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SPATIAL ASSESSMENT AND IMPACT OF ARTISANAL FISHERIES' ACTIVITY IN CAP DE CREUS

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ABSTRACT

North western Mediterranean is characterized to present a high fishing activity and consequently, the awareness to preserve and protect high ecological important areas has been recently on the scope. The region of Cap de Creus is lately being subjected of study in order to assess its values in the frame of the Habitat Directive and Natura 2000 Network, as the [1]LIFE+Indemares Project. By combining existing data of artisanal fisheries' components together with gathered substrate type and seabed composition, a spatial distribution of fishing activity is pretended. The spatial approach of the diverse fishing types acting in this area has been the main tool when assessing the consistency of fishing pressure onto the seabed. Benthic communities seem to be more affected when the confluence in space of two or more fishing types occur. Consequently, alternating parceling and seasonal closures among the main fishing gear types, in order to minimize the impact onto benthic communities as also setting no-take zones is strongly suggested. The establishment of a MPA in the near future has to be seen for all stakeholders as one step contributing to an efficient sustainability of the ecosystem, once the potential impact of this fishing activity has been shown. Mid-scale benefits by means of reducing fishing pressure in the area will enhance both alternative income solutions and spillover offset as a result of habitat recovery.

Keywords: métier, GIS, fishing spatial activity, MPA, fisheries management, Cap de Creus.

INTRODUCTION

European directives are strongly encouraging to increase coastal but also offshore marine protected areas in each European country. A significant human pressure is causing the decreasing health of the oceans and threatens the availability of the natural resources (Claudet & Pelletier 2004). MPAs have been envisaged not only as a potential tool for conservation but also as safeguard to cultural heritage, human activities and their impact. Cape Creus area is currently being studied in order to evaluate its potential ecological value to become the first MPA offshore from the [1]LIFE+Indemares Project, in the frame of the Habitat Directive and Natura 2000 Network as well as the [2]Biodiversity Law at the national level. In order to define a first step on the fisheries' domains in Cap de Creus, an instrumental study pretends to be done by taking advantage of the stocktaking conducted by the FAO-COPEMED Project.

The Mediterranean is characterized for having high diversity of fishing gears and target species; artisanal fisheries represent an 80% of the EU Mediterranean fleet (COM 2002). Artisanal fisheries are defined as the combination of port, gear, target species, fishing zone and fishing season (FAO 1995) and these are mainly characterized by owning boats 12m maximum size and with a small capital investment (Colloca et al. 2004). The concept of *métier* is applied in order to define the real effort invested in a resource due to the heterogeneity of captures; assessing the distribution of fleets considering strategies, practices (i.e. target species and their behavior) and fishermen's knowledge (Coppola 2006). Métiers allow the identification of more operative ordination units and they include any type of gear, except for typically semi-industrial or industrial ones such as trawlnets, large seines for small pelagic fish, gear targeting large pelagic fish (purse seines, longlines, drift nets, stationary uncovered pound nets –madragues–, tuna rods, and trolling lines), hydraulic mollusk dredges and large longliners. Any type of fishing that uses light is also considered an artisanal fishery (FAO 1995). The diversity of artisanal fisheries can be explained at the technical and economical levels. Regarding the technical characteristics, small tonnage, low power and reduced autonomy (<24hours) prevail. In terms of socio-economic factors influencing artisanal fisheries, they can be listed as

[1]LIFE+INDEMARES LIFE07/NAT/E/000732
[2] Law 42/2007, December 13th, Natural and Biodiversity Heritage

ownership of the boats, practice of other professional activities, crew size (small, 1 to 5 people), connection of employment with investment, direct sale of fish to shops or restaurants, low tonnage of individual catches but highly valuable and small hierarchy in the work at sea (Coppola 2006). From the point of view of fisheries exploitation, the continental shelf and the shelf-break are the most interesting areas where most of the resources are and hosting a wide range of habitats.

Artisanal fishing activities in Cap de Creus have been characterized by one day's work; ensuring fishermen to be generally backing home after the journey. Despite alternating seasons for target species and closed fishing seasons, fishing takes place all year around weather permitting. Fishermen's local knowledge determines this seasonality by considering species behavior and its abundance along the year (Stelzenmüller et al. 2007) and tend to decrease as distance and depth increase (Demestre et al. 1986). Fishers tend to state the lack of specificity in their fishing grounds' choice, but instead weather and previous fishing day experiences determine their destination. The first organized fishing exploitations recorded in the area of Cap de Creus come from year 812 (Bas et al. 1955).

Up to date, fisheries management has not been very effective, often ignoring ecosystem components and interactions such as habitat, predator and prey of target species (Pikitch et al. 2004). Fishing activities increasingly participate in habitat destruction, accidental mortality of nontarget species, changing functioning and structuring of ecosystems and causing evolutionary shifts in the demography of populations (Pikitch et al. 2004). Worldwide, fishing is affecting the seabed habitat on the continental shelf (Kaiser et al. 2002). It is clear that any fishing gear will disturb the sediment and resident community at some degree but not all fishing methodologies affect habitats in the same way; likewise, levels of disturbance vary among habitat types as a result of fishing intensity and frequency. Bottom-fishing activities involving mobile fishing gear have a physical impact on the seabed and the biota living there (Kaiser et al. 2002). Consequently, it is important to know the intensity of the disturbance which will depend on used gear, sediment type and water depth (Kaiser et al. 2002). Accordingly, an approach by means of the spatial definition of fishing activities and their overlapping will serve to value the status of existent communities by marking off the habitat impact in a patchy distribution. Thus, this is an essential tool to be taken into consideration when analyzing an area for protection.

Often, the lack of good quality benthic habitat maps is the main obstacle to effectively protect a vulnerable habitat for fishing activities (Kaiser et al. 2002).

The use of GIS tools is often used to account for spatial predictions (Stelzenmüller et al. 2007, Requena Moreno 2009, Forcada et al. 2010). In here, an approach to assess vulnerable and less damaged communities combined with spatial coincidence in time of fishing gears is done.

[3]*LIFE+Indemares Project* – Inventory and designation of marine Natura 2000 areas in the Spanish sea

In June 2009, the agreement of creating a network of ten marine protected areas was publicly approved in order to extend and expand the Natura 2000 Network to the marine realm in the Spanish sea. The record which this list arose from was the report presented by WWF/Adena in 2006 (Marcos 2005), where a panel of Spanish scientists proposed 76 littoral and offshore areas prioritary for conservation. Promoted by Spain and with the approval and participation of the European Commission (LIFE+), this project was raised as LIFE+INDEMARES, and currently these ten areas are in process of being scientifically studied. These assessments are necessary to be able to identify habitats and species as well as to evaluate the past and present impact of fisheries' activities –among others– in these sites, in order not only to protect but to well-manage the area in a sustainable way. Therefore, besides the role of the Spanish Ministry of Environment, two research institutions (CSIC –Spanish Council for Scientific Research- and IEO –Spanish Institute for Oceanography), Biodiversity Foundation and several NGOs (Alnitak, CEMMA, Oceana, SECAC, SEO/BirdLife and WWF/Spain) together with the Spanish Secretary of the Sea operate in a coordinate way. The obtained results will allow completing the marine Natura 2000 Network in Spain, in an agreed way with the fisheries sector (especially fishermen associations –*confraries*-) for a mid and long-term direct benefit for all parts. These planned cruises will promote information, participation and awareness to the population.

