetation constituted, in particular, by *Posidonia oceanica* or any other marine phanerogam.
- Fishing using dredges, trawls and seines is also prohibited over coralligenous and maërl habitats.
- The use of towed dredges and trawl nets at depths below 1000 meters is prohibited
- Moreover, Member States will adopt the appropriate measures to guarantee the suitable compilation of scientific information in order to identify and cartographically describe the habitats to be protected in accordance with the European Regulation.

The General Fisheries Commission for the Mediterranean (GFCM) in 2009, "*noting the SAC recommendations to ban the use of towed and fixed gears and longlines for demersal resources in an area on the continental shelf and slope of the Eastern Gulf of Lions […] and considering that more scientific information is needed with a view to understand the relevance of other adjacent areas on the continental shelf and slope for the protection of spawners and sensitive habitats as well as to better known the level and spatial distribution of the fishing effort exerted […]"* among other considerations (REC.CM-GFCM/33/2009/1) declared a fisheries restricted habitat in the area studied (Figure 4).

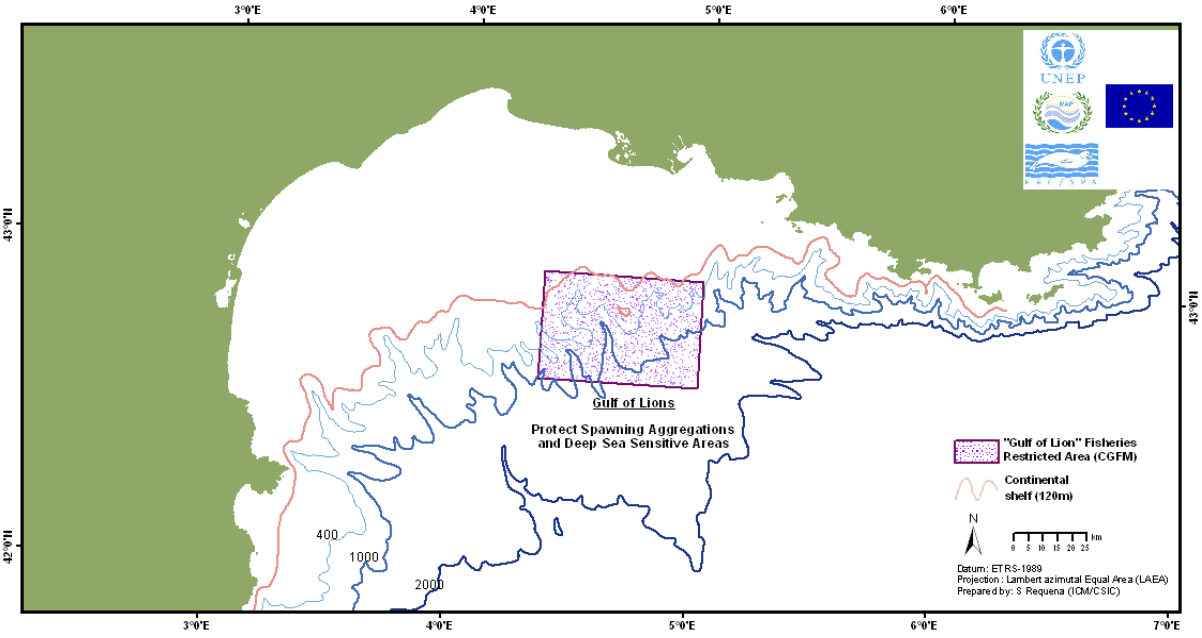


Figure 4. Fisheries restricted area (FRA) to protect spawning aggregations and deep-sea sensitive habitats in the Gulf of Lions. Recommendations GFCM/33/2009/1 and GFCM/2006/3 from FAO.

PART I

ABIOTIC AND BIOTIC CHARACTERISATION

3. Geological setting of the Gulf of Lions

3.1 General geomorphology

The Gulf of Lions is a passive, prograding continental margin that extends from Cap de Creus in Spain to Toulon in France (Louis, 1914; Russell, 1942; Ulses et al., 2008). It is characterized by having an unusually broad continental shelf for the Mediterranean basin, reaching lengths of up to 72 km in its widest locations. Its shelf break is well defined at 100-200 m depth and incised by a complex network of submarine canyons (Figure 5), which converge towards the base of the slope, with tributaries of different orders reaching depths of almost 2000 m (Canals et al., 2004). Due to differences in shelf width along the continental margin, some of these canyons can be found relatively close to the shore, just a few kilometres from land (for example Cap de Creus canyon in the western part of the gulf), while others appear relatively far offshore (e.g. Grand and Petit Rhône canyons in the eastern part of the gulf).

The intricate network of submarine canyons plays an important role in the dynamics of the continental margin. Canyon heads represent nearly 30% of the 120 m depth shelf break area and almost half of the slope surface can be attributed to canyon walls (Courp and Monaco, 1990). The continental slope gradient ranges from an average of 10° at its uppermost part, down to 2° at the deeper ends (Figure 6), close to 2000 m. The slope reaches the flat areas of the Balearic Basin plain at depths below 2500 m (Got and Aloisi, 1990).

The set of submarine canyons found on the continental margin of the Gulf of Lions mainly developed during the Quaternary period. The current morphology and sedimentary structure of the continental slope and rise of the gulf resulted from interactions between sediment supply, especially the inputs from the Rhône River, eustatic oscillations, mobility of Messinian evaporites, destabilization and remobilization of previously accumulated sediments and geodynamic evolution of the basin during the Plio-Quaternary (Canals and Got, 1986). The prevalence of these factors, added to more sporadic events, determined the formation of the majority of the submarine canyons in the gulf, with the exception of Cap de Creus and Petit Rhône canyons, both of tectonic origin (Canals and Got, 1986). Figure 7 shows actual modelled substrate in the estudied area.

3.1.1 Particular features

Continental margin and shelf

The Gulf of Lions continental margin[1] is dominated by complex pressure deformation structures covered by a relatively thin Holocene sediment layer irregularly distributed over the margin (Canals et al., 2004). The Holocene layer consists of acoustically transparent sediments, mainly formed by the deposition of terrigenous muds during the last sea level rise, approximately 18,000 years before present. This sedimentary cover is formed by alternating silty/clayey and sandy deposits and can be mainly found on inner- and mid-shelf regions (Got and Aloisi, 1990). It is thickest next to the Rhône River mouth (approximately 50 m) and becomes thinner towards the west. It is less than 10 m thick off the Roussillon shelf and does not exceed 1 m off Cap de Creus, allowing Quaternary rocky formations to outcrop on the inner part of the shelf (Durrieu de Madron et al., 2008).

The continental shelf[2] is mainly dominated by the terrigenous input of the Rhône River and by the dominant south-western currents of the region, which distribute the sediments all the way to the Cap de Creus region (Canals and Got, 1986). These sediments settle at different rates on the shelf, depending on the location, ranging from 10 to 60 cm per 100 years. The highest accumulation rates are found in the vicinity of the Rhône River mouth, where they range from 30 to 50 g $cm^{-2} \bullet y^{-1}$. Rates decrease rapidly seaward and gradually along-shore. The average accumulation rate on the shelf is 0.20-0.30 $g \bullet cm^{-2} \bullet y^{-1}$ (Zuo et al., 1997).

Continental slope

The continental slope is characterised by a complex network of submarine canyons that greatly influence sediment dispersal and accumulation. Differences in slope morphology and hydrodynamics affect the transit and sedimentation of terrigenous material. Sedimentary conditions on the continental slope seem to be highly unstable, as reworking and erosion reflect and result in complex morphology (Got and Aloisi, 1990). In general, Holocene deposits are thin on the Gulf of Lions continental slope, with 1-2 m average sediment thickness on canyon bases and 0.5 m on intercanyon highs and on deep-sea fans (Got and Aloisi, 1990). The sediment thickness is also reduced on canyon walls and can even be totally lacking due to erosion. The sedimentation rates on the slope decrease with increasing depths, with an average of 0.09 g $cm^{-2} \bullet y^{-1}$ for the upper slope and 0.03 g $cm^{-2} \bullet y^{-1}$ for the deeper part of the slope (Zuo et al., 1997)

According to Canals and Got (1986), the Gulf of Lions continental shelf and rise can be divided in two clear sectors, which respond to differences in morphology and functioning, the N-S dividing line being placed on top of the Sete canyon:

[1] The area between a continent's shoreline and the beginning of the ocean floor. It includes the continental shelf, continental rise, and continental slope.

[2] That part of the continental margin which is between the shoreline and the shelf break or, where there is no noticeable slope, between the shoreline and the point where the depth of the superjacent water is approximately between 100 and 200 m. In the Gulf of Lions context the shelfbreak can be considered to lye around 120 m depth (Cameron and Askew, 2011).

- From Cap de Creus canyon to Sete canyon. The submarine canyons show a radial disposition and average slopes are somewhat low (7º). The confluence zone of these canyos shows the highest deposition rates.

- From Sete Canyon to Petite Rhône canyon. The submarine canyons show a parallel distribution following a N-S orientation. The slope in this area is a bit higher than in the other sector (11º), promoting more intense sediment transits.

4. The Sardo-Balear Abyssal plain

The Sardo-Balear Abyssal plain is characterised by its very flat morphology and by presenting very low sedimentation rates (Canals and Got, 1986). Submarine canyons seem to play an important role in the formation of Holocene deposits, mainly due to downslope sediment transport, which is believed to be more active during low-sea level stages. Several sedimentary bodies can be found on the abyssal plain, which seem to be related to the major submarine canyons. These bodies can be interpreted as sandy-clay deposits. The sedimentation processes are amplified in front of the major river sources, such as the Rhône River, and in some specific areas (for example Lacaze-Duthiers Canyon. where a deep-sea fan is formed (Got and Aloisi, 1990).

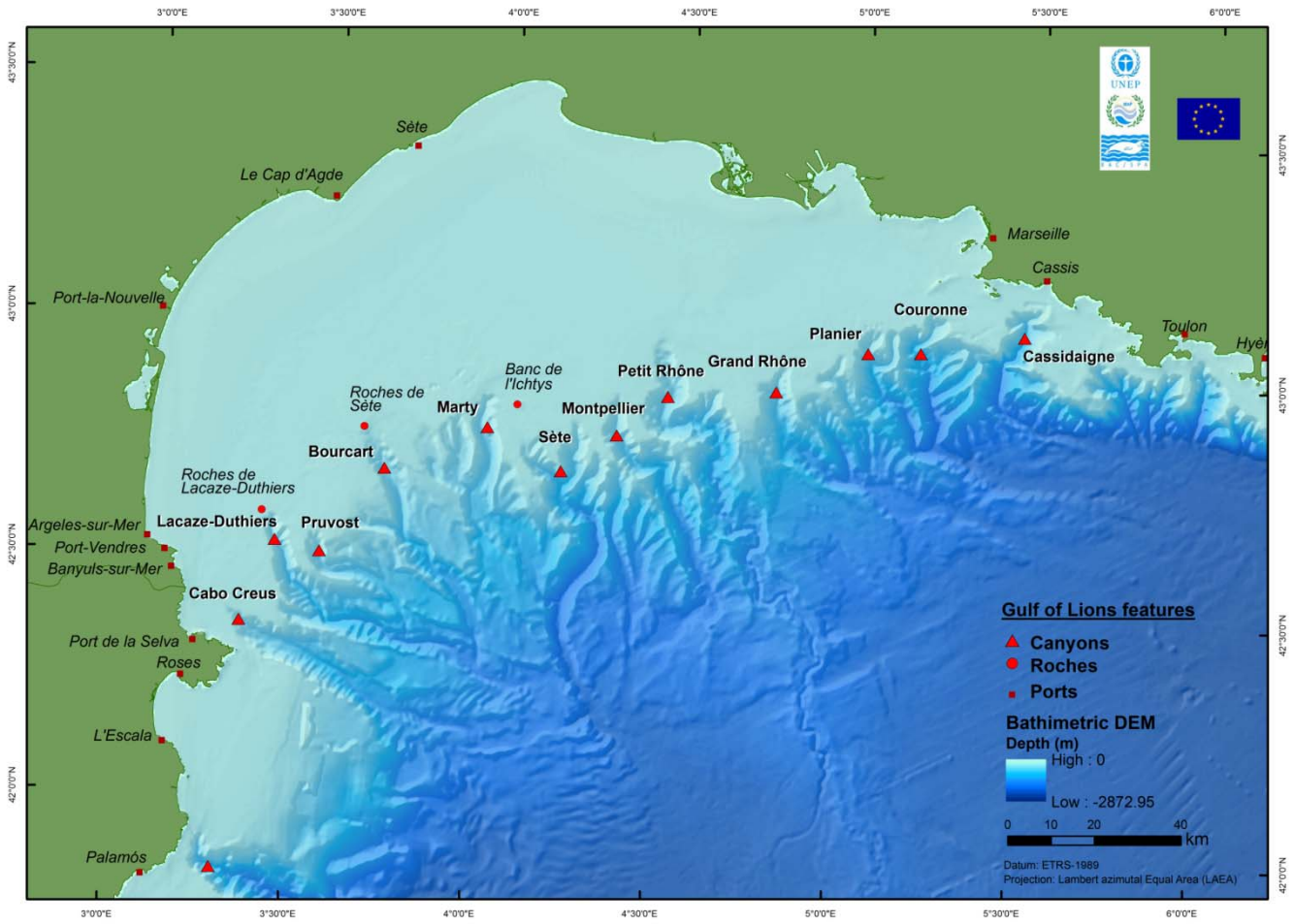


Figure 5. Submarine features of the Gulf of Lions.

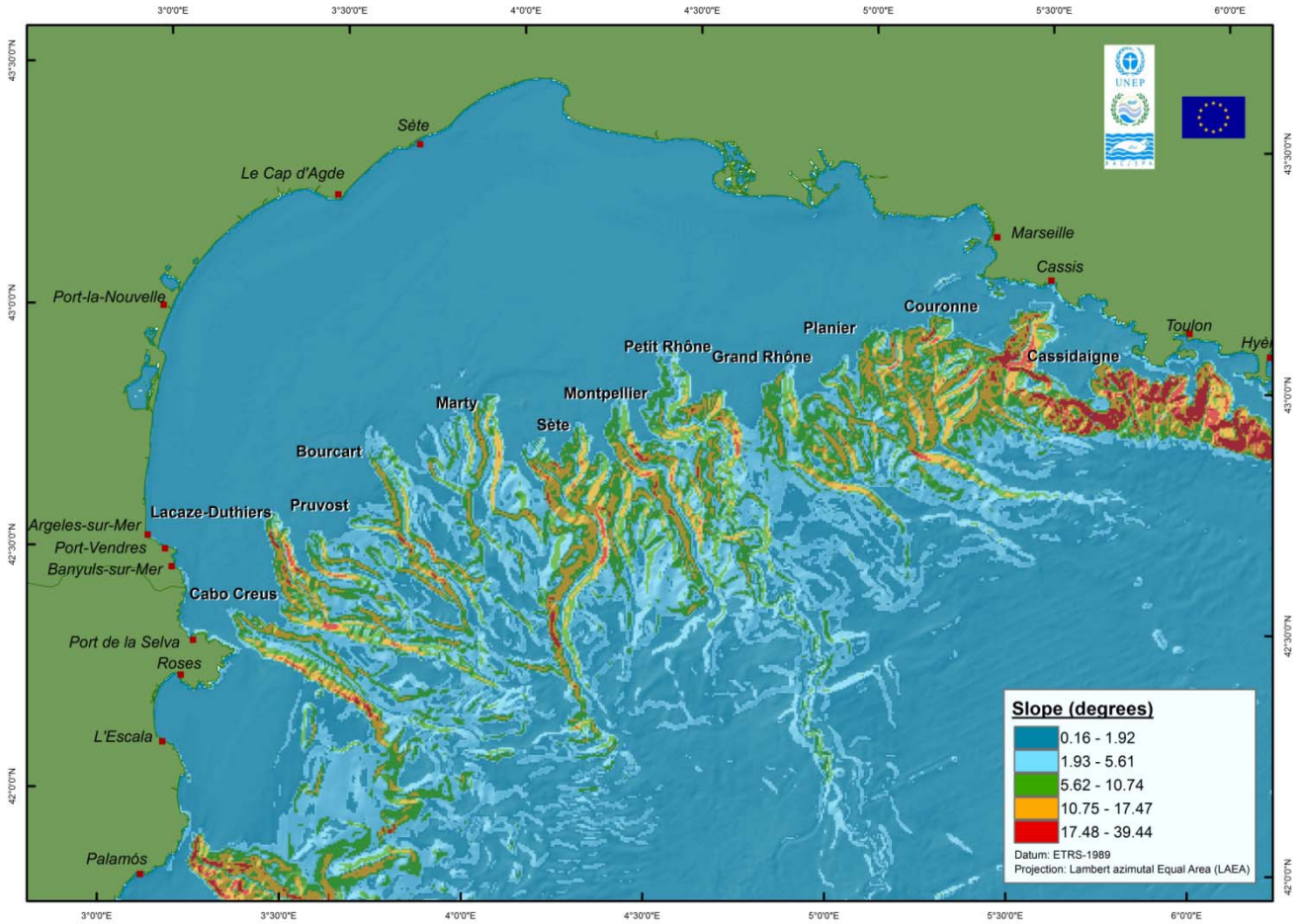


Figure 6. Slope gradient (degrees) in the Golf of Lions area.