[3] *http://www.indemares.es*

[4]FAO-COPEMED Project

Born in 1996 this project consisted on supporting the fisheries management in the Western and Central Mediterranean aiming to maintain marine resources and ecosystems in a sustainable way. The lack of systematic information on artisanal fisheries and the poor level of knowledge of this sector, together with the need to integrate data within countries, lead to the creation of the FAO-COPEMED Project. This included taking into account the biology, environment, economy and society throughout scientific cooperation. Composed by eight member countries: Algeria, France, Italy, Libyan Arab Jamahiriya, Malta, Morocco, Spain and Tunisia; the challenge consisted in assessing artisanal fisheries throughout a project activity at a regional level.

The decline in the marine resources of certain areas due to the ongoing overfishing and overcapacity of many fish populations has unavoidable consequences on the fishermen's community income and the environmental degradation. FAO-COPEMED is under the responsibility of the Fisheries and Aquaculture Management Division (FIMF) and the Food and Agriculture Organization (FAO); it is being promoted as well by the FAO's General Fisheries Commission for the Mediterranean (GFCM) in order to facilitate as far as possible the research on shared stocks.

This project has been the first-ever inventory of regional artisanal fisheries in this area of the Mediterranean. A new working plan was created in order to define fleets considered as artisanal fisheries, locating and stocktaking all the artisanal fisheries' communities in the region and the data collection. Considered as a pioneer study in widening scientific knowledge and regional cooperation for the sustainable management of the Mediterranean fisheries, it intends the future application into other regions (Alarcón 2001).

Initially its period duration was 5 years; however it was extended until May 2005. Complementarily, in 2008, an extension of the FAO-COPEMED Project into a second phase called FAO-COPEMED II entered on duty with a planned duration of 3 years promoting scientific cooperation within the countries in order to face the expectations

[4] *http://www.faocopemed.org*

regarding fisheries management. This second phase pretends to consider biological, environmental, economical, social and institutional sides (FAO-COPEMED 2008).

Socio-political framework

The Common Fisheries Policy (CFP) born as a management tool for fishing activity in the EU in collaboration with the EU countries' fisheries (territorial management in the 12-mile zone) has not succeeded as expected since its start (FAO 2008). The subsequent reforms in 2002 and 2009 seek to involve stakeholders from all Member States towards economic, environmental and social sustainability of fishing activities in the co-management conception.

Owing to the particular character of the Mediterranean led by an important tradition in self-management, ancestry and history of management institutions, in Spain the so-called *cofradías*, in Catalonia *confraries*, have prevailed as the local management institutions. When democracy was implanted, they became corporate organizations with exclusivity of territorial areas and administrative tasks as well as the base of the present co-management being public law corporations (Alegret 1999b). Their main function is offering marketing and administrative services to their associates (Alegret 1996b), the most important of which is the daily auction at the fish market. In addition, small-scale fisheries in a ¨high-seas¨ area, regional dependency of fisheries, significant market for undersized fish, high tradition in fish consumption and lack of enforcement tradition in certain areas, explain the distinctiveness of confraries' functioning. In Catalonia, fisheries' management competences rely on the autonomous regional government. The main issue of the coastal fishing sector in this area, as in most of the country, is to adjust catches to demand. In Alegret (1999b), the figure of confraries linking the fisheries sector and the administration serving as a co-management instrument, is seen as a transformation into top-down governance due to their loss of power in the face of merchants. The lack of coordination between the administrations in subdivisions of the maritime territory divide the competences and responsibilities in many issues such as minimum sizes, fishing effort, closed seasons, fleet modernization or creation of protected areas (Alegret 1999b). Since the entrance of Spain into the European Union, fishing competences are not only represented by confraries but also by the Producer's Organizations (POs) in order to organize first hand marketing of their members' quotes through the operation of a withdrawal price scheme (Symes et al. 2003, Camiñas et al. 2004).

Confraries manage fishing activities in their territorial limits according to three types of fleet: trawling, purse-seining and artisanal. Each one sets up a timetable for port entry and exit, closed fishing periods and regulations for each particular fleet in the fishing zones hold under jurisdiction. These resolutions are proposed to the administration to become laws. Moreover, management of catch and sales, control of the first stage of commercialization (auction market) and vessel registration among other tasks is as well under their administration domains. Since the second half of the 20th century the success of trawling and purse-seining and the expansion of tourism activities have resulted in a decrease of the artisanal fleet which up to date had been the most common activity. In turn, fishermen find new ways to share subsistence fishing (Hernández 2005). It is important to note that besides the difficulties in keeping up in the fisheries business, fuel subsidies are a great support and assistance to fishing professionals which in turn could serve as an incentive to support general regulations for marine protected areas (Gómez et al. 2006). National jurisdiction extends up its territorial Sea to 12 miles. Additionally, in 1997 Spain claimed a wider fisheries protection zone (by Royal Decree No. 1315/1997) in accordance with maritime borders and exclusive competences.

On the other hand, together with artisanal and commercial fisheries, there is the significance of recreational activities when quantifying fishing effort. Studies by Lloret & Riera (2008) reveal the importance of such activities when comparing annual catches with the artisanal fisheries; not only economically but also biological and ecologically. Unluckily, these activities in particular spearfishing are little known worldwide and the coexistence with uncontrolled recreational fishing is part of the big battle of professional anglers; thus, a complete integrated management for marine resources is not easy to assess.

When studying marine areas for conservation purposes, one of the main objections is to localize the anthropogenic pressure exercised in the area. Fishing tradition has distinguished this area since the old times; however, during the last decades fishing pressure is an evident fact. Just like in other fishing regions in Europe, the Mediterranean faces the problem of reconciling the economic activity with sustainable fish stocks and habitat conservation; thus, achieving a well understanding of key communities and fisheries' distribution is a first step for an integrated management with the main stakeholders, the fishermen.

By taking advantage of the stocktaking of the main fishery components associated with artisanal fisheries, a compilation with other existent regional information from the area is intended in order to find out the main goal. GIS software has been used as the main tool aiming to obtain the most complete conception of the spatial fishing activity in Cap de Creus and to assess the incidence of gears on an unprotected ecosystem. The focus on determining the degree of impact of certain areas according to the coexistence of one or more fishing gears will serve *a priori* to assess the vulnerability of the existent community types. There is expectation in the relationship between outstanding communities and less exploited areas.

MATERIAL & METHODS

Study area: Cap de Creus

Historically, Cap de Creus has been the first maritime-terrestrial park to be established in Spain in 1998, representing the marine domain in a 22%. The Natural Park was divided in several areas of protection (around Cape Creus peninsula, from Bol Nou in cala Tamariua (Port de la Selva), until Punta Falconera (Roses) except for the Cadaquès Bay). The rest of the park contains three natural partial reserves: Los Farallons, Cap de Creus and Cap Norfeu. Additionally, there is one integral marine reserve in S'Encalladora (Orejas & Gili 2009). Even if the protection figure is already existent, it is intended to extend the protected area to offshore waters comprising shelf, shelf-break and canyon. By considering the depth gradient, a more complete scheme of the system can be offered.

Cap de Creus is considered an extensive area (Figure 1). The littoral zone (0 to 60m), the continental shelf (60 to 150-200m) and the underwater canyon (with ecological studies from the 150-400m but abiotic information up to 2150m) (Orejas & Gili 2009). Cap de Creus canyon is the western canyon of a conspicuous underwater canyon system found in the Gulf of Lions from Toulon to Blanes.

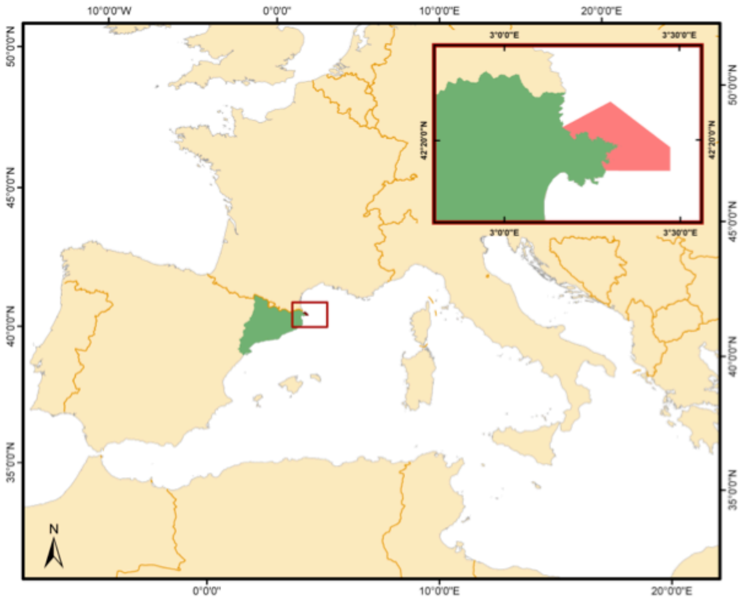

Figure 0. Study area of the LIFE+ Indemares Project in Cap de Creus (in red)

It is an area of complex bathymetry and very nutrient rich from the outflow of several rivers (Rhône river from Gulf of Lions and the local rivers Ter, Fluvià and Muga). It starts at the continental shelf at about 90-100m depth and it extends up to 5Km off the coast (42°18’49.202 N – 003°34’ 6.000 E). The canyon is oriented northwest-southeast giving a V-shape structure breaking into the open sea. In total is about 95Km long and presents a maximum depth of 2150m.

The Liguro-Provenzal-Catalan current (aka Northern Current) from the Gulf of Lions, the input from the above mentioned rivers together with strong dominant north winds causing water mixing, make of this area a highly productive zone. Consequently, it is an area conducive to the agglomeration of pelagic fish among others.

The presence of free water currents coming from the Gulf of Lions collide with the outstanding Cape Creus causing its displacement from the coast and allowing littoral currents between this and the coast. Another phenomenon is the deep convection occurring in winter when a maximum in surface salinity combined with strong, cold and dry northerly winds and a cyclonic circulation, known as the Western Mediterranean Deep Water formation are found (Salat 1996). This process produces dense water which sinks to the bottom as a section of newly formed deep water. The cascading effect is been reported as an alternative mechanism to deep water formation in the northern Catalan

Sea (Fieux 1974). Ulses et al. (2008) refer to water cascading and to marine storms as two mechanisms responsible of regulating shelf-slope exchanges causing downwelling to submarine canyons. During winter, the cooling from northwesterly winds destratify and increase in density water from the shelf enabling the plunging down the slope.

The current system along the Gulf is strengthen and accelerated by the wind, receiving the south westernmost part of the Gulf, the highest intensity. In this extremity, the narrowing of Cap de Creus shelf together with the offshore limitation by the Cape Creus Canyon, result in a larger acceleration of currents. A well-figured simulation of currents in the area can be found in Ulses et al. (2008). The spreading of continental influence on waters is preferred for spawning as shown in studies with anchovy by Salat (1996), coinciding with the water stratification period in spring and summer, which otherwise would be nutrient poor.

Winds are strongly a limiting factor in this area. Their high frequency and intensity mark the fishing activity in Cap de Creus which preclude going out in the sea. North from Cape Creus northerly winds dominate the scene along with the rough conditions of the Gulf of Lions, especially during winter season. The so-called Tramontane and Mistral winds (northwestern and northern winds respectively) are characterized to be the most frequent, strong, dry, cold and reaching a persistence up to several days (Salat 1996). In turn, the noted episodes of vertical water mixing along the coast are responsible of the water nutrient enrichment. In Gulf of Roses, Tramontane and southwestern and western winds dominate the area, whereas heading south winds lose their intensity.

Regarding the substrate, variability along the coastal region is clearly observed. The upper part from Cape Creus is characterized by rocky, dark and high coast with little vegetation belonging biological and geographically to the Gulf of Lions. From Cape Creus to Cadaquès Bay also rocky and little vegetation but low coast are characteristic. By moving south, and highlighting Cape Norfeus as the starting of the Gulf of Roses, a high and steep coast border the zone until the town of Roses (Bas et al. 1955). This Bay is distinguished to present all along the Gulf until the next town of L'Escala, a low coast and a marsh area as well as the inflow of Muga and Fluvià rivers.

Sandy and muddy bottoms seem to dominate the area, however a mixture of sandy and muddy bottoms as also gravel and rocks complete the substrate composition. In addition, protected seagrass beds can be found on those coastal areas where well-conserved communities of *Posidonia oceanica* are developed. The southern part of the canyon, in front of Roses Bay, is the broadest and most extensive part of the shelf due to river deposition processes (Bas et al. 1955).

Underwater canyons present many areas acting as deep reefs, in where many species form structures where others find refuge. High abundance of corals are present in the rocky bottoms whereas in the deepest parts Maërl bottoms abound (concentration of species of calcified red seaweed), commonly associated to a high diversity of sessile species (Orejas & Gili 2009). In other cases in the Atlantic it has been seen how deep cold corals are an ideal habitat for juvenile and larvae of several fish species. Many of these species have a high commercial value, thus acting again as a refugee from fishing pressure, by allowing the recovery of stocks in depletion. The high regime of currents mentioned above allows the high concentration of particles in the water column, serving to feed many organisms. Additionally, cetacean species are also associated to underwater canyons such are finback whales, bottlenose dolphins and striped dolphins.