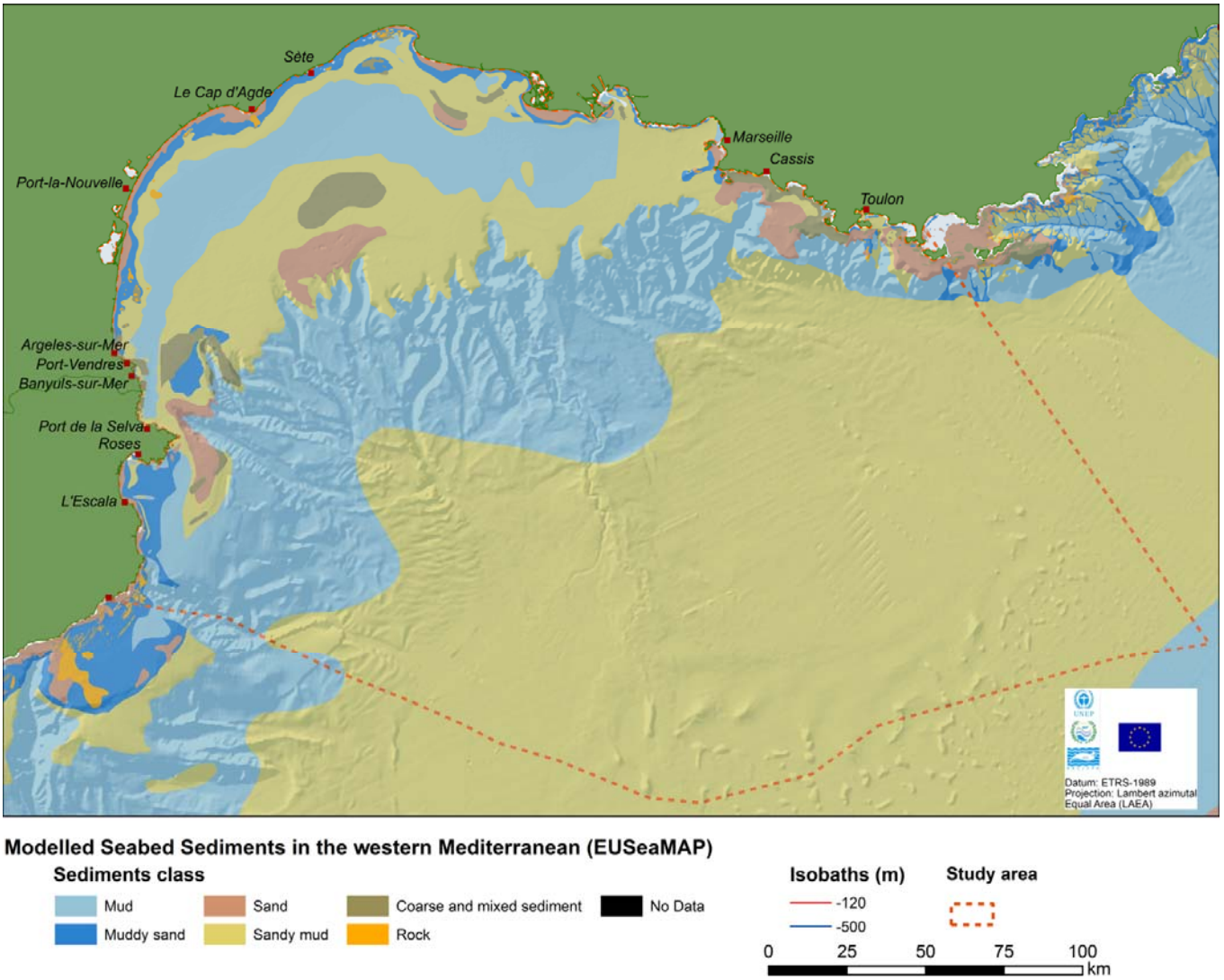


Figure 7. Modelled seabed substrate map from EUSeaMap project. From the original modified Folk classification 2 substrate classes were removed from this map due their litoral nature: *Posidonia oceanica* and *Cymodocea* substrates (EUSeaMap 2011b).

5. River discharge

The depositional system of the Gulf of Lions is mainly determined by topography, sediment supply and water circulation. The relatively low sediment inputs irregularly discharged over the years due to the Mediterranean climatic conditions has influenced the geological features of the shelf and slope. Almost 11 million tons of fine-grained sediment are discharged annually by the Rhône and the other north-western Mediterranean rivers that flow into the gulf. The Rhône River alone supplies most of the terrigenous sediment to the Gulf of Lions continental shelf, accounting for almost 80-90% of the new terrigenous inputs (Courp and Monaco, 1990; Bourrin and Durrieu de Madron, 2006).

This fluvial system is characterised by a strong inter-annual variability, where the discharge of large amounts of sedimentary material can occur within just a few days (Bourrin and Durrieu de Madron, 2006). The Rhône River largely contributes to the input of freshwater and suspended-sediment discharge to the Gulf of Lions, mainly due to the large catchment area it encompasses, of nearly 100,000 km2. It represents 80-90% of the Gulf of Lions freshwater input, with mean liquid discharge at the mouth of 1,700 m3•s-1 and peak discharges of up to 13,000 m3•s-1 (Data from December 2003, Arnau et al., 2004), averaging annual discharges of 55,000 million m3 of water per year (Bourrin and Durrieu de Madron, 2006). As it can be expected, highest river discharge periods are generally found in spring and autumn. The freshwater input of the Rhône can be negligible from a dynamical point of view since its values are 1000 times lower than the flux of the general circulation (Millot, 1990).

Rhône river sediment discharge estimates from the past three decades range between 7 to 10 million tones per year (Antonelli et al., 2004; Bourrin and Durrieu de Madron, 2006), although values vary according to different authors. A clear decreasing trend, however, can be observed in Rhône sediment discharge when analysing long-term data sets. At the beginning of the century, Rhône discharge was estimated at 30•106 ton•y-1 (Surell, 1847), a significant larger amount than present day values. This can be attributed to the construction of dams during the 1950s (Got and Aloisi, 1990).

The dominant current system on the Gulf of Lions flows towards the southwest. Hence, the associated freshwater plume produced by the Rhône river sediment discharge tends to get deflected south-westward by the general water-mass movement, moving sediments along the coastline (Arnau et al., 2004). River plumes usually expand over the continental shelf at a relatively short distance from the coast. In situations when Mistral and Tramuntana winds blow, the brackish waters produced by the Rhône can reach the outer part of the shelf and slope, located a few kilometres away from the coastline. This situation creates a wind-induced coastal upwelling of deeper and denser waters (Arnau et al., 2004).

6. Oceanography of the Gulf of Lions

The Gulf of Lions can be considered a very dynamical system with regards of current dynamics and wave action, with highly variable hydrodynamic phenomena developing simultaneously.

These processes include the general water-mass circulation along the continental slope, the formation of dense water both on the shelf and offshore, a seasonal variation of the water column stratification, fresh water inputs from the Rhône river and the extreme energies associated with meteorological conditions (Millot, 1990; Raimbault and Durrieu de Madron, 2003). Tides and natural oscillations have small amplitudes in the Gulf of Lions, so the associated currents can be negligible.

The general circulation of the Gulf of Lions is southwestward and it seems to be forced during wintertime by thermohaline processes, involving the formation of dense water and smaller-scale phenomena such as up- and downwellings induced by wind gusts. South-easterly winds blow violently from autumn to spring, with gusts up to ~50 knots. Their energy generates large swells and intense long shore currents also important for sediment transport (Millot, 1990).

The main component of the water-mass circulation in the western Mediterranean basin is related to the Liguro-Provençal Current or Northern Current, a stream whose flux is about 2•106 m3•s-1 (Millot, 1990; Raimbault and Durrieu de Madron, 2003). The Northern Current also exhibits usual seasonal differences. During summer it is wider (35 km), shallower (~200 m), and weaker (maximum currents of 40–50 cm s^{-1}) than during the winter (28 km, 250–300 m, 70 cm s^{-1}) respectively (Petrenko, 2003). This current involves water of Atlantic origin in the surface layers, and follows the continental slope along the coast of Provence and the Gulf of Lions (Millot, 1990). Although this current follows the continental slope south-westwards most of the time, intrusions onto the shelf may occur, especially during north-westerly wind events.

The presence of the intricate network of submarine canyons at the shelf-break produces small-scale currents that flow towards different directions, mostly downslope. The main pattern of this circulation implies that the nepheloid bottom layer enters the canyons preferentially across their edges, influencing the sediment dispersal in the system (Millot, 1990). Tramuntana and Mistral winds, which blow most part of the year, cool down inner-shelf waters promoting local upwelling of intermediate waters of the Northern Current. This process can be mainly found along the coasts of Provence and Camargue (Millot, 1990).

The seasonal variability that can be found in the stratification of surficial waters has a great influence in the hydrological setting of the Gulf of Lions. From spring to autumn, a thermocline is formed at 10-20 m depth on continental shelf waters, separating an upper layer with a mean temperature of about 20°C from a bottom layer with minimum temperature around 13.5°C on the shelf. This thermocline facilitates the movement of surface waters over the bottom layer. When cold temperatures arrive, the stratification weakens and the waters become homogeneous, especially in the offshore region of the gulf. This lack of stratification

in the water contributes towards the mixing of river sediments along the whole water column (Millot, 1990).

The water discharges from the Rhône River also influence the hydrological characteristics of the Gulf. Near the river mouth, the fresh water layer is a few meters thick but it only of a few centimeters high some kilometers seaward. The prevailing windy conditions promote water mixing making both layers at least dynamically inseparable. Nevertheless, the turbid river water is generally clearly detected far from the mouth through remote sensing imagery (Lorthiois et al., 2012). Most of the time, the plume is deflected south-westward, as expected from the effect of the Mistral wind and the general circulation on the shelf (Millot, 1990).

The Gulf of Lions is also a wind-dominated area, with frequent episodes of strong winds. The effects of such wind intensity have an effect on ocean circulation and waves, although the general setting of the Gulf of Lions limits the fetch of these winds and thus the height of the waves they produce (significant wave height is generally lower than 2 m). The strongest wind episodes come from the northerly winds Tramontane and Mistral, which blow intensively during the winter months. The Tramontane episodes promote local downwelling along the western coastline of the gulf, while the Mistral wind induces local upwelling along the northern. Both winds induce distinctive and opposite circulation cells on the continental shelf, favouring the intrusion of slope waters in the eastern and central parts, promoting at the same time the export of shelf water towards the south-western end of the Gulf (Millot, 1990).

The cold and dry northern winds that blow intensively during autumn and winter months cause the disappearance of the summer stratification of the water column. The cooling of shelf waters eventually leads to the formation of homogeneous coastal waters that are denser than the offshore waters leading to a process of baroclinic instability (Ulses et al., 2008). The density of surface waters can reach that of the deeper ones, forming a bottom gravity plume that propagates across the shelf and cascades down the continental slope until it reaches its equilibrium density (Millot, 1990). The presence of the river inputs along the continental shelf, mainly due to the Rhône River, implies that the density of the newly formed dense water only sinks down to a few hundred metres, flowing mostly along canyon heads. Because of the relatively low speed values induced by cascading, this phenomenon is unable to excavate the canyons and their associated furrows, but it does have an impact on sediment dispersal along the gulf (Millot, 1990).

PART II

BIOLOGICAL DESCRIPTION OF THE STUDY AREA

7. Benthic communities

7.1.1 Biocenosis of the Gulf of Lions

We reviewed the current knowledge on the benthic communities that dwell from the circalittoral zone to the deep-sea region that can potentially be found on the Gulf of Lions continental shelf and slope. We summarized the information gathered in recent surveys (Gili et al., 2011; Fourt and Goujard, 2012.) accomplished by the French government (*Agence des aires marines protégées*) and the Spanish government (INDEMARES consortium). The benthic communities here reported are vital for the selection of sites to be included in the national inventories of natural sites of conservation interest.

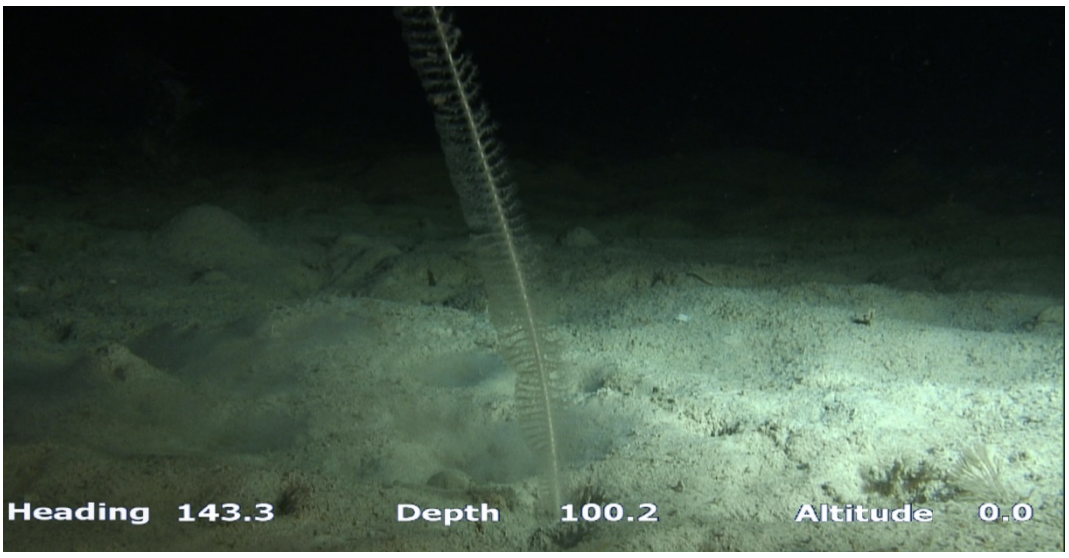
All information provided in this section has been adapted to fulfil the specifications of the Barcelona Convention. The habitats/biocenoses and facies/associations described below follow the format of the reference list of Marine habitat types (UNEP-MAP-RAC/SPA 2006). All descriptions originate from Pérès and Picard (1964), Pérès (1984) and Bellan-Santini et al. (2002). Additional updates have been added where possible, including additional communities that are not listed in the reference list of Marine habitat types (UNEP-MAP-RAC/SPA 2006).