Topography of the area is already very precise but biology still needs to be defined. Due to the previous projects [5]HERMES and [6]DEEP CORAL, a bioprospection from Cap de Creus canyon has been done. However, a deeper study on the ecology and biology will allow establishing more satisfactory protection measures. By using ROV and manned submergible vehicle images, high abundance of cables and abandonment fishing gears has been detected showing the impact of fishing activities in the area (Annex I, Figures 1,2). It is known that the past trawling activity destroyed many areas on the continental shelf and slope; this is supported by the presence of surviving species in similar habitats, which are known to be in unreachable areas, far from the fishing pressure. The impoverished mud communities in the continental shelf might be a consequence of: i. major activity of bottom trawling by boats, ii. instability of the substrata which is mainly

[5] Hot Spot Ecosystem Research on the Margins of European Seas; Goce-CT-2005-511234-I
[6] National Project; CTM2005-07756-C02-02/MAR

composed by carcasses of bivalves and detritus together with the slope of the area, make colonization and settlement of sessile species even harder (Orejas & Gili 2009).

The area of Cap de Creus in study by the LIFE+INDEMARES Project corresponds to 1168 Km^2 from which 216Km^2 refer to a reduced study area to analyze fishing pressure and bionomy interaction.

Data collection

The information regarding artisanal fisheries in Cap de Creus was obtained throughout questionnaires circulated around fishermen in the area of Catalonia between December 2000 and March 2001 by the regional FAO consultant (Annex II). The surveys consisted in interviewing either the majors or the secretariat of the fishing guilds and fishermen representing the main métiers in the area in order to fill in a sheet for each of them. The meetings were previously set by fax citations. The ports of interest have been selected and the organization of the data by métiers has been displayed in excel file (CD). A fieldtrip to the ports of interest was conducted in order to validate that currently the main métiers prevail. The use of surveys to the fishing communities has been seen in other studies (Rocha et al. 2004, Forcada et al. 2010) to provide a good assessment for fisheries.

Standardization of the data items from the FAO-COPEMED Project

Fishing Zone

The standard fishing zone is defined as the main range of depths in which the métier is practiced. Four main ranges allow the classification and design of the fishing zone according to the depth by combining it with already existing data regarding the bathymetry in Cap de Creus[7]. These are: coastal waters (0 - <75), medium range (>50 - <150), deep waters (≥100 - ≤250) and deep canyon waters (>250).

Fishing Substrate

The description includes the nature of the sea bottom. It is been classified into the following substrates: sandy, muddy sandy (predominance of sand), sandy muddy (predominance of mud), muddy, rocky and gravel. Likewise, a correlation with this

[7] Species covering a large range starting less than 100 meters up to deep waters are considered to have a wide range.

information and available substrate type information has been combined, allowing to place in space a distribution by bottom quality. In those cases where two or more features concur the one with more coverage has prevailed.

Fishing Season

The standard fishing season is defined as the main period of the year during which the métier is practiced in a certain fishing zone targeting a given species. It is expressed according to the months where the practice is done by containing zero (no activity) or 1 (activity) values, following from January to December.

Fishing Port

Based on a nationwide project, only those ports located around Cap de Creus area with enough data to analyze their operative artisanal fishing units have been selected. These ports are located in geographic coordinate units which are Port de la Selva, Llançà, Cadaquès, Roses, L'Escala and l'Estartit. It is important to note that four out of the six localities offer fish markets (Llançà, Port de la Selva, Roses and l'Escala), Cadaquès sells at the auction in Roses whereas l'Estartit sells at the auction in L'Escala. In Cadaquès, a small community of fishermen remains, known as *testimonial confraria*, which do not have a port itself but where fishing tradition is maintained. A description of the port's history, tradition and most common target species is found in Annex II.

Target Species

Fishermen use very selective gears as a species-driven activity to catch primarily fished species with a certain effort, which are called target species. However, more than one target species can be caught simultaneously. Considering up to six the number of species for each particular métier, there will be named as target species and associated or secondary species.

Classification of fishing gears

Fishing gears are sorted based on the FAO classification (FAO 1990), as a standard for a homogeneous list illustrated in Table 1. Nevertheless, due to the oversimplification of some gears, an explanation of particular regional fishing techniques has also been developed (Annex II).

Table 1. Fishing gears nomenclature (FAO 1990)

FAO Classification	Regional fishing gears' nomenclature
Trammel nets	Tremalls
Gillnets	Solta, Soltes, Joeller(a)
Set Longlines	Palangró, Palangre
Combined Gillnets-Trammel nets	Bolitxa
Pots	Nanses, Cadup, Pots, Morener
Miscellaneous gears	Mariscadors, Coraler, Cucaire
Handline and pole-lines	Potera
Boat dredges	Gàbia

Spatial structure

The GIS software allows the spatial location of fishing gears and the related items. ArcView and ArcCatalog 9.3 GIS (ESRI Corp., Redlands, California) software in combination with the Spatial Analyst extension have been used to spatially distribute the data and to obtain the resulting maps.

Data structure and analysis

All the information used in this case study has been obtained from public sources and institutions.

In order to frame the area of interest based on the available information, a fishnet of 500x500m square cell (0.25 Km^2) has been created by freely downloading the fishnet grid extension from the [8]ESRI website. Working with geographical grids systems is highly recommended in localizing spatial data and it has been proposed as the multipurpose Pan-European Standard (EEA 2008, INSPIRE 2009). An equal area of cells is suitable when generalizing data (INSPIRE 2009).

[8] http://arcscripts.esri.com/details.asp?dbid=12807

The fishnet has been set over the study area and those grids associated to the inland part have been deleted, thus containing each grid associated qualitative marine data. The result obtained is a 4581-cell grid covering a surface area of 1145.25 Km^2. Cell grids provide harmonization and reduce the complexity of spatial datasets particularly when combined, due to each cell has a unique cell code identifying resolution, row and column.

Information processing:

1. Mapping in GIS format (georeferencing) the information available of potential fishing grounds and species in the 50s from the literature (Bas et al. 1955). This data has been edited by converting to polylines (fishing grounds) and points (species) the features employed to characterize information in the map according to the nature of the data.
2. Adapting available existent layer files have been converted using GIS extensions and applications to suit to the fishnet of study. Geoprocessing tools (spatial joining, merging, dissolving and clipping) have allowed fusing and combining the information ensuring that each cell grid encloses each feature. The selecting tool from the attribute table has permitted to map for each of the selected variables in study. This methodology has been used in other studies to map bird communities (Requena Moreno 2009, Carboneras & Requena Moreno 2010).

Coverage layers:

The following coverage layers have been provided by CSIC scientists who had previously created these layers for other projects.

Bathymetry- LIFE+INDEMARES LIFE07/NAT/E/000732 from TRAGSATEC (General Secretary of the Sea) for the shelf, Fugro for the canyon & AOA, ICM/CSIC for the shelf and slope.

This layer has been modified and reconverted from a raster image to a vector format. An extension from Marine Geospatial Ecology Tools has been used (Roberts et al. in press).