IV CIRCALITTORAL

IV.1. MUDS

IV.1.1. Biocenosis of coastal terrigenous muds

IV.1.1.2. Facies of sticky muds with Virgularia mirabilis and Pennatula phosphorea



This facies is found on coastal mud, a terrigenous rather mobile mud in areas with low sedimentation rates and reduced hydrodynamism up 400m depth. This habitat is dominated

by the sea pens *Virgularia mirabilis, Pennatula* (*phosphorea*), and sometimes *Veretillum cynomorium* is also often associated to them. Brittlestars such as *Amphiura* spp. are particularly characteristic of this habitat whilst infaunal species include the tube building polychaetes and deposit feeding bivalves. Burrowing megafauna including *Nephrops norvegicus* are common in deeper muds.

IV.1.1.3 Facies of sticky muds with Alcyonium palmatum and Stichopus regalis

This facies occur in areas with low sedimentation rates and is characterized by the dominance of *Alcyonium plamatum* and the bivalve *Pteria hirundo*, ascidians (e.g. *Diazona violacea*) and the large holothurioid *Stichopus regalis*. In the Cap the Creus canyon, two different *facies* can be distinguished in the upper canyon rim and canyon head, those with shared dominance between sea pens and ceriantharians, and those dominated by sea pens and hydrozoans (Gili et al., 2011).

IV.2. SANDS

IV.2.1 Biocenosis of the muddy detritic bottom

IV.2.1.1. Facies with Ophiotrix quinquemaculata

This facies are found on muddy sand with a mixture of broken shells. Because of the low sedimentation rates, small hard substrates such as shells remain on surface and allow the development of sessile epifauna. Sometimes, the brittle star *Ophiothrix quinquemaculata* can be found in fairly abundant densities.

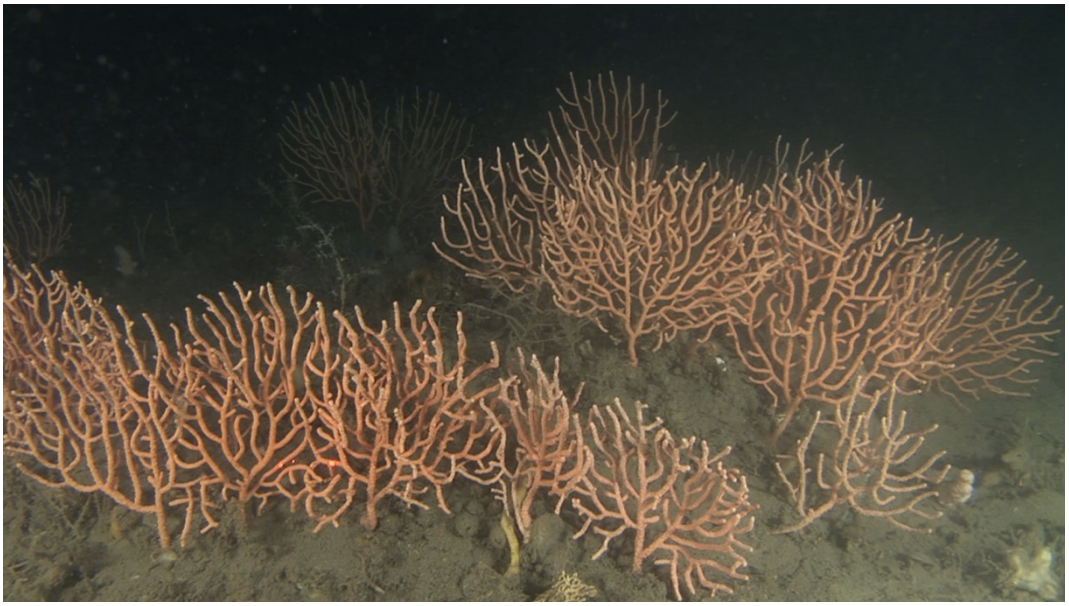
IV.2.3 Biocenosis of shelf-edge detritic bottom

IV.2.3.2 Facies with Leptometra phalangium

This facies, found on the shelf edge in the western Mediterranean, is characterised by the high abundance of the crynoid *Leptometra phalangium*. This species is a suspension-feeder that inhabits areas with a high hydrodynamism and high input of organic matter and plankton. The presence of *L. phalangium* enhances habitat heterogeneity by developing three-dimensional communities, allowing consistent species richness and high rates of primary and secondary productivity (Ardizzone, 2006). *Leptometra* beds, hosting large biomasses of benthopelagic fish and recruits (Colloca et al., 2004), are mainly characterised by a high abundance of spawners of commercially important species, e.g. red mullet *Mullus barbatus*, hake *Merluccius merluccius*, blue whiting *Micromesistius poutassou* and *Trisopterus minutus capelanus* (Bellan-Santini et al., 2002).

IV.3. HARD BEDS AND ROCKS

IV.3.3 Biocenosis of shelf-edge rock



A fairly specific assemblage on the shelf break and the upper part of the slope, with poorly developed calcareous red algae characteristic of the coralligenous bicenosis. This biocenosis is mentioned in the reference list of Marine habitat types (UNEP-MAP-RAC/SPA 2006), however it is not well defined. Here it corresponds to the offshore rocky-bottom assemblage defined in Pérès (1984) and "*Roche du large* " in Pérès and Picard (1964). This biocenosis is found from 90 to 300m depth, on rocky areas, however it is usually covered with a very thin layer of sediment. The predominant components of this biocenosis are suspension-feeders as expected in areas with strong currents and high turbidity. This type of biocenosis is dominated by large-sized sponges (e. *Poecillastra compresa*, *Rhizaxinella pyrifera, Phakellia ventilabrum*, *Axinella* spp.), the yellow scleractinian *Dendrophyllia cornigera*, the black coral *Antipathes fragilis*, many bryozoans, brachiopods, polychaetes and echinoderms, which are also well represented. Decapods like *Palinurus elephas and P. mauritanicus* are also common. The biocenosis of the "*Roche du large*" may play an important role in controlling the benthic biodiversity of the Mediterranean circalittoral (Bo et al., 2012).

To date, there are no facies described for this type of biocenosis, however recent experimental surveys from MEDSECAN and INDEMARES cruises reported the presence of several dominant components:

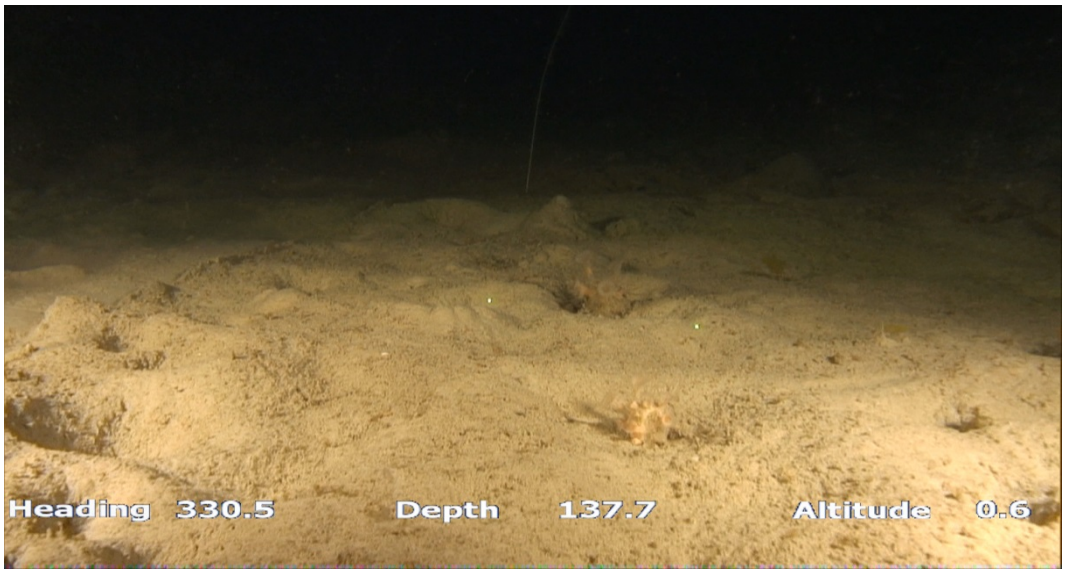
Gorgonians : Eunicella spp. and *Paramuricea clavata*
Oyster bancs with *Neopycnodonte cochlear*
Sponges: Aplysina cavernicola, Spongia lamella and *Desmacidon* sp.

V. BATHYAL

V.1. MUDS

V.1.1.Biocenosis of bathyal muds

V.1.1.1. Facies of sandy muds with Thenea muricata



This facies is found on sandy muds populated mainly by the small sponge *Thenea muricata*. This facies is poorly described in the original description from (Pérès and Picard, 1964). Experimental surveys from MEDSECAN canyons show that some commercial fishes and decapods (e.g. *Gadiculus argenteus, Merluccius merluccius, Nephrops norvegicus*) and the sponge *Rhizaxinella* sp. are frequently found. This facies in the Gulf of Lions was mainly observed between 250 and 350m depth.

V.1.1.2 Facies of soft muds with Funiculina quadrangularis and Apporhais seressianus.

This facies, present on the shelf edge and upper slope up to a depth of 350m is characterized by sandy muds, in which the cnidarian *Funiculina quadrangularis* and the gastropod *Apporhais seressianus* are dominant. On gently inclined bottoms the sea pen *Kophobelemnon leuckarti* is also abundant. These suspension feeders presumably increase the three-dimensional complexity of soft-bottoms, and can contain abundant populations of some commercial crustaceans, such as *Parapenaeus longirostris* and *Nephrops norvegicus* and cephalopods (*Eledone cirrhosa, Illex illecebrosus coindetii and Todaropsis eblanae*).

Other communities found on soft bottoms not present in the reference list of Marine habitat types (UNEP-MAP-RAC/SPA 2006).

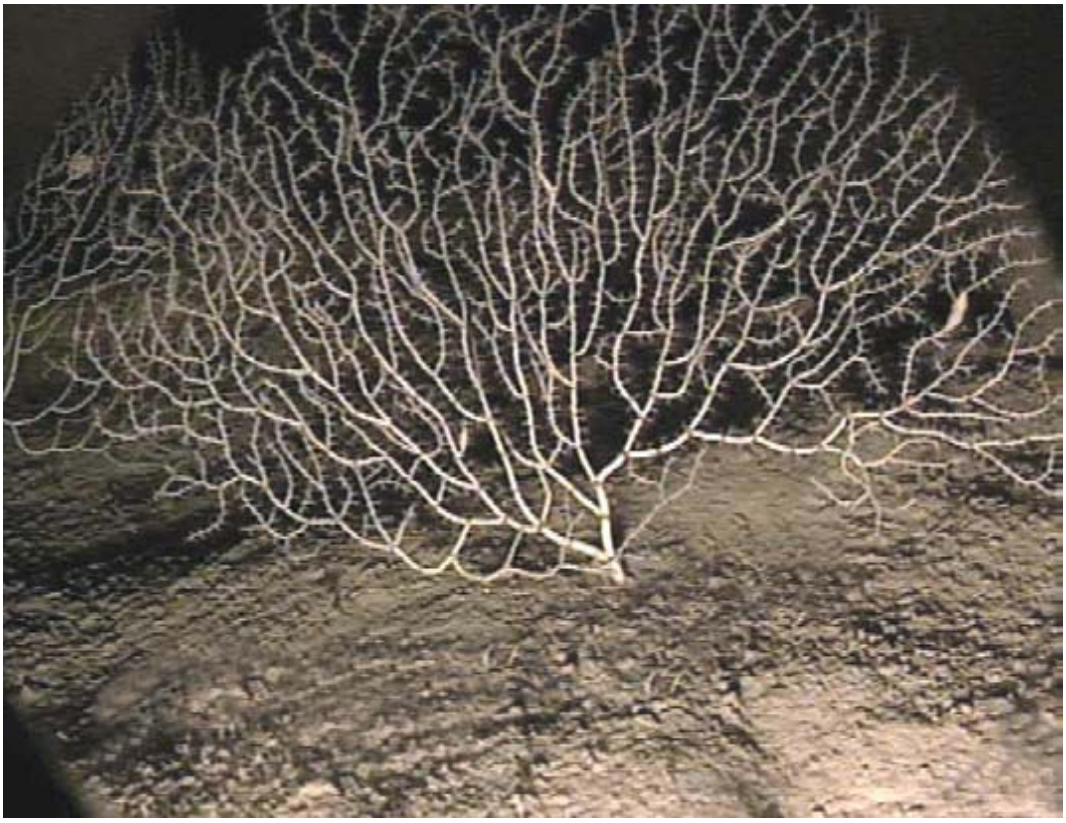
Facies with *Ceriantharia*

These facies have been observed in soft muddy bottoms in several canyons from 250 to 400m depths. They are characterized by the high abundance of large *Ceriantharia* (species not identified (Fourt and Goujard, 2012). In Algerian waters, the big cerianthid *Branchiocerianthus norvegicus* is common (Pérès, 1984). Also dominant in this type of community are fish and cephalopods of commercial interest (e.g. *Helicolenus dactylopterus*, *Merlucccius merluccius*, *Eledone cirrhosa*).

V.1.1.3. Facies of compact muds with Isidella elongata

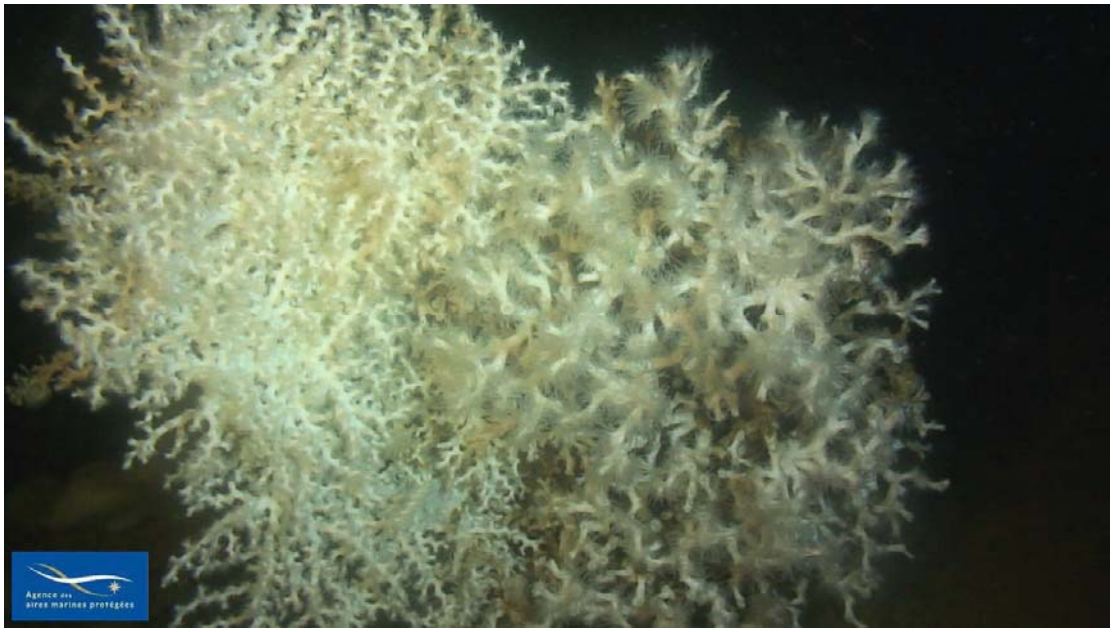
This facies is present on deeper grounds (mainly 400-800m depth) over bahtyal muds, at the base of the continental slope and bathyal plain (with little or no slope) and is characterised by compact muds in which the cnidarian *Isidella elongata* is present. *Isidella elongata* usually presents epibionts like the actinia *Gephyra* (*Amphianthus dohrni*), the crustacean *Scalpellum scalpellum*, the bivalvia *Chlamys* and Scyliorhinidae eggs. Some commercial fishes, decapods and cephalopods (e.g. *Merluccius merluccius*, *Micromesistius poutassou*, *Parapenaeus longirostris*, *Aristaeomorpha foliacea*, *Aristeus antennatus*, *Bathypolypus*

sponsalis) are found in high abundances in this facies. This facies in the Gulf of Lions was mainly observed between 350 and 620m depth.



V.3. HARD BEDS AND ROCKS

V.3.1.Biocenosis of deep-sea corals



These facies appear bellow 200 m, generally on steep rocky areas in the shelf break and

canyons, where strong currents and steep slope prevent sedimentation (Bellan-Santini et al., 2002, Zibrowius, 2003). Deep-sea or cold-water corals from complex three-dimensional habitats, creating biodiversity hotspots, increasing densities of associated species, accumulate suspended detritus and influence the local hydrodynamic flow field (Zibrowius, 2003; Freiwald et al., 2004; Taviani et al. 2011). Mainly two species of scleractinians *Lophelia pertusa* and *Madrepora oculata* are characterizing these facies. The associated fauna on alive and dead skeletons include: sponges, polychaetes, echinoderms and bryozoans. Cold-water corals are also considered an important habitat for larval fish and crustaceans (e.g. D'Onghia et al., 2010). These communities are still poorly known in the Mediterranean, highlighting its conservation interest (Bellan-Santini et al., 2002; Zibrowius, 2003; Taviani et al., 2011).

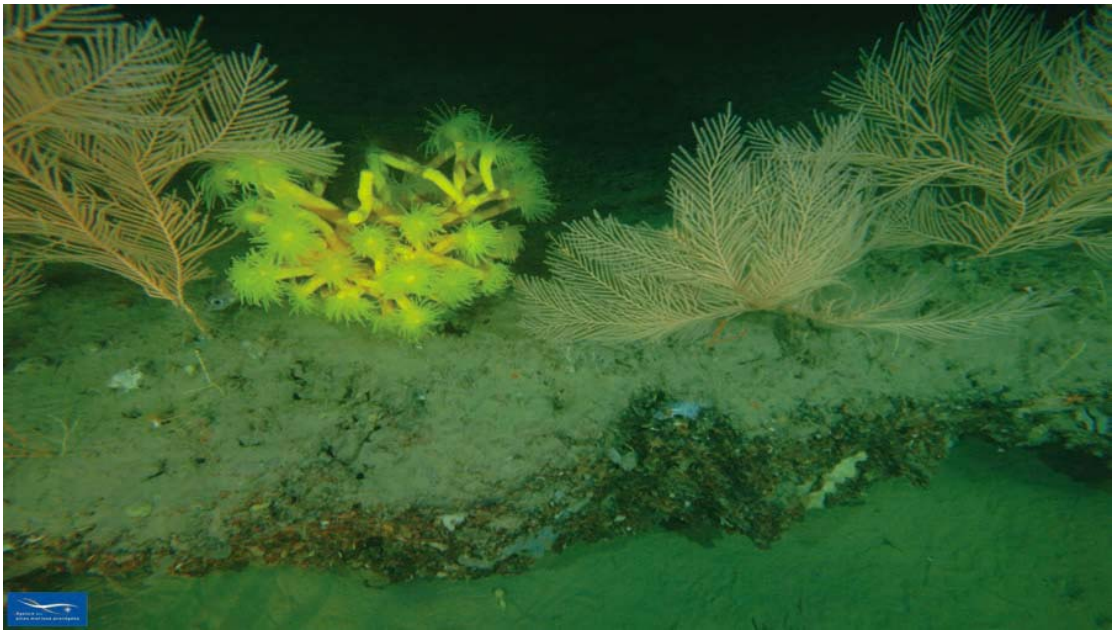
Other communities found on hard substrates not present in the reference list of Marine habitat types (UNEP-MAP-RAC/SPA 2006).

Facies of *Neopycnodonte zibrowii*

A large number of subfossil oysters (*Neopycnodonte zibrowii*) were localized in several canyons, on rocky bottoms up to depths of 500m. This species might live up to 500 years old (Wisshak et al., 2009) and are testimonial of ancient shallow sublittoral environments. A living specimen of *Neopycnodonte zibrowii* might have been found (Fourt and Goujard, 2012), confirming the presence of alive specimens in the Gulf of Lions. From the existing reports, it seems that this species succeeds on vertical cliffs and underneath bedrock (Wisshak et al., 2009).

Facies of *Callogorgia verticillata* and *Viminella flagellum*

The gorgonian *Callogorgia verticillata* has been observed in large numbers on rocky substrates at depths of ca. 350-450m. This species seems to appear accompanied by other gorgonians (e.g. *Viminella flagellum*) and antipatharians (e.g. *Leipathes glaberrima, Antipathes dichotoma*) and deep-sea sponges. Large benthic cnidarians can play an important role since they create complex tree-dimensional habitats, allowing for high diversity levels and producing biodiversity hotspots.



8. Seaturtles, seabirds and cetaceans

8.1.1. Seaturtles

In the Mediterranean three species of seaturtles are frequent, the leatherback turtle (*Dermochelys coriacea*), the green turtle (*Chelonia mydas*) and the loggerhead turtle (*Caretta caretta*). These last two breed in the basin, but only the loggerhead turtle population is relatively important.

Most of the clutches of loggerhead turtle (*Caretta caretta*) are laid in Greece, Turkey, Cyprus and Lybia (Casale et al., 2010), but they occur in almost all marine areas, with the highest densities reported in the western Mediterranean, in the Alboran Sea, Balearics, Sicily Strait, and the Ionian Sea.

France has reported some nesting areas in Corsica Island in the past (Oliver, 2010), with a new intent in 2002 and an exceptional nesting event in 2006 in Saint-Tropez, the northernmost nesting event in the world, whereas Spain can be considered as a sporadic nesting country. Some episodes in Almeria-2001, Valencia-2006 and Barcelona-2008 succeeded with confirmed emergence of hatchlings.

Although loggerhead turtles (*Caretta caretta*) can be observed all along the French coasts and all year round, it presence follows a seasonal cycle. They are more abundant from May

to September with a pick in June and August. This area seems to be used as a feeding ground and probably is also important as a corridor during migrational moviments. Similarly, data from different sources (Garcia, 2010; Carreras and Tomás, 2010; WWF 2002) show a similar behavior along the northeast cost of Spain (Catalonia), where bycatch data reported from longliners, trawlers and purseseiner shown a marked maximun between May and September. Although maximum fishing effort occurs in summer (WWF 2002), this period also concurs with a high active period for turtles (Garcia, 2010), so these kind of studies based in baycatch data could be considered as a reasonable aproach to the turtles concurrence.

The loggerhead turtle (*Caretta caretta*) and the green turtle (*Chelonia mydas*) are both uplisted as Endangered in the IUCN Red List of Threatened Species. Both species are expected to suffer a remarkably population reduction in the next ten years. In the study area, mortality associated with entanglement in marine fisheries is the primary incidental threat; the responsible fishing techniques include drift netting, trawling and long-lining.

8.1.2. Seabirds

The Gulf of Lions is a hotspot of productivity in the Mediterranean Sea. Seabirds from colonies situated 150-500 km away fly 4-16 hours to forage in its waters. The Mediterranean seabird community contains many endemic taxa, including some species that are threatened globally, and the area is important for their conservation. All four Procellariiforms (petrels and shearwaters) present in the Mediterranean are endemic taxa: two at species level (*Puffinus mauretanicus* and *Puffinus yelkouan*) and two at subspecies level (*Calonectris d. diomedea* and *Hydrobates pelagicus melitensis*). Besides, one endemic cormorant (Shag Phala*crocorax aristotelis desmarestii*), three gulls (Mediterranean *Larus melanocephalus*, Audouin's *Larus audouinii* and Yellow-legged *Larus michahellis michahellis*) and one tern (Lesser-crested *Sterna bengalensis emigrate*) also originate from the Mediterranean region.

Yelkouan shearwater *Puffinus yelkouan* has recently been uplisted to IUCN 'VU' status due to ongoing rapid population decline, caused by extremely low breeding success and adult survival owing to fisheries bycatch and predation by introduced mammals (BirdLife International, 2011). Some 10,000 birds feed in central and coastal waters of the Gulf of Lions during the breeding season, although the French breeding population is 'only' 1400-1700 pairs.

The distribution of the critically-endangered Balearic shearwater *Puffinus mauretanicus* extends to the S coastal waters of the Gulf of Lions, where several 100s-1000s may concentrate for foraging, a large proportion of the global population. The species feeds on small pelagic fish and also on trawler discards, and is at threat from bycatch in longline fisheries.

Cory's shearwater *Calonectris diomedea* is the most pelagic of Mediterranean shearwaters. The endemic Mediterranean population is large, but the species suffers the heaviest bycatch toll of all seabirds in longline fisheries, and is declining in several areas. The Gulf of Lions attracts foraging birds from local as well as distant colonies (Corsica, Sardinia, Balearics), so is important at regional scale.

The Mediterranean Storm-petrel *Hydrobates pelagicus melitensis* has a disperse distribution over the outer half of the continental shelf of the Gulf of Lions, often far from land. This minimises their probability of contact with humans and makes the species less vulnerable to interactions at sea than other Mediterranean seabirds. But as a predator in the ecosystem, the species depends on the general health and productivity of the marine environment. It is extremely long-lived, and so dependent on low adult mortality.

Other species with relevant populations in conservation terms whose distribution extends to the offshore waters of the Gulf of Lions are: the endemic Mediterranean shag *Phalacrocorax aristotelis desmarestii*; a coastal species, the Northern gannet *Morus bassanus* of the Atlantic continental shelf, which penetrates the Mediterranean in winter; Audouin's *Larus audouinii*; Mediterranean gull *Larus melanocephalus* and the Sandwich tern *Sterna sandvicensis*.

The conservation of the Gulf of Lions for seabirds has implications over a much wider area. The long-term preservation of its role as a major foraging ground in the north-western Mediterranean Sea is probably key to the stability of the populations that nest in Spain, France and Italy, and also to those that use it during the winter season and nest elsewhere.

Three areas within the Gulf of Lions shelf and slope area are of special conservation value for seabirds and deserve to be protected (Figure 8):

W sector: Cap de Creus area
Particularly important for all 3 shearwater species, Shag, Northern gannet and other migratory seabirds. Intensively fished (trawling, longlining, artisanal, purse-seining), with several episodes of bycatch recorded recently; addressing this issue must be forefront of management policy. Fishing should be regulated to prevent excessive captures and the destruction of fish habitat.

Central canyons and continental shelf of the Gulf of Lions
Frequented by large numbers of shearwaters of the 3 species and intensively fished, so high probability of interaction. Management measures should seek to minimise the probability of mortality through bycatch and safeguard the long-term maintenance of fish populations, particularly anchovy and sardine. A scientific observer programme, in collaboration with the fishing industry, is especially appropriate in this area.

E sector: Marseille – îles d'Hyères
Similar characteristics to W sector: Cap de Creus area at the opposite end of the Gulf of Lions. Fishing and disturbance are equally the main threats at sea, and management should seek to address risks of interaction and minimise the probability of mortality through bycatch. Fishing regulations should seek long-term sustainability and minimal impact on the ecosystem. Disturbance should also be kept to a minimum near key spots on land (breeding colonies, resting places).

Increased risk of pollution near important harbours like Marseille, as well as high density of plastic debris, close to bird-rich areas. The distant slope waters are considered to be of undifferentiated value for foraging seabirds.

The information presented in this heading has been provided by Carboneras (2011).

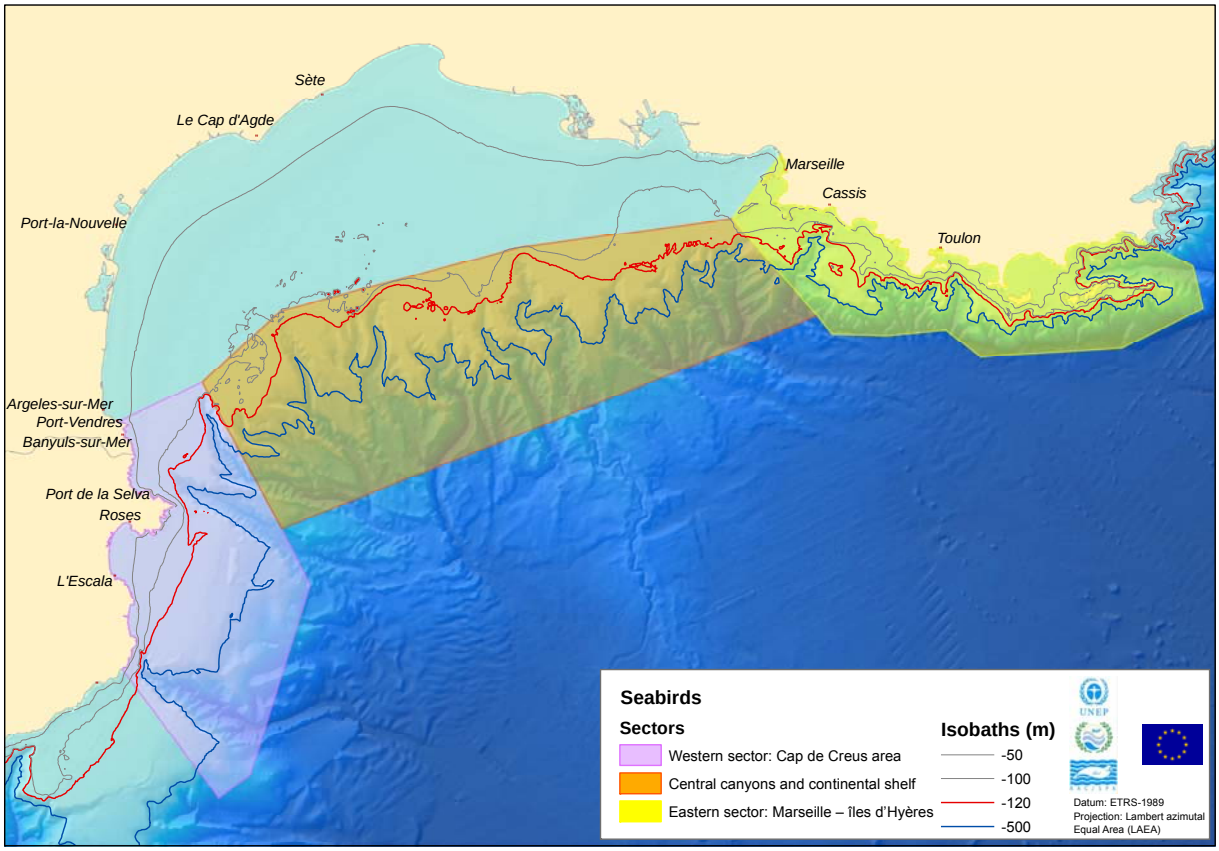


Figure 8. Sectors of interest for seabirds (Carboneras, 2011).

8.1.3 Cetaceans

The Gulf of Lions represents the natural continuation westward of the contiguous PELAGOS Sanctuary recognised for its cetacean richness (Gannier, 2006 ;). It shares important cetacean habitats and is likely inhabited by the same cetacean populations that occur in the Sanctuary (Delacourtie *et al*., 2009 ; Di-Méglio and David, 2010 ; Notarbartolo and Agardy, 2009).

For this summary, only common or regular species have been taken in account, see Figure 9. The continental shelf is the habitat of the bottlenose dolphin (*Tursiops truncatus*), from the coast through the shelf edge and canyon's head. The slope appears more frequented by four teutophageous species: Risso's dolphins (*Grampus griseus*) are encountered all along the slope, merely its upper part. Concerning sperm whales (Physeter macrocephalus), Pilot whales (*Globicephala melas*) and Cuvier's beaked whales (*Ziphius cavirostris*), they seem to exploit more the lower part of the slope and preferentially some peculiar canyon's systemes: Creus and Lacaze-Duthier for the three species and Sète and Marti for the sperm whale and

pilot whale. Concerning more pelagic waters, they are frequented by fin whales (*Balaenoptera physalus*), pilot whales and merely by the striped dolphin (*Stenella coeruleoalba*).