Substrate type- Provided by the General Secretary of the Sea

Bionomy- Integration of Bionomy of the Coast provided by R.Sardá (CEAB-CSIC), S.Rossi (UAB) and J.M.Gili (ICM/CSIC) from the project INTERREG IIIA4 (Euroregion

Mediterranean Pyrenees) and Bionomy of Canyon and Continental Shelf from ICM/CSIC from the following projects: HERMES (Goce-CT-2005-511234-I); DEEP CORAL (CTM2005-07756-C02-02/MAR) and additional actions (CTM2005-24174-E, CTM2006-27063-E/MAR, CTM2007-28748-E/MAR). This information has been integrated with the Bionomy of the continental shelf from Desbruyères et al. (1972-73) (Annex III, Figure 18).

Layers referring to:

Coastline- Corine land cover 2000 coastline. Sources: Each coast segment has inherited the Corine land cover 2000 class, and also the attributes from Eurosion shoreline, version 2.1 2004, regarding geomorphology, type of coast and erosion trends. Owner: European Environment Agency, URL: http://www.eea.europa.eu. Available in http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2000-coastline

European rivers- Sources: WISE (Water Information System for Europe) large rivers and large lakes, Water Pattern Europe, scale 10 million, version 2, from EUROSTAT GISCO database; Water Framework Directive article 3 data on rivers and lakes from countries; Joint Research Centre catchment database CCM1. Owner: European Environment Agency, URL: http://www.eea.europa.eu. Available in http://www.eea.europa.eu/data-and-maps/data/wise-large-rivers-and-large-lakes

Ports and others have been obtained from available European and regional sources (such as DARP –Department of Agriculture & Fisheries) and Google Earth 4.2.

The coordinate reference system employed is the Universal Transverse Mercator (UTM) using the World Geodetic System 84 (WGS84) as the geodetic datum for storage and analysis. The UTM zone is 31.

RESULTS

A total of 73 métiers have allowed the spatial fishing distribution (CD – Excel sheet).

Composition in number of fishermen and fleet from the main ports surrounding Cap de Creus area

The fleet composition from the ports of study recorded from 2000-2001 (FAO-COPEMED Project) presented some differences. Regarding the amount of fishermen in each of the areas, these were mainly concentrated in three of the ports: L'Escala, Roses and Llançà (Figure 2, left). On the other hand, the number of boats was more equally distributed among the ports (Figure 2, right). These graphs included Colera and Port de la Selva because their fleets contribute to the fishing activity as well. However, on the basis of the FAO-COPEMED study, individual data for these two ports was not collected because they belong to the adjacent fishing guilds.

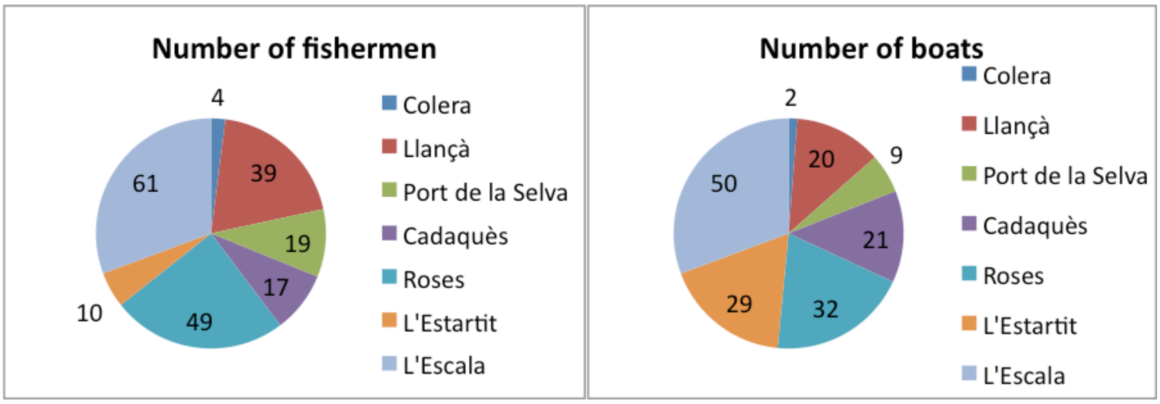

Figure 2. Fleet composition in number of fishermen and number of boats per each one of the ports of study

When looking at the role of fisheries in the Girona Province, the ports of study represented more than 50% in both fishermen and fleet composition, showing the importance of the fisheries' role in Cape Creus (Figure 3).

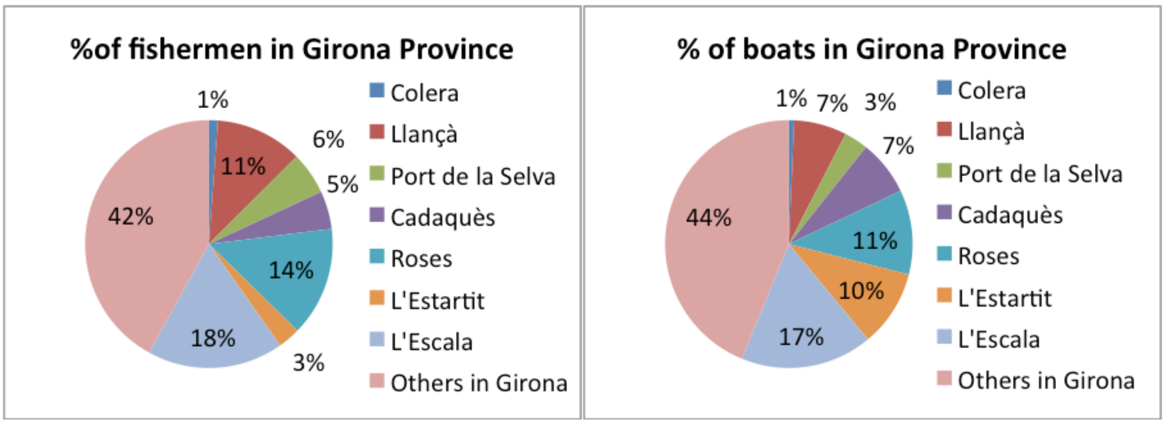

Figure 3. Fleet composition in percentages of fishermen and boats from the Girona Province

When data from different sources was contrasted, suspicions of the reliability and precision of data were raised. The following figure (Figure 4) compared data from the FAO-COPEMED Project and from Boix (2003). Both sets of information were recorded between years 2000-2001, and besides apparent similarities in numbers, there were some clearly different data especially in terms of fleet number. Due to the specificity of the information required, and the little change expected to fluctuate each year, these differences were substantial.