The northern part of the western Mediterranean Sea is a highly important area for all kind of cetaceans: planctophageous (Fin whale *Balaenotera physalus*), teutophageous (Pilot whale *Globicephala melas*, Cuvier's beaked whale *Ziphius cavirostris*, Risso's dolphin *Grampus griseus* and sperm whale *Physeter macrocephalus*), ichtyophageous (bottlenose dolphin *Tursiops truncatus*) and mixed (striped dolphin *Stenella coeruleoalba*). This fact is highlighted by the prospecting effort developed in the north of the area. Although less effort has been placed in the study of the south and the west of the area, habitat suitability maps and recent studies indicate that the species richness and frequentation of this part of the area could be as high as in the Sanctuary PELAGOS (Cotté et al., 2009, 2010; Di-Méglio N. et David L. 2010 ; Castellote et al., 2008 ; Praca and Gannier, 2008).

Among these common and regular species, one species is classified, within the IUCN status of conservation, as Endangered (sperm whale), three as "Vulnerable" (fin whale, striped dolphin and bottlenose dolphin) and three as Data Deficient (Risso's dolphin, pilot whale and Cuvier's beaked whale). Considering species, no management or conservation measures have been taken as yet specifically for the conservation of several species: sperm whale, pilot whales, striped dolphin or Risso's dolphin, although generic protection laws (national and international ones) for cetaceans exist. In parallel, various kinds of marine protected areas exist or have been proposed throughout the Mediterranean. Although not always specifically intended for one cetacean species or another, several measures once implemented, could contribute to their conservation.

The information presented in this heading has been provided by (David, 2011).

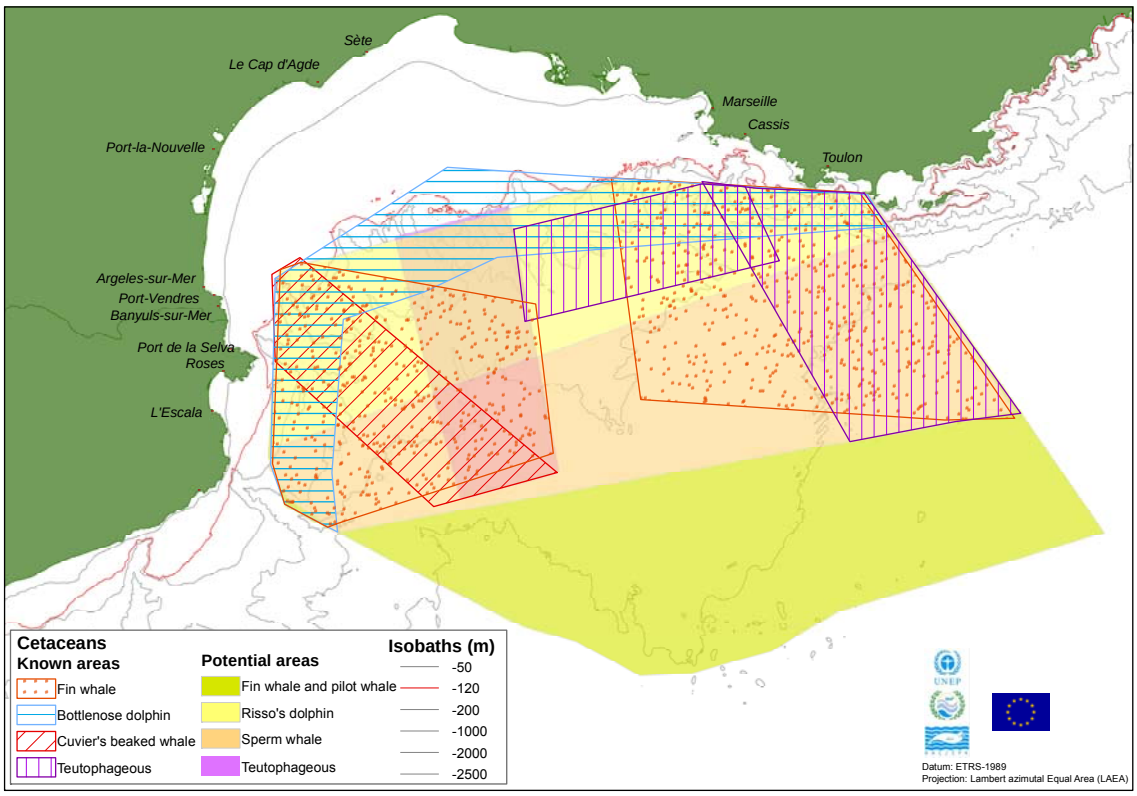


Figure 9. Important areas (known and potential, for the conservation of bottlenose dolphin (*Tursiops truncatus*), fin whale (*Balaenoptera physalus*) and teutophageous species (sperm whale *Physeter macrocephalus*, Risso's dolphin *Grampus griseus*, pilot whale *Globicephala melas* and Cuvier's beaked whale *Ziphius cavirostris*) on the continental slope (provided by David, 2011).

8.1.4. Fisheries

The Gulf of Lions supports fisheries that include bottom and pelagic trawls, purse seines, gill nets and longlines, and is furthermore an important spawning area for many pelagic and demersal species. The demersal fisheries are multi-species and multi-gear fisheries. The marine living resources of the Gulf of Lions are a "shared stock" which is essentially exploited by French and Spanish fishing fleets. The main fishing grounds exploited by these fleets cover the entire continental shelf from the coastline to the 500 metres isobath, with an area of some 14,000 square kilometres covered by sandy deposits. This particular geomorphology has been conducive to the development of trawling activities (Lleonart and Maynou, 2003; Farrugio, 2010; Farrugio and Marin, 1999).

The fleets exploiting the marine resources of the Gulf of Lions are mainly based in the French ports of Sète and Le Grau du Roi, which group more than 60 % of the boats and insure about 70 % of the halieutic production of the Gulf of Lions and in the Spanish ports of Roses and Port de la Selva (Farrugio, 2010) (Figure 10). In 2010, 220 boats where involved in the demersal fishery: 111 French bottom trawlers, 67 French gillnetters, 27 Spanish bottom trawlers and 15 Spanish long-liners, while 14 French and 6 Spanish purse seiners where fishing small pelagics in 2007-2008. Both fleets are subject to the rules of the EC Common Fisheries Policy, particularly to the management framework established by the Council Regulation No. 1967/2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea.

French trawlers are the main component of the fleet exploiting the marine resources of the Gulf of Lions. This fleet can be divided into two main components, one (around 50 boats) directed to the catch of small pelagic species (mainly anchovy *Engraulis encrasicholus* and sardine *Sardina pilchardus*), the remaining 61 trawlers directed to the exploitation of a great diversity of demersal species.

The major part of the landings from the Gulf of Lions are done by the trawlers; during the last decade they where composed of around 1/3 of demersal fishes molluscs and crustaceans and around 2/3 of small pelagic species, mainly sardine and anchovy. According to the FAO FISHSTAT database this production fluctuates for the last 30 years between 30000 and 40000 tons per year. The trawlers fishery exploits a highly diversified demersal species assemblage: hake (*Merluccius merluccius*) striped mullet (*Mullus barbatus*), red mullet (*Mullus surmuletus*), angler (*Lophius piscatorius*), black-bellied angler (*Lophius budegassa*), european conger (*Conger conger*), poor-cod (*Trisopterus minutus capelanus*), fourspotted megrim (*Lepidorhombus boscii*), soles (*Solea spp.*), horned octopus (*Eledone cirrhosa*), squids (*Illex coindetii*), gilthead seabream (*Sparus aurata*), european seabass (*Dicentrarchus labrax*), seabreams (*Pagellus spp.*), blue whiting (*Micromesistius poutassou*), and the tub gurnard (*Chelidonichtys lucerna*) are among the most important species caught (Farrugio, 2010, GFCM, 2006).

The recent trawl surveys made by IFREMER in the Gulf confirm that there is an east-to-west gradient and that the average sizes and the abundances of several target species are smaller in the western part of the continental slope, where they are exploited at the same time by the French and Spanish boats, than in the eastern part where the fishing effort effort is less important.

The small-scale boats operating in the Gulf of Lions are also essentially French. They are split over 45 sites along the coastline of the Languedoc-Roussillon region (Bolopion et al., 2000; Guillou and Crespi, 1999). In general the small-scale fleet of the Gulf of Lions is declining. However, this activity is still much to the fore, with 769 registered active entities and 81% of total manpower in 2008. A total of 171 boats where registered in Port-Vendres, 222 in Sète, 175 in Martigues and 201 in Marseille (JRC, 2008). In 2010 the small-scale fleet of the Languedoc-Rousillon was composed of 897 boats (Aldebert et al., 1993).

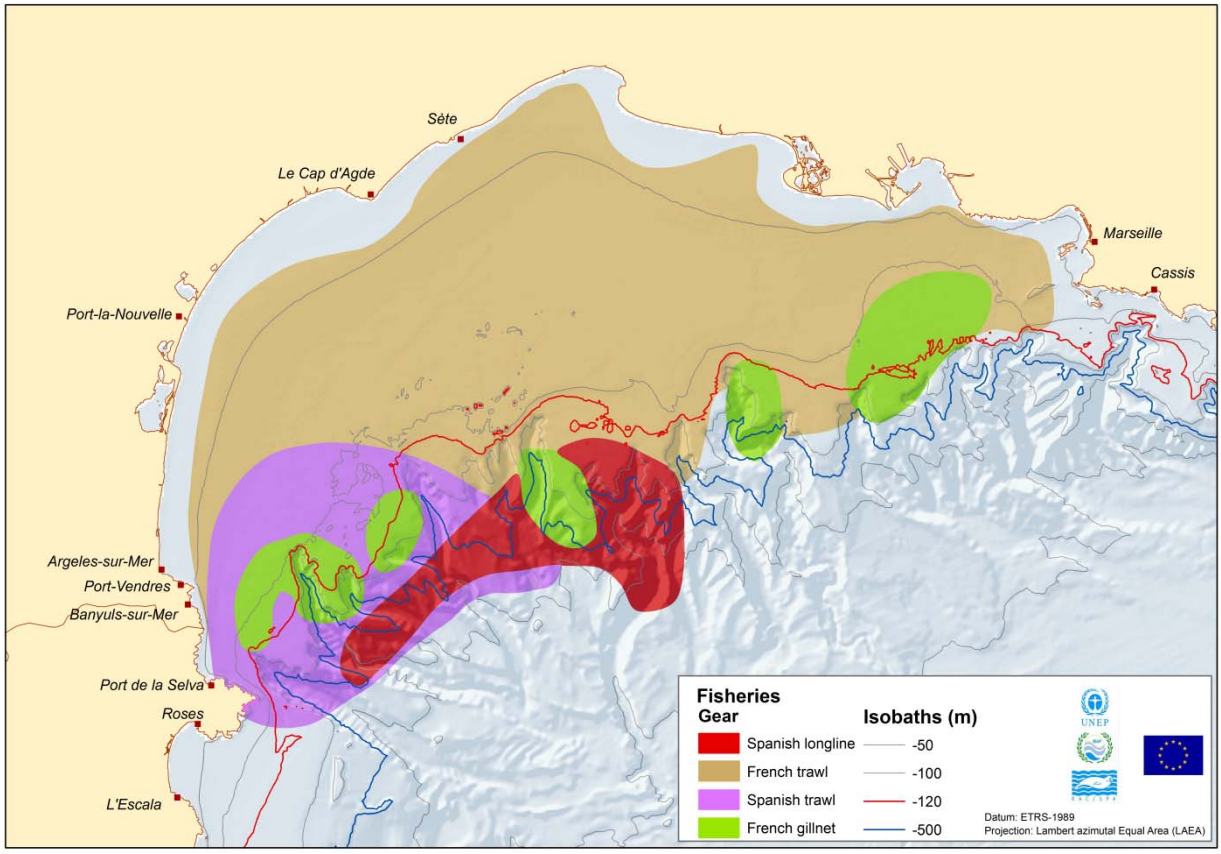


Figure 10. The fishing sectors of the various components of the French-Spanish fleet. From Farrugio (2011) and Aldebert et al. (1993).

9. Anthropogenic pressure

9.1.1. Benthic communities

Potential threats on these biocenosis and its facies generally come from fishing and principally from trawling. Any type of fishing gear may cause disturbance on the sediment and benthic communities to some degree; however, not all fishing methods affect the habitat in the same way. Bottom-fishing activities involving mobile fishing gears have a direct physical interaction

with the seabed and its biota, and the levels of disturbance vary among habitats as a result of fishing frequency and intensity. Bottom trawling impacts on benthic communities causing the re-suspension of sediment, modifying the fluxes of nutrients, reducing the structural complexity of the benthic communities and leading, eventually, to their complete elimination (Olsgard et al., 2008; Hinz et al., 2009). Also, the direct effect of abandoned long-line fishing lines entangled in cold-water coral communities has been reported (Madurell et al. 2012).

9.1.2. Seaturtles

Fisheries can be considered as a major concern issue regarding turtle conservation in the Mediterranean waters and also in the Gulf of Lions. The text under this heading is an extract of probably, the most comprehensive study about sources of bycatch of loggerhead sea turtles (*Caretta caretta*) in the western Mediterranean (Álvarez de Quevedo et al., 2010). A survey, including questionnaires to fishers and observers on board fishing vessels, was conducted to assess turtle bycatch in the waters off Catalonia (northeastern Spain), a region inhabited mainly by loggerhead sea turtles from the highly endangered eastern Mediterranean rookeries. As this report confirmed the data produced by the interviews results were used to estimate turtle bycatch. The number of turtles caught monthly per vessel was estimated at 0.01 for bottom longlines, 0.02 for trammelnets, 0.07 for bottom trawling, and 1.2 for drifting longlines. From these values, 481 (95% CI: 472–491) turtles were caught as bycatch by the whole fleet. Bottom trawling and trammelnets were the most widely used fishing gears (33 and 31% of the total 11 237 fishing months), but most turtles were caught either by bottom trawlers (249; 95% CI 83–415) or by drifting longlines (124; 95% CI: 40–199). The bottom trawler bycatch was higher than expected in areas with a wide continental shelf. These data can be extrapolated to the whole Gulf of Lions area, and should be considered to take protective measures against this bycatch.

Typically, most of northeastern Spain bottom trawlers operate on the deeper side of the continental shelf and the upper slope (Bas, 2003; Massutí and Reñones, 2005). However, where the continental shelf is wide and the upper slope too far from the home-port to be reached on a daily trip, trawlers are forced to restrict their activity to the shelf (Bas, 2003). This is the situation along the coast of central mainland Spain, where the width of the continental shelf is at its maximum, and it is precisely the area where the highest level of turtle bycatch was observed in the present study. Conversely, average loggerhead sea turtle bycatch in trawls remains low where most of the fleet operate on the upper slope (Carreras et al., 2004).

Some surveys showed that bottom trawlers take turtles all year-round, but with a possible peak in winter. Aerial surveys covering the southern part of the study area have shown that turtles are there all year-round, with no apparent seasonality in abundance, but satellite tracking has revealed that at least some turtles leave the area and move south in winter. These data would indicate that the apparent peak in CPUE during winter might be a sampling artefact or, if real, is not caused by a higher density of turtles in the area but because of a greater vulnerability of turtles to bottom trawlers then as a result of the lower temperature of the seawater.