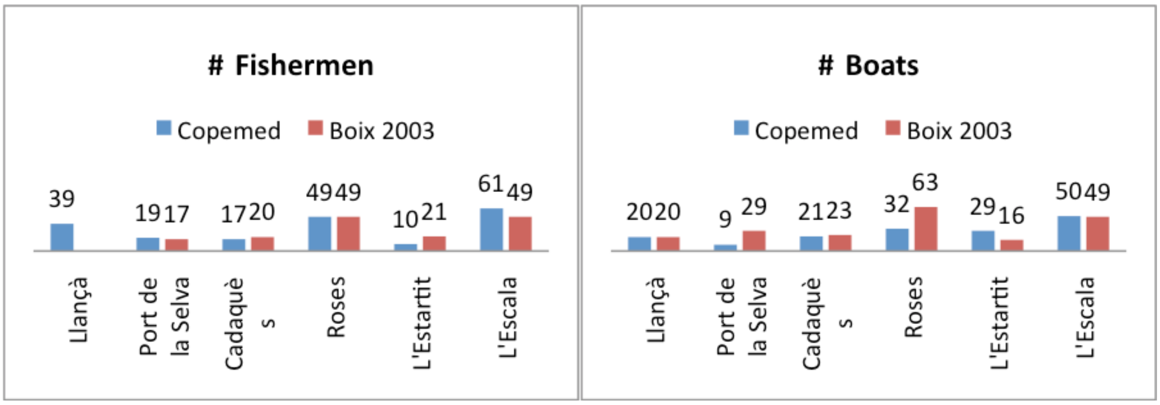

Figure 4. Comparison of the number of fishermen and boats from two studies

Another source of available data was provided by the Regional Government of Catalonia ([9]DARP). It is a broad-like type of data of the fleet situation along the ports from Catalonia throughout the last 10 years; this can serve us to have an insight of the evolution of the fishing activity through changes in fleet composition.

The data is separated into minor arts, trawling, purse-seining, and surface and bottom longlining; longline gears exerted by minor fisheries are catalogued as such, as a consequence, it is not easy to estimate the exact fraction for each type of the fishing gear employed.

When comparing the fleet from 2000 and 2009 (Figure 5), a decline of minor arts in nearly a 50% (from 339 to 192) in detriment of trawling and minor of purse-seining and longlining was shown. However, no data regarding boat length and power was implied.

[9] http://www20.gencat.cat/portal/site/DAR

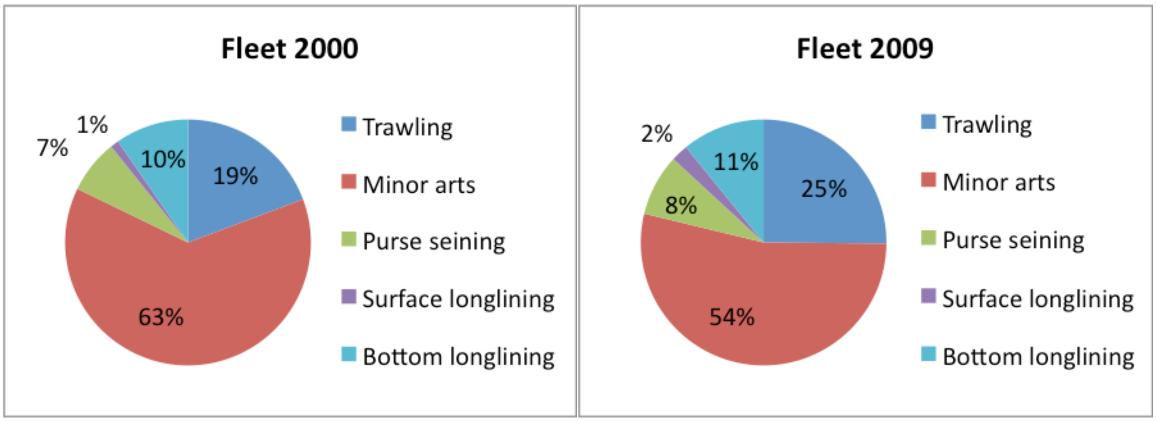

Figure 5. Evolution of the fleet from 2000 and 2009

By looking throughout a short-term evolution of the fleet (ten years period), most significant changes were observed from 2006 and onwards (Figure 6).

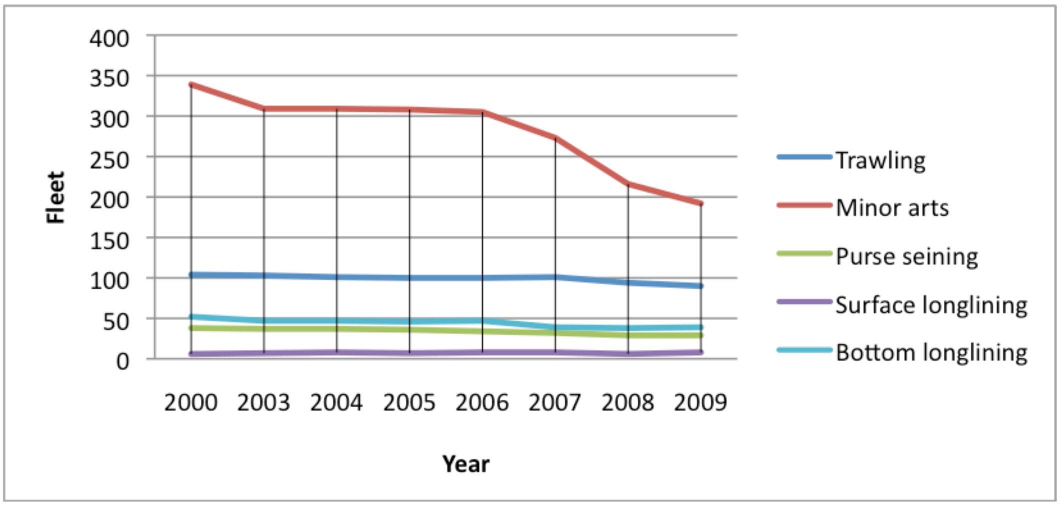

Figure 6. Evolution of the fishing fleet from 2000-2009

In the study from Boix (2003) representing data from 2001, in which displayed data shared the same fishing classification than the one from DARP some discrepancies in the information provided were shown when combined (Figure 7).

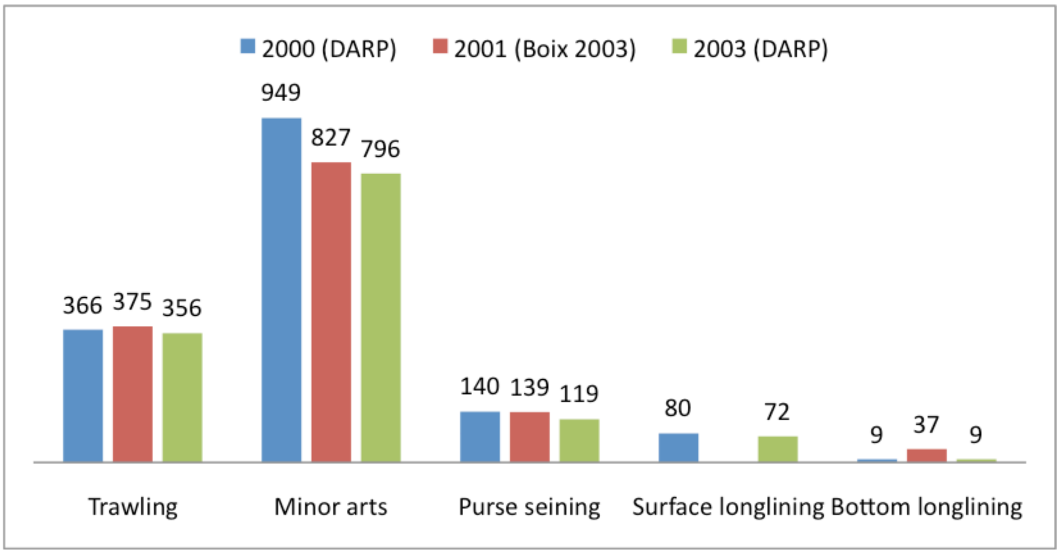

Figure 7. Comparison of the fleet composition from different sources

Target species

Similarities in caught target species have been seen around other marine reserves in the Western and Central Mediterranean (Colloca et al. 2004, Forcada et al. 2010). The cephalopoda family was dominated by *Octopus vulgaris*, *Sepia officinalis* and *Loligo vulgaris*; the crustacean by *Hommarus gammarus* and *Palinurus elephas*; as well as other species from the Sparidae and Mullidae family (Annex IV).