9.1.3 Seabirds

A characteristic of the Mediterranean marine birds is its long-term exposure to human influence. Through history, some aspects of human activity have had positive effects on seabirds (e.g. the creation of specific habitats like rice fields and salt pans, the provision of food through fishing discards, etc), but overall and in the long-term the result of the human-seabird interaction has been detrimental for seabirds. Their current population sizes are

nowhere near what they were before the ‘humanisation’ of the Mediterranean (Carboneras, 2011).

Seabirds primarily interact with fisheries as they forage, and therefore foraging behaviour often determines their vulnerability to being caught in fishing gear. In the case of longline fisheries, species that plunge dive or pursuit dive (gannets and shearwaters) are particularly vulnerable to being caught during setting or hauling of longlines (both demersal and pelagic) as they are able to access bait even at substantial depths under the surface. Surface-seizing birds such as gulls are also vulnerable, as the baited hooks can take a while to sink below the surface when setting.

A risk assessment undertaken by Carboneras (2009) found that for key Mediterranean Action Plan species there was a very high or high risk known, or predicted risk of capture according to the feeding habits and the gear characteristics of pelagic or demersal longlines for the following species of interest in the Gulf of Lions area: cory's shearwater (*Calonectris diomedea*), balearic shearwater (*Puffinus mauretanicus*), yelkouan shearwater (*Puffinus yelkouan*) and audouin's gull (*Larus audouinii*). Three additional species had a moderate risk: northern gannet (*Morus bassanus*), great skua (*Catharacta skua*) and yellow-legged gull (*Larus michahellis*). The Mediterranean gull (*Larus melanocephalus*) has an unknown level of interaction with longlines. Although not much research has been undertaken, some studies have shown that gillnets may be a problem in the Mediterranean, especially to populations of Mediterranean shag (*Phalacrocorax aristotelis desmarestii*), so this species is also included below.

The Northeast coast of Spain also has important foraging areas for seabirds in the Western Mediterranean linked to the high productivity of the sea, with some of the largest populations and greatest diversity of seabirds and breeding colonies occuring near the Ebro Delta and Columbretes Islands (Abello et al., 2003; Arcos et al., 2009). This is valid also for the Cape of Creus area related to the particular hidrodinamics of the continental shelf and canyon and Gulf of Lions area, linked to the Rhone river plume high productive waters (Carboneras, 2012, pers.comm). So interaction with fisheries during the breeding season is a major concern.

9.1.4. Cetaceans

Marine mammals have to share their environment with several human activities: fisheries, maritime traffic of commercial vessels, nautical activities, oil and gas exploitation, military exercises, etc. These activities can have negative impacts on animals, groups or even population.

Cetaceans have then to face several threats, which can be cumulative, as ship strike, by-catch, harassment, habitat degradation or loss, noise or chemical pollutants, etc. Concerning direct threats, like collision with large commercial vessels, fin whales and sperm whales are the most at risk (David et al., 2011 ; Di-Méglio et al., in press) and merely over the slope of the Gulf of Lions area. The Gulf of Lions is one of the highly exploited areas by fisheries. All types of gear are employed, from trawl to longline and nets. Most of the fisherboats work over the shelf and shelf edge but some of them exploit also the pelagic area. Concerning by-

catch, striped dolphin, bottlenose dolphin and sperm whale are the most impacted and to a lesser extend Cuvier's beaked whale, Risso's dolphin and pilot whale. Finally, small vessels also can be a threat, from disturbance to harassment. The first impact is due only to the density of vessels in an area. Then the passage of an intrusive boat over a group of cetaceans can disturb them punctually so they stop their activity to swim away. The repeated "visit" of boats could lead the group to let the area free and search for a sub-optimal area but a calmer one also. All species are concerned by disturbance or harassment and merely on coastal areas and also over the slope (Mayol et al., 2012).

PART III.

SYNTHESIS OF THE ECOSYSTEM FUNCTIONING OF THE 'GULF OF LIONS SHELF AND SLOPE' AREA

1. Primary production and nutrient patterns in the Gulf of Lions

The Gulf of Lions together with the North Adriatic regions is an exception to the general rule for the Mediterranean biological production, being one of the most productive areas in the Mediterranean.

The Mediterranean Sea is known to have a negative water balance. To compensate the excess evaporation over precipitation and river runoff, surface Atlantic water flows into the Mediterranean basin whilst deeper Mediterranean water flows out at Gibraltar to balance the salt (Lacombe, 1988, Cruzado and Velazquez, 1990). Since less nutrients are contained in the inflowing surface Atlantic water than in the deeper outflowing Mediterranean water, the Mediterranean basin is relatively impoverished in nutrients with respect to the open ocean. As a consequence, the Mediterranean Sea is an oligotrophic system (Margalef, 1985) and particularly in summer (Jaques and Treguer, 1986).

The vicinity of the river Rhone, which is the largest one in the basin, delivers an important nutrient load (Heussner et al., 1988). The general patter of nutrient distribution and concentration in the area of the Gulf of Lions strongly dependents however on seasonal hydrographic conditions. During summer, the area is not influenced by the Rhône River water discharges, therefore surface nutrient concentrations are extremely low, indicating strong nutrient limitation of phytoplankton growth. As a consequence, a strong nutricline extends between 50 and 100 m depth. Below these depths all the nutrient concentrations slowly increase downwards until they reach maximum values at depths between 100 and 800 m, depending on the nutrient and the season. During winter, surface nutrient concentrations reach higher values. Deep vertical convective cells developing in the deep-water formation area and upwelling at the thermohaline frontal zone existing at the outer boundary of this area bring about this fertilization, which is little utilized by the winter light-limited phytoplankton (Cruzado and Velazquez, 1990).

Surface waters of the Gulf of Lions are enriched over the offshore concentrations due to the Rhône River discharge, forming a tongue of low-salinity seawater in the eastern part of the Gulf. The vertical distributions of nutrient concentrations in the area are dominated by the strong salinity gradients, which vary drastically according to the meteorological conditions. The wind plays an important role in controlling the vertical distributions of salinity and thus of nutrients. During calm weather conditions, a shallow layer 2-10 m thick, containing a very large proportion of freshwater, lies on top of a subsurface layer containing almost undiluted seawater. This stratification breaks down in winter, due to frequent wind events. Under these circumstances, the transition from the fresher surface water to the saline subsurface water is less sharp and, mixing of fresh and salt waters takes place to depths of 40 m and more (Cruzado and Velazquez, 1989).

The influence of the Rhône River water extends over a large part of the Gulf, being confined over the shelf by the density front, which is in dynamic equilibrium with the Liguro-Provençal Current. As far as water budget is concerned, the Gulf of Lions is a net exporter of water. Seawater moves horizontally into the Gulf from the open sea, mixes with the river water, flowing

out along the southwestern coastal area. Taking into account the amounts of river water entering into the area (about 1500 m^3 s^{-1}) and the nitrogen concentrations in the river (about 100/µg-at. l^{-1}) of nitrate and about the same amount of ammonium), the nitrogen contributions of the river to the fertilization of the area would be about 150.000 tm N y^{-1}. This amount of nutrients, using the Redfield molar ratio (C/N = 106/16), would support a primary production, averaged over the entire Gulf (about 15.000 km2), of about 60 g C m^{-2} y^{-1} from the river. Assuming an average nitrogen concentration of about 4/µg-at. N 1^{-1} in a period of 6 months, the flux of nitrogen into the euphotic zone of the Gulf of Lions should amount to a value similar to that contributed by the river, i.e. about 60 g C m^{-2} y-l. This produces a total annual production of about 120 g C m^{-2} y^{-1} (Jaques and Treguer, 1986) that is closely to the annual production for the adjacent deep-water formation area and the highest annual production rates in the Mediterranean Sea (López-Sandoval et al., 2011).

The conservative mixing of the river water nutrients with those in seawater, for a wide range of salinities, is close to a straight line; this allows nutrient uptake and consequent phytoplankton development to take place, if at all, at very low rates within the "dilution zone". By the time the water reaches the plume boundary, the nutrient concentrations are low and the salinity stratification weak. This means that phytoplankton development takes place, to the extent permitted by light, far away from the nutrient source. The result is a spreading of the fertilization carried out by the nutrients discharged over a relatively large area and an extension of the phytoplankton growth to an even larger area, eventually covering most of the Gulf of Lions and neighboring zones along the coast of Catalonia (NE Spain). Moreover, the production sustained by the seawater upwelling at the high salinity wedge in the deep-water formation area that runs along the shelf slope is very important to the formation of a large river plume. On the other hand, because of such spreading of the river water, eutrophication processes are unlikely to occur in the near shore area; this is in agreement with previous suggestions, that rivers discharging in open-coast areas are less prone to acute eutrophication than are large sewage outfalls and rivers discharging in enclosed shallow estuaries (Cruzado, 1987).

The main hydrographic and environmental features of the north western Mediterranean basin (Salat and Cruzado, 1981; Millot, 1987, Font et al., 1988, Bethoux et al., 1988) can thus be summarized as follows:

1. The upper layers of the central western Mediterranean are occupied by Modified Atlantic Surface Water of salinity below 38 ppm.
2. In the northwestern parts of the basin, off the Gulf of Lions, an area of deep-water formation extends off the shelf to the southwest with surface water of salinity above 38 ppm. This water, with a very small vertical salinity gradient, is formed during winter by cooling and evaporation of a well-mixed water column and it remains all year round, with high salinities close to those typical of intermediate and deep waters.
3. A strong thermohaline front between the above water and the Modified Atlantic Surface in the central parts of the basin supports some upwelling, which contributes to the fertilization of the Gulf of Lions.
4. The Liguro-Provençal Current persistently flows over the slope, from the inner Ligurian Sea and along the coast of southeastern France, off the Gulf of Lions shelf and along the east coast of Spain, at least as far south as the strait between Ibiza and Spain's mainland.

5. Freshwater discharge along the coast, mostly by the Rhône River, makes the water in the Gulf of Lions and over the shelf along the French and Spanish coasts less saline than the surface water further offshore.

2. Sedimentation processes in the Gulf of Lions

The Gulf of Lions presents the highest density of submarine canyons in the entire basin, some of which extending for more than 100 km, cutting the entire continental slope and reaching depths deeper than 2000 m (Pusceddu et al., 2010). Hydrological measurements collected since 1950 in the Lacaze-Duthiers canyon, which is located at the SW outlet of the crescent-shaped shelf, revealed the spreading of dense shelf water plumes (Sanchez-Vidal et al., 2009) that reached equilibrium depths between 170 and 800 m depth. Continuous temperature measurements carried out since 1993 in the same canyon revealed that dense shelf water cascading reached 500 m depth almost every winter. Moreover intense and dense shelf-water cascading occurred triggered by abnormally cold, strong and persistent winds. During these years of intense cascading dense waters flow down-slope over the bottom reaching the lower continental slope and basin at depths in excess of 2000 m. These sinking water phenomena in the Gulf of Lions are an annually recurrent phenomenon that peaks at decadal to sub-decadal time scales. In the last years several studies conducted in this region aimed at identifying the consequences of cascading on the sediment and organic matter transported to the deep sea during these episodic though recurrent events (Sanchez-Vidal et al., 2008).

Several signals of ecosystem change were documented in the south westernmost canyons (Lacaze-Duthiers and Cap de Creus) during the major flushing events observed in recent years (Pusceddu et al., 2010): a rapid drop in deep water temperature, the raise of down-canyon currents (peaks up to $1 ms^{-1}$), the concurrent increase of bottom water turbidity, and a dramatic increase in downward fluxes of material exported from the shelf and upper slope (Canals et al., 2006). These events were able to resuspend and transport several million tons of fine sedimentary particles down canyon, a mass comparable to the mean annual solid transport of all rivers opening into the Gulf of Lions. During the cascading, both fine and coarse shelf and upper canyon sediments contributed to the mass flux, whereas advection of fine material via nepheloid layers dominated down-slope fluxes during pre- and post-cascading. The resulting change in grain-size affected the flux of mineral-bound terrigenous organic carbon, indicating that the down-canyon transport of land-derived organic matter did not occur as bulk but rather its composition are driven by sediment sorting associated with different transport mechanisms. While export of degraded sedimentary organic matter dominated during the early stage of water sinking, export of more labile marine organic Carbon took place during the last stage of this sinking event due to the phytoplankton bloom that occurred in late winter on the shelf (Pusceddu et al., 2010). Hence, the significant export of modern marine organic Carbon observed in the canyons after the pulsed input of terrigenous organic Carbon, suggests that the off-shelf marine export during the cascading season refuels the adjacent deep-sea basin with fresh organic matter (Pusceddu et al., 2010).

The dense shelf water cascading events can represent one of the most important processes fuelling the deep sea with fresh resources that are able to sustain high levels of ecosystem

functioning in the Gulf of Lions. These episodic events, especially those of high intensity, have positive or negative effects on the benthos, by fuelling the deep sea floor with large amounts of bioavailable particles or by disrupting the benthic habitats, respectively. Results from a multidisciplinary investigation carried out in the Gulf of Lions revealed that meiofaunal abundance in canyon sediments during several years of high sinking water events were up to one order of magnitude lower than during periods characterized by the lack of dense shelf water formation (Pusceddu et al., 2010). However, whether meiofauna almost disappeared due to cascading (i.e. flushed away entrained with seafloor erosion under the effect of sediment-laden turbulent flows. or was diluted by the 'azoic' sediments brought in by the cascading remains still unclear.

The general sediment transport in the Gulf of Lions is also, a consequence of the different forcing events and is shown by the along-canyon cumulative transport (Palanques et al., 2006). The early winter events were produced by a strong eastern storm accompanied by a very significant flood and high river sediment discharges (5 Mt in the Rhone River). These events generated intense sediment resuspension and downwelling of warmer shelf water, with sharp increases in near-bottom down-canyon sediment fluxes in the western submarine canyons and less sharp increases in the central canyons along the Gulf of Lions continental shelf break. The canyons head have recurrent sediment transport events during shelf water cascading events and sporadic strong sediment transport events during strong eastern storms. Storm-induced downwelling can be combined with cascading, thus enhancing the sediment transport.

When these processes are very intense and occur at the end of or after the flood season, they can flush the sediment stored on the shelf, mainly though the Cap de Creus Canyon, at the southwestern end of the Gulf. Thus, the western and central submarine canyons show a sporadic sediment flush transport pattern, fed by river floods and controlled by strong storms combined with cascading. In the easternmost submarine canyons, sediment transport events are smaller and mainly associated with shelf water cascading (Palanques et al., 2006). River floods by themselves do not generate strong sediment transport through canyons, but they generate temporal deposits on the shelf that are winnowed and transferred offshore during sporadic strong eastern storms and seasonal cascading events. Similar behavior has been observed in the other central canyons, where sediment is stored temporarily in shelf depocentres until a strong storm reaches the area (Puig et al., 2003). Other canyons probably also follow this pattern.

3. Zooplankton patterns in the Gulf of Lions

In the Gulf of Lions, the distribution of zooplankton biomass is rather heterogeneous despite its limited geographical extent (Gaudy et al., 2003). The enrichment effect of Rhone river input and the oligotrophic influence of the North Mediterranean Current are the main distribution factors of zooplankton biomass. Biomass increases according to an offshore–coastal gradient and an east-west gradient. The input of continental water (mainly the Rhone river) results in lower temperature and salinity conditions near the coast, and in richer food conditions for zooplankton increasing the total particulate organic Nitrogen and Carbon, also the chlorophyll concentration and of primary production.

Zooplankton biomass is twice as abundant in spring. In winter, the general potential food enrichment is limited to the area close to the Rhone discharge, but in spring, when the freshwater input is more important, it influences all the central and western part of the Gulf. On the contrary, offshore regions display poorer food conditions due to the oligotrophic character of the North Mediterranean Current.