Seasonality

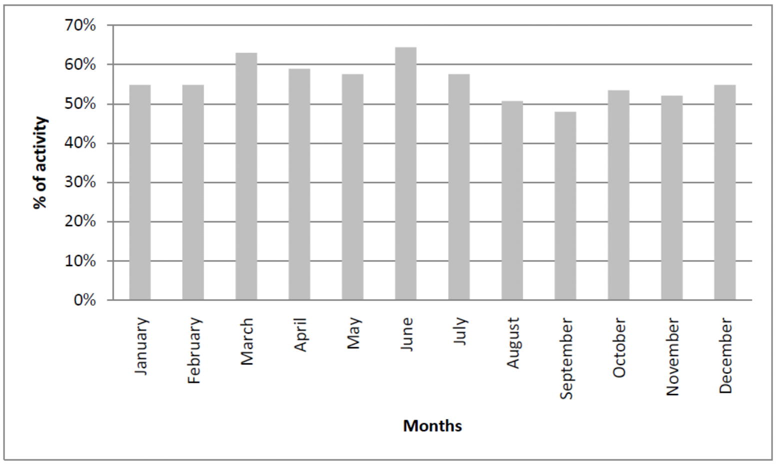

Figure 8. Seasonality of total fishing activities

Fishing activities were hold all year around (Figure 8). The intensity of such activities can be higher or poorer depending on the fishing gear employed due to the fishing closures throughout the year for certain target species. March and June seemed to be the months in which more métiers are practiced; reaching a percentage of activity in these months over 60%. However one cannot state these months represented the highest catches. On the other hand, August, September and the winter months showed percentages slightly lower, around 50%, meaning less fishing métiers are used in the sea.

To follow, the specificity by métiers has been shown for each type of gear (Figures 9-17). Minor gears tended to present more seasonal closures. An example of it were pots in which neither in August nor September were used, coinciding with the fact that their main target species (*Octopus vulgaris* and *Sepia officinalis*) have their reproduction period during this time, thus, a closing season seemed to be set. Combining gillnets-trammel nets gear clearly showed a sensibility for the winter months. The most abundant fishing gears had a greater selectivity shown by a greater number of target species. An exception was seen by bottom longliners which mainly caught *Merluccius merluccius* all year long, and during the winter season *Pagellus bogaraveo* was targeted as well. Some species illustrated a clearly specificity for gear type, i.e. *Palinurus elephas* for trammel nets or *Octopus vulgaris* by pots; whereas others could be considered as shared species such as the family Mullidae and *Merluccius merluccius*.