Associated to river low salinity waters, high copepod and other zooplankton group densities have been recorded in the Gulf of Lions (Razouls and Kouwenberg, 1993) along with an increase in zooplankton biomass and feeding activity in the outflow plume of the Rhône River (Pagano et al., 1993). These rich zooplankton production areas have been reported to be important spawning grounds of anchovy in the northwestern Mediterranean, favoring larval fish survival (Palomera et al., 2007) as well as the diet and condition of the adults (Banaru and Harmelin-Vivien, 2009). Furthermore, over the shelf, topographic irregularities can greatly modify circulation producing complex plankton distributions (Alvarez et al., 1996). Hence, submarine canyons at the continental margin of the NW Mediterranean can interact with the Northern Mediterranean Current and modify the general circulation, generating topographically controlled up- and downwellings and affecting the shelf-slope water exchange (Durrieu de Madron et al., 1994). All these processes favour high concentrations of zooplankton and fish larvae along all Gulf of Lions shelf and near the coast (Sabatés and Olivar, 1996).

The geographical and temporal variations of zooplankton biomass are positively linked to the level of the primary production but also depend on the quality of food. In spring, the increase of food energy necessary to account for the seasonal enhancement of the zooplankton biomass needs a complement of phytoplankton food by another source of food, of animal nature, mainly organic particles and pico and nanoplankton (Saiz et al., 2013). On the contrary, in winter, plant food seems sufficient for the maintenance of the lower zooplankton biomass observed at this season. The average secondary production was 54 mg C m^{-2} d^{-1} in spring and 19 mg C m^{-2} d^{-1} in winter, which represents 11% and 12% of the primary production, respectively (Gaudy et al., 2003).

4. Benthic communities in the Gulf of Lions

The available information on the benthic habitats on the shelf and slope area of the Gulf of Lions from the European Nature Information System (EUNIS) is summarized in Figure 11. Although EUNIS is the most comprehensive marine benthic habitat classification currently in use, the marine habitats described up to date in this classification system do not include detailed data for the biocenoses and facies found recently on the shelf and slope of the Gulf of Lions. Thus, the name of the main biocenoses and facies distributed in the shelf and slope of the Gulf of Lions according to their bathymetric position is summed up (see table below) (code names of the habitats according to the UNEP-MAP-RAC/SPA (2006) classification of the Marine habitat types for the Mediterranean).

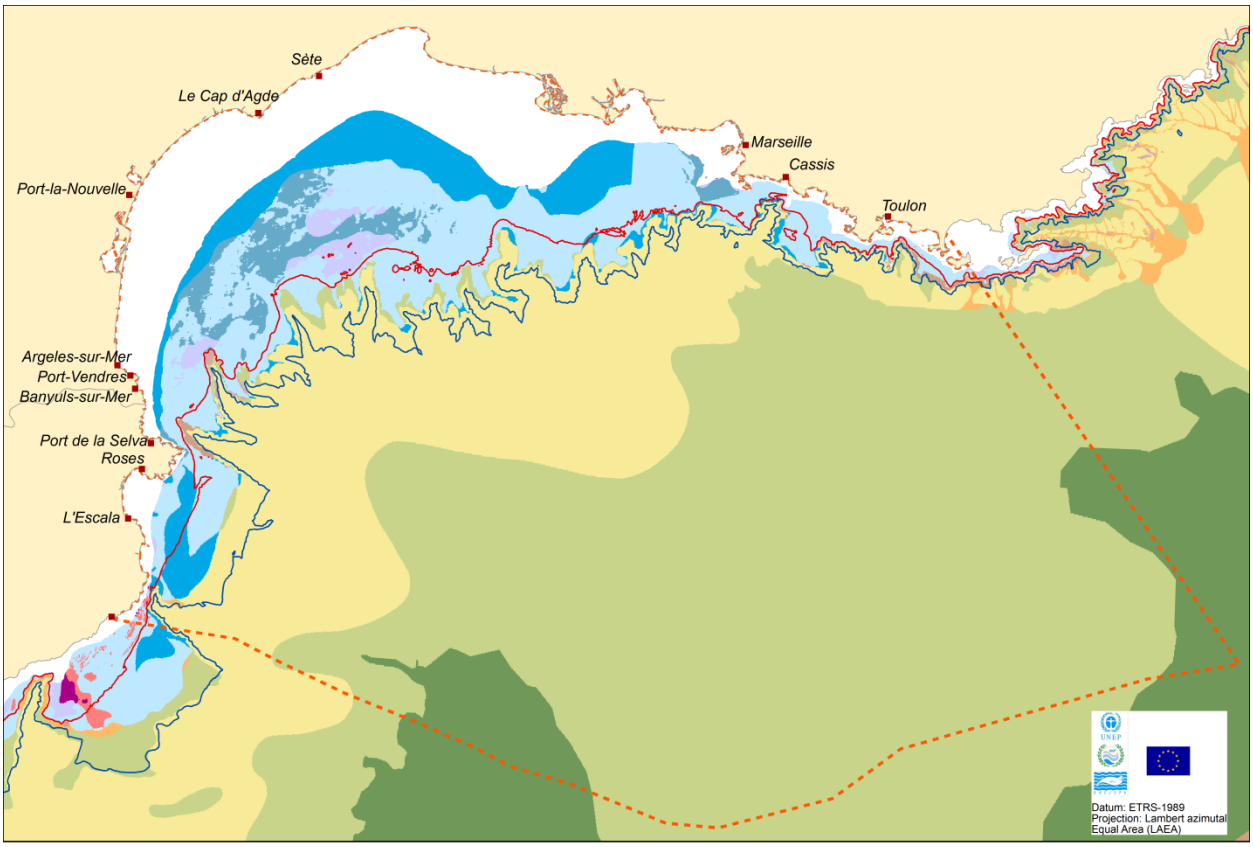


Figure 11. Modelled Seabed Habitats in the estudied area (EUSeaMAP project) under 80 meters depth. This is a predictive EUNIS seabed habitat map following the EUNIS 2007-11 classification system. The EUNIS classification has been supplemented by additional categories in deep-sea areas.

This list is based on the recent data obtained from the information gathered in recent surveys (Gili et al., 2011, Fourt and Goujard, 2012) accomplished by the French government (*Agence des aires marines protégées*) and Spanish government (INDEMARES consortium). The shelf and slope of the Gulf of Lions is a highly productive area that exhibits a mosaic of habitats of soft and hard bottom faunal communites. Fourteen biocenoses or facies have been described, from which four of them are previously un-described (Table 1). All habitats are classified as sensitive habitats and essential marine habitats (Ardizzone, 2006, GFCM 2008). Also most relevant species recurrently observed with the above described benthic communities are listed in table 2 and their international protection status. These habitats represent sensitive habitats of high biodiversity value that take into account the ecological

value of habitats, habitats that are essential to rare, endangered or threatened species or habitats that are considered of importance because of their value as natural heritage, and are mainly based on the potential role of the habitats in sustaining the productivity of fishing grounds. All the habitats listed are highly susceptible to fishing pressure and highly sensitive to bottom trawling disturbance, along with the exacerbating effects of climate change. These threats makes these areas high priorities for inclusion in any future comprehensive MPA.

CANYONS OF THE GULF OF LIONS AND ROCKY BANCS

	Communities	Cap de Creus	Lacaze duthiers	Pruvost	Bourcart	Marti	Sète	Montpellier	Petit Rhoône	Grand Rhône	Couronne	Planier	Cassidaigne	"Roches de Lacaze-Dutiers"	Roches de Sète	Ichtys Banc
CIRCA	Facies of sticky muds with *Virgularia mirabilis* and *Pennatula (phosphorea)*	X									X					
CIRCA	Facies of sticky muds with *Alcyonium palmatum* and *Stichopus regalis*	X														
CIRCA	Facies with *Ophiothrix quinquemaculata*	X														
CIRCA	Facies with *Leptometra phalangium*	X	X	X		X		X	X	X						
CIRCA	Biocenosis of shelf-edge rock ("Roche du large")	X											X	X	X	X
CIRCA	*Facies of Sponges	X											X	X	X	
CIRCA	*Oysters bancs (*Neopycnodonte cochlear*)		X											X	X	
BATH	Facies of sandy muds with *Thenea muricata*				X	X	X	X	X							
BATH	Facies of soft muds with *Funiculina quadrangularis* and *Apporhais seressianus*	X				X	X		X							
BATH	Facies of compact muds with *Isidella elongate*				X	X		X	X	X						
BATH	*Facies with Ceriantharia			X	X	X			X			X				
BATH	Biocenosis of Cold-water corals	X	X										X			
BATH	*Facies of *Neopycnodonte zibrowii*		X									X	X			
BATH	*Facies of *Callogorgia verticillata*				X							X	X			
	*Communities not listed in the classification of Marine habitat types (UNEP-MAP-RAC/SPA 2006)															

Table 1. Described biocenoses in the Gulf of Lions area

Taxon	UICN	CITES[2]	Berna Convention[3]	Barcelona Convention[4]	Habitats Directive[5]
Scyllarus (Arctus) arctus			P3	Annex III	
Palinurus elephas			P3	Annex III	
Palinurus mauritanicus	Least Concern (LC)[1]				
Corallium rubrum					Annex V
Leiopathes glaberrima		Annex II			
Antipathes dichotoma		Annex II			
Antipathella subpinnata		Annex II			
Caryophylliidae		Annex II			
Scleractinia		Annex II			
Dendrophyllia cornigera		Annex II			
Desmophyllum dianthus		Annex II			
Lophelia pertusa		Annex II			
Madrepora oculata		Annex II			
Spongia (Spongia) lamella			P3		Annex III
Aplysina cavernicola			P3		

1 Cockcroft, A., Butler, M. & MacDiarmid, A. 2011. Palinurus mauritanicus. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2.
2 Convention on International Trade in Endangered Species of Wild Fauna and Flora (1963).
3 Convention on the Conservation of European Wildlife and Natural Habitats (1979).
4 Convention for the Protection Of The Mediterranean Sea Against Pollutiond (1976), revised in 1995 as the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean.
5 Council directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

Table 2. Most relevant species associated to the benthic communities described in the Gulf of Lions and international protection status.

5. Fishes, seabirds and cetaceans: bathymetric synthesis

Continental shelf (60-90 m)

The bottom trawl surveys carried out by the Fishery Laboratory of IFREMER on the continental shelf and the upper part of the slope of the Gulf of Lions between 1983 and 2009 have provided quantitative biological data, geographic distribution and abundance indices of the main demersal resources (Blanchard, 2001). These reports give information on more than 40 species. Altogether, their results confirm older observations (Maurin, 1968) and show that the distribution of most of fish species is mainly linked to the bathymetry and to the types of substratum (Table 3).

CONTINENTAL SHELF		CONTINENTAL SLOPE	
Species	**kg/km²**	**Species**	**kg/km²**
Trisopterus minutus	108	*Micromesistius poutassou*	225
Trachurus trachurus	72	*Galeus melastomus*	179
Merluccius merluccius	52	*Lophius piscatorius*	66
Lophius budegassa	39	*Helicolenus dactylopterus*	66
Eutrigla gurnardus	38	*Nephrops norvegicus*	59
Eledone cirrhosa	29	*Phycis blennoides*	27
Scyliorhinus canicula	22	*Merluccius merluccius*	22
Micromesistius poutassou	20	*Pagellus bogaraveo*	22
Pagellus acarne	17	*Scyliorhinus canicula*	19
Octopus vulgaris	16	*Trachurus trachurus*	15
Trachurus mediterraneus	11	*Lopius budegassa*	15
Mullus barbatus	11	*Raja clavata*	15
Boops boops	11	*Eledone cirrhosa*	13
Lophius piscatorius	9	*Pagellus acarne*	11
Eledone moschata	8	*Lepidorhombus boscii*	10
Aspitrigla cuculus	6	*Aristeus antennatus*	9
Citharus linguatula	6		
Lepidorhombus boscii	5		

Table 3 List of the main species caught during the trawl surveys in the Gulf of Lions during the period 1994-2009 with their abundance indices (extracted from Farrugio, 2011)

The upper zones of the continental shelf are inhabited by species like red mullets (*Mullus barbatus*, *Mullus surmuletus*), sole (*Solea solea*), gurnards (*Trigla sp*.), poor cod (*Trisopterus minutus capelanus*), Black Sea whiting (*Merlangius merlangus*) and some shrimps.

Most of the small pelagic species are in general distributed close to the coast, over the continental shelf. The majority of these species undertake rather well defined seasonal migrations, which explain the seasonal character of their fisheries. Sardine (*Sardina*

pilchardus), anchovy (*Engraulis encrasicholus*) and horse mackerel (*Trachurus trachurus* and *Trachurus mediterraneus*) move close to the coast during the summer months, which corresponds to the

main fishing period of these species. During the winter, they move away from the coast and shift to more or less deeper waters (David, 2011).

The presence of fishing vessels acts as a visible mark for seabird distribution, since bycatch species have become an important part of the diet for many seabirds. The area of Cap de Creus in the west and the Provence in the east have become important areas for birds, particularly for all 3 shearwater species (*Puffinus mauretanicus*, *Puffinus yelkouan* and *Calonectris diomedea*), the Shag (*Phalacrocorax aristotelis desmarestii*), the Northern gannet (*Morus bassanus*) and other migratory seabirds. Most of these species feed mainly in the nearshore and in frontal areas, either naturally, or attending to trawlers in search of discards.

The continental shelf is not a preferred habitat for most of the cetacean species inhabiting in the Gulf of Lions, being the bottlenose dolphin (*Tursiops truncatus*) the most commonly observed species in such area, with a distribution ranging from the coast through the shelf edge and canyon's heads (Gnone et al., 2011).

Shelf break and upper slope (90-400 m)

Experimental fishing with gillnets done in 1977 offshore the French-Spanish border at depths comprised between 100 and 150 m (Campillo, 1979) showed a great abundance of selachians (more than 70% of the total catch in weight). The bony fishes represented 22% among which the most abundant where the hake (*Merluccius merluccius*), the horse mackerel (Tra*churus trachurus*), the rosefish (*Helicolenus dactylopterus*), the monkfish (*Lophius piscatorius*) and the axillary sea bream (*Pagellus acarne*). In general all of these fishes where adults having reached or exceeded their size at first maturity. On the continental slope there are also many fish species of great economic interest. In the upper part of the continental slope. 200 and 400 m. it is common (*Merluccius merluccius*), Norway lobsters (*Nephrops norvegicus*) and various shrimps (e.g *Aristeus antennatus*, *Parapenaeus longirostris*).

The distribution and the seasonal abundance of the most commercially important species have remained particularly stable in time for many years. This situation is due to the presence of the canyons on the continental slope, situated outside the traditional fishing sectors, which are "reservoirs" sheltering fishes having escaped the fishery of juveniles on the continental shelf and being able to reach the adulthood, reproduce and insure the perpetuity of the resources (Farrugio, 2010).

An important case in the Gulf of Lions is the hake (*Merluccius merluccius* L., 1758) fishery. This demersal species is very widely distributed in the whole gulf, from the coastal sector until 800 m depth, but mainly present between 80 and 150 m depth (Farrugio and Marin, 1999). Eggs and larvae are present preferentially on the continental shelf with a peak of abundance between 100 and 200 m. The age group O (< 15cm) is very abundant from June untill November between 100-150m. Its higher densities are located on the upper border of

the slope (Farrugio and Marin, 1999) at depths lower than 200 m (Recasens et al., 1998). The age group 1 (15-18 cm) is dominant in these same places but can also be met in the coastal zone while the group 2+ (>18 cm) occupies the whole shelf with variable but particularly important spatio-temporal concentrations on the border of the continental slope and on the upper part of the canyons. The juveniles do not seem to show a preference for a precise geographical sector but show a distribution varying in time and space between 80 to 150 m depth. The adults are more scattered in spring and in summer than in autumn and winter. They are found from 100 m to areas deeper than 400 m in spring and in summer. However several observations (Ferraton et al., 2007) suggest an influence of the water of the Rhône river on the biology of the young hakes (5-14 cm) as they are mainly concentrated in the area off the Rhône delta. Besides, they have in general a better hepato-somatic index and a better condition factor in that area. This can be explained by the fact that the part of the continental shelf near the delta benefits very probably from a strong primary phytoplanctonic production that could infer a greater production of the essential preys of the juvenile hake.

Given the conservation value for both fisheries and vulnerable ecosystems in the Mediterranean this area was selected as a demersal area for hake (Figure 12) (UNEP-MAP-RAC/SPA 2010a).

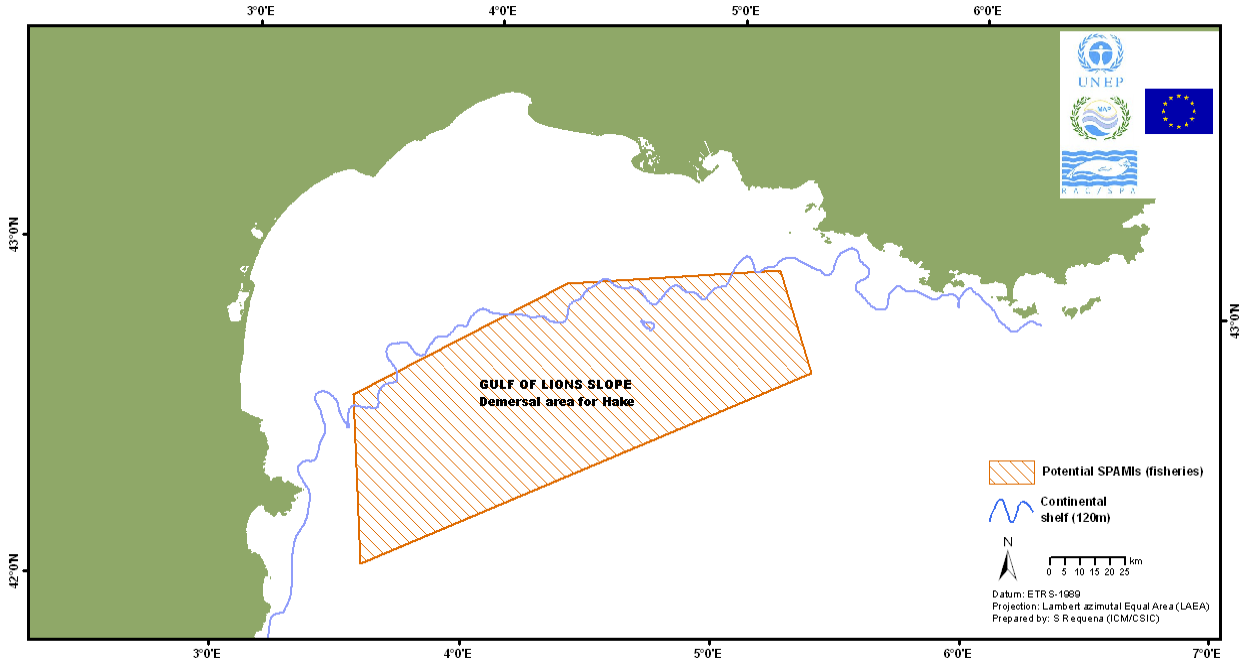


Figure 12. Results from the previous project phase related to the 'Gulf of Lions shelf and slope'. Potential SPAMIs in the Mediterranean areas beyond national jurisdiction in order to protect ecosystems from fishing disturbance. From UNEP-MAP-RAC/SPA (2010a). Fisheries conservation and vulnerable ecosystems in the Mediterranean open seas, including the deep seas.

Based on its conservation value for Mediterranean seabirds, an important area for birds is identified over the external continental shelf and heads of canyon in the central part of the Gulf of Lions. This area overlaps partially with the area included in the original proposal put forward in 2008 by the French *Agence des aires marines protégées* for consideration for a

future Natura 2000 site *Plateau et Têtes de Canyon du Golfe de Lion* because of its value as principal foraging grounds for the 3 shearwater species, Storm petrel and Northern gannet. This area is frequented by large numbers of shearwaters of the 3 species (*Puffinus yelkouan*, *Puffinus mauretanicus* and *Calonectris diomedea*) and is also intensively fished, so the probability of interaction is high. Management measures should be directed at minimising the probability of mortality through bycatch (Carboneras, 2009) and at safeguarding the long-term maintenance of fish populations, particularly of anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*).

The slope appears more frequented by teutophageous species. Risso's dolphins (*Grampus griseus*) are encountered all along the slope. Concerning sperm whales (*Physeter macrocephalus*), Pilot whales (*Globicephala melas*) and Cuvier's beaked whales (*Ziphius cavirostris*), they seem to exploit preferentially some peculiar canyon's systems: Creus and Lacaze-Duthiers for the three species and Sète and Marti for the sperm whale (*Physeter macrocephalus*) and pilot whale (*Globicephala melas*). For the coastal bottlenose dolphin (*Tursiops truncatus*), the shelf edge and canyon's heads are also important.

Deep sea (>400m)

In deeper waters, from 400 to 600m, the dominant species are the greater forkbread (*Phycis blennoides*), the blue whiting (*Micromesistius poutassou*) and the red shrimps (*Aristeus antennatus* and *Aristaemorpha foliacea*).

The presence of large mature individuals of several species of fishes and crustaceans has been particularly observed in the zone declared as a FRA. A total of 88 fish species were recorded, of which 12 are priority species for the GFCM. Up to 17 species accounted for 90% of the biomass caught during these surveys. The available data show that individuals from species of high economic importance particularly relevant to fisheries like hake, monkfish and Norway lobster occurring in the area are large adult specimens; furthermore the yields obtained for several species of fishes and crustaceans of high economic importance (*Lophius piscatorius*, *Nephrops norvegicus*, *Aristeus antennatus*, *Merluccius merluccius*, *Trigla lyra* and *Lepidorhombus boscii)* are higher than the ones registered at the same time in the landings of the commercial French and Spanish fisheries (Lleonart et al., 2008).

This bathymetric range is comparatively large (roughly about two thirds of the study area) but is relatively poor as a potential habitat for foraging seabirds. The absence of significant features in the bathymetry or in the water column, and the dispersed fishing activity (mostly consisting of pelagic longlining), give homogeneity to the area and make it rather unattractive for foraging seabirds. Only Mediterranean Storm petrels (*Hydrobates pelagicus melitensis)* regularly forage on these waters, and they do so at low densities. Thus, the outer part of the study area made of the external waters beyond the continental shelf is not identified as an important area for birds.

Concerning pelagic waters, the entire area is important for species inhabiting this habitat, like fin whales (*Balaenoptera physalus*), pilot whales (Globicepha*la melas*) and even sperm whales (*Physeter macrocephalus*).

Beyond the 600 m isobath, the bibliography consulted for this report did not bring enough information or conclusive evidence.

6. Conclusions. Identification of the areas in the Gulf of Lions shelf and slope area that may deserve to be protected

9.1.4 Criteria assessment

There exist a large number of criteria for the selection of marine protected areas. In 2010, Notarbartolo di Sciara and Agardy reviewed existing criteria, from the SPAMI selection criteria of the SPA/BD Protocol to the Barcelona Convention and the CBD criteria for the identification of ecologically or biologically significant areas to the the EU 'Habitats Directive' as well as other criteria such as those developed by or the World Heritage Convention (UNEP-MAP-RAC/SPA 2010b). From this review they presented an adaptation of the SPAMI selection criteria to Mediterranean Areas Beyond National Jurisdiction site selection combining some elements from other sets of criteria, in particular those developed with the CBD, which could help in the process. Althoug the proposed criteria were initially designed for the selection of EBSAs we consider that they application can be also useful for the identification of the areas inside the Gulf of Lions that may deserve to be protected.

9.1.5 Priority areas for conservation

A first outcome of our analysis is that the arc of the Gulf of Lions canyons approximately from 80 m depth to 1000 m depth, constitute one ecological unit and function as an area of special interest in the framework of the Integrated Ecosystem Assessment (Lewin et al., 2009). The area extends from the head of the canyons of the Gulf of Lions (from Cap de Creus to Cassidaigne) (Figure 13) along the border of the continental shelf and over the shelf break (80m depth) thus including the "Roches de Lacaze-Dutiers", the "Roches de Sète" and the "Ichtys Banc".

We applied the UNEP-MAP-RAC/SPA 2010 criteria to this area and scored each component according to a rank from 0 "Not at all", 1 "Low", 2 "Medium", 3 "High", to 4 "Very high" (Table 4). Our conclusion was that this area qualifies as "Very high interest" in four of the criteria: I importance for threatened, endangered or declining species and/or habitats; (d) vulnerability, fragility, sensitivity, or slow recovery, I biological productivity and (f) biological diversity. It qualifies as "High interest" in another two: (a) uniqueness or rarity and (b) special importance for life history stages of species and and as "Medium" in one, (g) naturalness.

Characteristics of the area proposed:

1. The area proposed coincides largely with that proposed to preserve the demersal resources and the vulnerable ecosystems in the Mediterranean named "Gulf of Lions slope" (UNEP-MAP-RAC/SPA, 2010a) except that the former did not include the Cap de Creus and Lacaze Duthiers canyons (see Figure 10).
2. The area can be considered a biodiversity hotspot, with exceptional geomorphological and oceanographical features in the Mediterranean context.

3. The proposed area also includes the GFCM Fisheries Restricted Area (FRA) called "Continental slope of the Eastern Gulf of Lions" valued for its role as a refuge for large spawners of several commercially important species, including hake.
4. The area hosts a mosaic of habitats of soft and hard bottom faunal communities up to fourteen described biocenoses or facies (from which four of them are previously un-described). Although the extent of all these habitats is still poorly known, all habitats are classified as sensitive and essential marine habitats (Ardizzone, 2006, GFCM 2008). Essential benthic habitats on soft bottoms are more relevant in the central area. These habitats are hosting large biomasses of commercial fish, decapods and cephalopods as well as recruits (i.e. Facies with *Virgularia mirabilis* and *Pennatula* (*phosphorea*); Facies with *Leptometra phalangium*; Facies with *Thenea muricata*; Facies with *Funiculina quadrangularis*; facies with *Isidella elongata*). Essential benthic habitats on hard substrates are mainly localized on the edge of the Gulf canyons (i.e. Cap de Creus, Lacaze-Duthiers and Cassidaigne), and on circalittoral rocky-bancs. These habitats provide habitat, feeding grounds, recruitment and nursery functions for a range species including commercial species, however the number of associated with these habitats is still unknown.
5. The area proposed is also of high interest as feeding grounds for seabirds and cetaceans. Large numbers of shearwaters of the 3 Mediterranean endemic species feed in these waters, principally on anchovy and sardine. Cetacean species seem to exploit the canyons system differentially, whereas the shelf edge and canyon's heads are also important for the more coastal bottlenose dolphin (*Tursiops truncatus*).

Criteria	**Score**
Uniqueness or rarity. *The area contains either (i) unique ("the only one of its kind"), rare (occurs only in few locations) or endemic species, populations or communities, and/or (ii) unique, rare or distinct, habitats or ecosystems; and/or (iii) unique or unusual geomorphological or oceanographic features.*	High
Special importance for life history stages of species *Areas that are required for a population to survive and thrive.*	High
Importance for threatened, endangered or declining species and/or habitats *Area containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species.*	Very high
Vulnerability, Fragility, Sensitivity, or Slow recovery *Areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.*	Very high
Biological productivity. *Areas containing species, populations or communities with comparatively higher natural biological productivity.*	Very high
Biological diversity *Areas containing comparatively higher diversity of ecosystems, habitats, communities, or species, or has higher genetic diversity.*	Very high
Naturalness *Areas with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation.*	Medium
Cultural representativeness *Area has a high representative value with respect to the cultural heritage, due to the existence of environmentally sound traditional activities integrated with nature which support the well-being of local populations.*	Not considered

Table 4 Scoring: 0 “Not at all”, 1 “Low”, 2 “Medium”, 3 “High”, 4 “Very high”

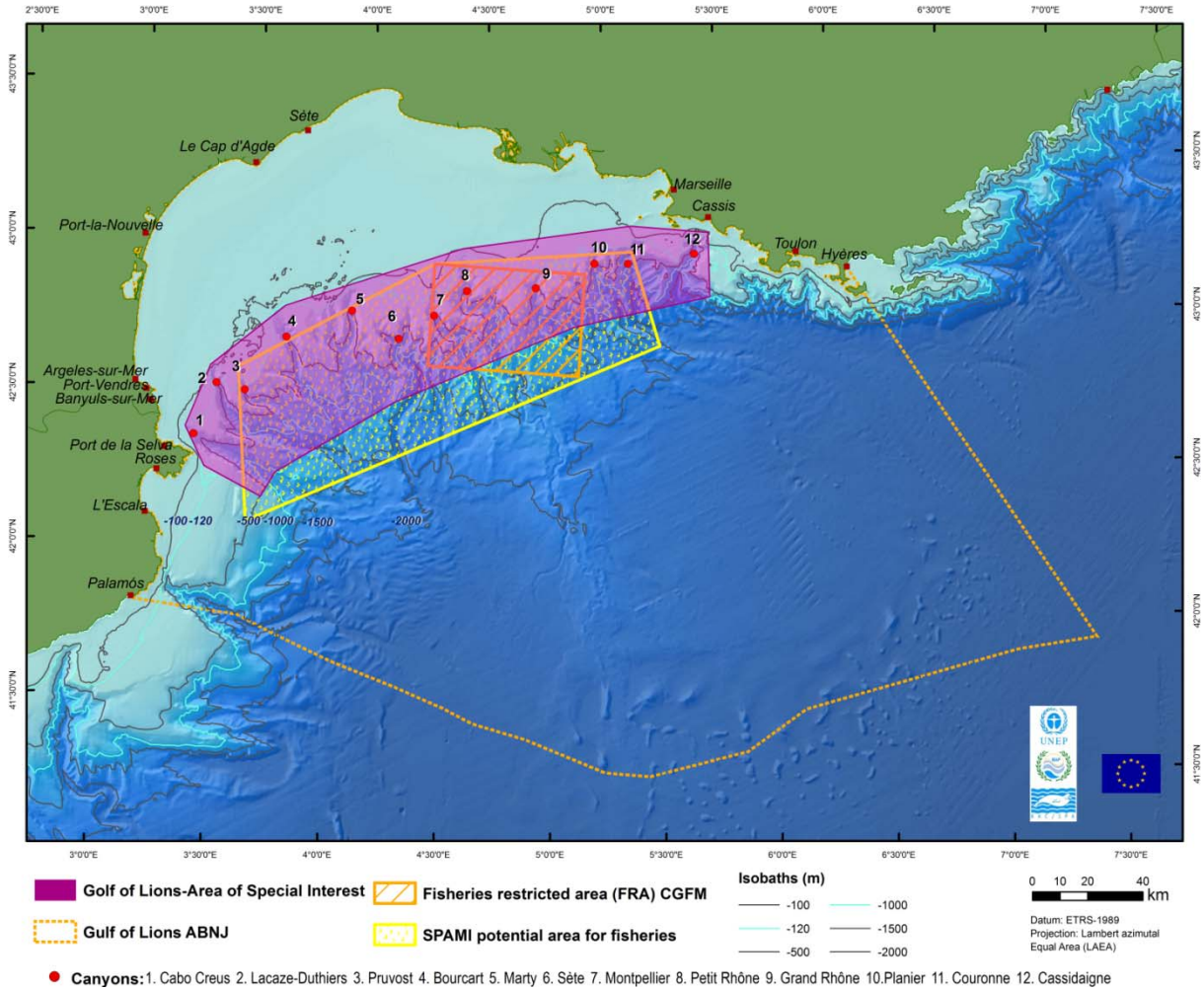


Figure 13. Area of Special Interest in the Gulf of Lions for the RAC/SPA project to identify and establish Marine Protected Areas in the open seas, including the deep seas.

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