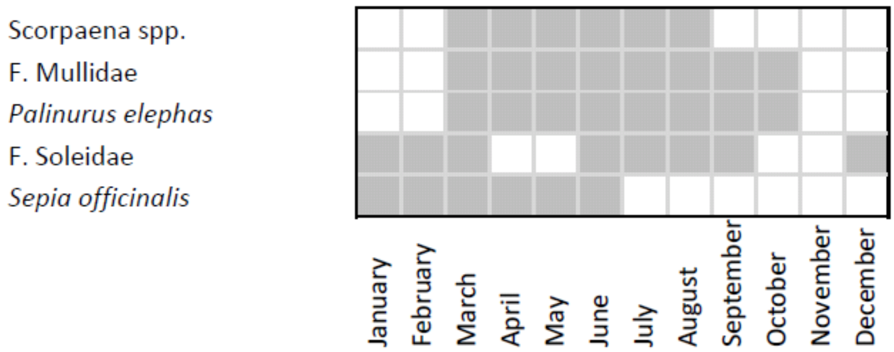

Figure 9. Trammel net

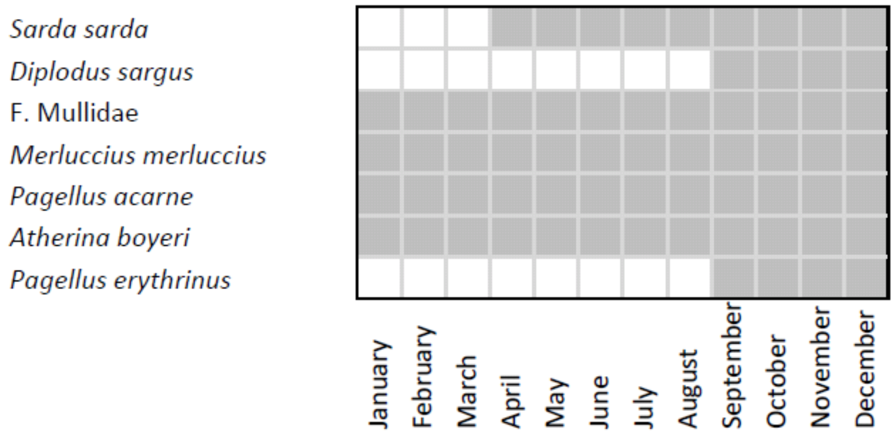

Figure 10. Gillnet

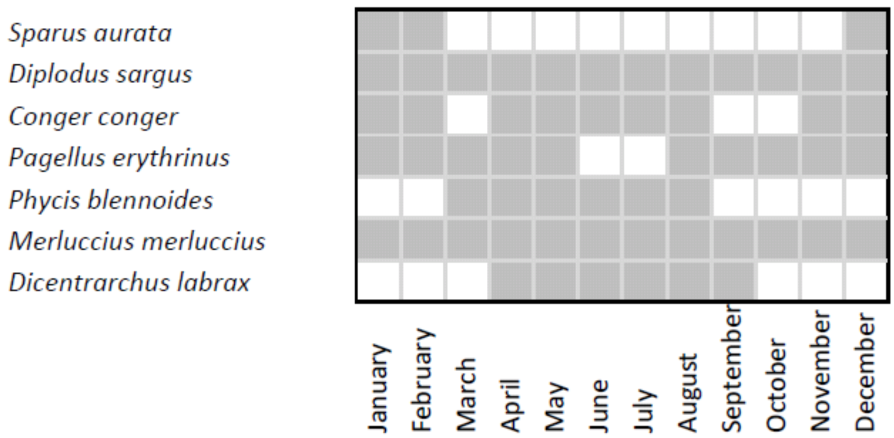

Figure 11. Surface longline

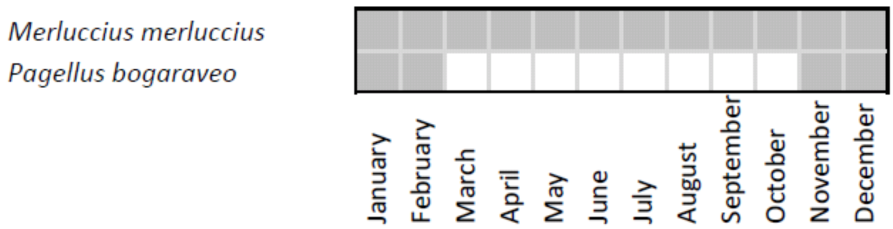

Figure 12. Bottom longline

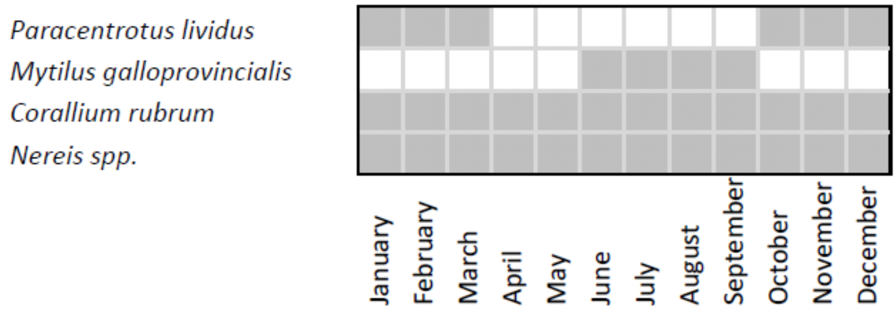

Figure 13. Miscellaneous gear

Figure 14. Boat or vessel seines

Figure 15. Combined gillnet-trammel net

Figure 16. Handline and pole-line

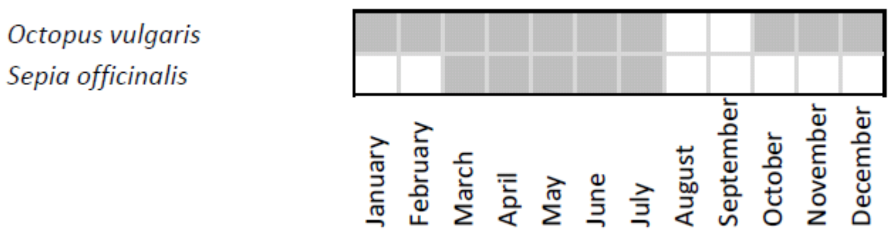

Figure 17. Pot

Fishing gears

The resulting spatial distribution for each fishing gear type acting on the area of Cap de Creus can be graphically seen in Annex V and their individual coverage from the overall surface of the cell grid model is represented in Table 2. Because the purpose of study paid a particular interest in analyzing the offshore part of the area of Cape Creus and due to the limited range of action of certain fishing gears, a division was made. Pots, handline and pole-lines, boat or vessel seines and other miscellaneous gear were classified as *minor gears*. In addition, due to just one statement of combined gillnet-trammel nets in one of the ports together with the knowledge of loss of use, it was deemed insufficient to spatially distribute this gear in the area. A distribution of the composition of each fishing type by port is shown in Annex V (Figure 15).

Table 2. Coverage percentage for each fishing gear type

Gear type	
Trammel net	32%
Gillnet	26%
Combined gillnet-trammel net	4%
Longline	26%
Bottom longline	36%
Miscellaneous gear	6%
Handline and pole-line	7%
Pot	10%
Boat or vessel seine	4%

A complete map resulted from combining layers with the data regarding type of substrate (bottom quality), bathymetry and fishing zone (Figure 18). Consequently, each cell grid contained a value attributed to each characteristic, allowing their combination for a spatial distribution.

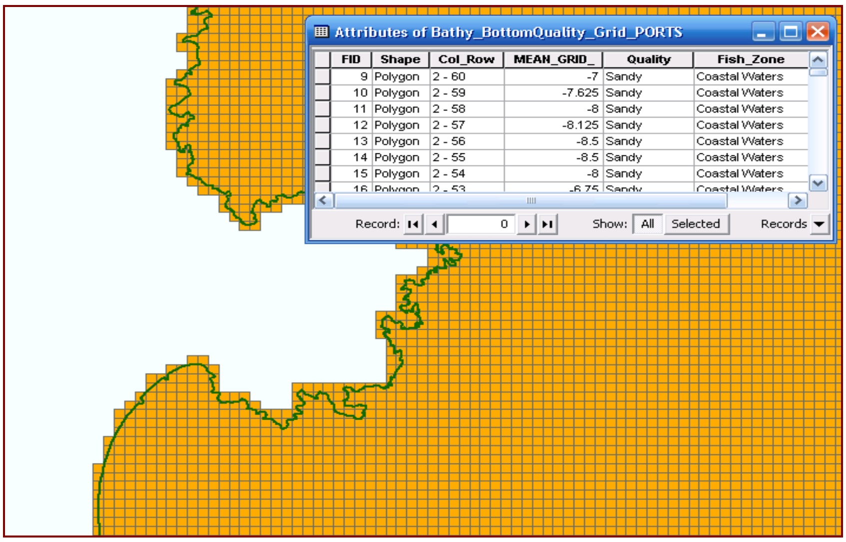

Figure 18. Resulting grid with combined information

Substrate type and fishing gears

Bottom quality data was transformed to the cell grid model (see Annex VI). Percentages of the type of substrate's coverage showed a predominant composition of sandy bottoms in nearly 46%. But sand is also present in other substrates designated as sandy muddy (mud with presence of sand) and muddy sandy (sand with presence of mud) representing a 16% and 2% in that order. The next most abundant substrate is composed by mud in a 22% whereas the less represented are rocky (11%) and gravel (4%) bottoms. This characterization is important to assess most preferred fishing bottoms (Annex VII). By looking at the spatial location of each type of fishing, the less abundant substrate types (rocks and gravel) are totally covered by at least a type of gear, whereas sandy and muddy bottoms have to some extent no fishing activity.

Fishing zones and fishing gear

Medium range and deep waters represented the most abundant part of the study area in a 42%. To follow, medium range and coastal waters were represented in a 17% and 19% respectively. At a lower rate, waters shared between the coastal and medium sections corresponded to a 9%, deep waters in a 5% and strictly waters from the deepest parts of the canyon stood for the 8% (see Annex VI). This characterization is important to assess most preferred fishing zones (Annex VIII).

Overlap value

An overlap value was set to define the coincidence in space of two or more fishing gears and to detect the degree of impact over the system (Figure 19). Only those gears previously considered as acting in a broader scale over the area of study for protection had been considered by excluding thus, minor gears. The added values could then be ranged from 0 to 4. The lack of fishing gears detected in an area obtained the value of 0, for those areas where only one fishing gear acts, 1 was the given value, when two of the gears overlap got a value of 2, and when up to three of the fishing gears coincide the rating was 3. A value of 4 was not obtained meaning that in any area the confluence of all arts had been recorded.

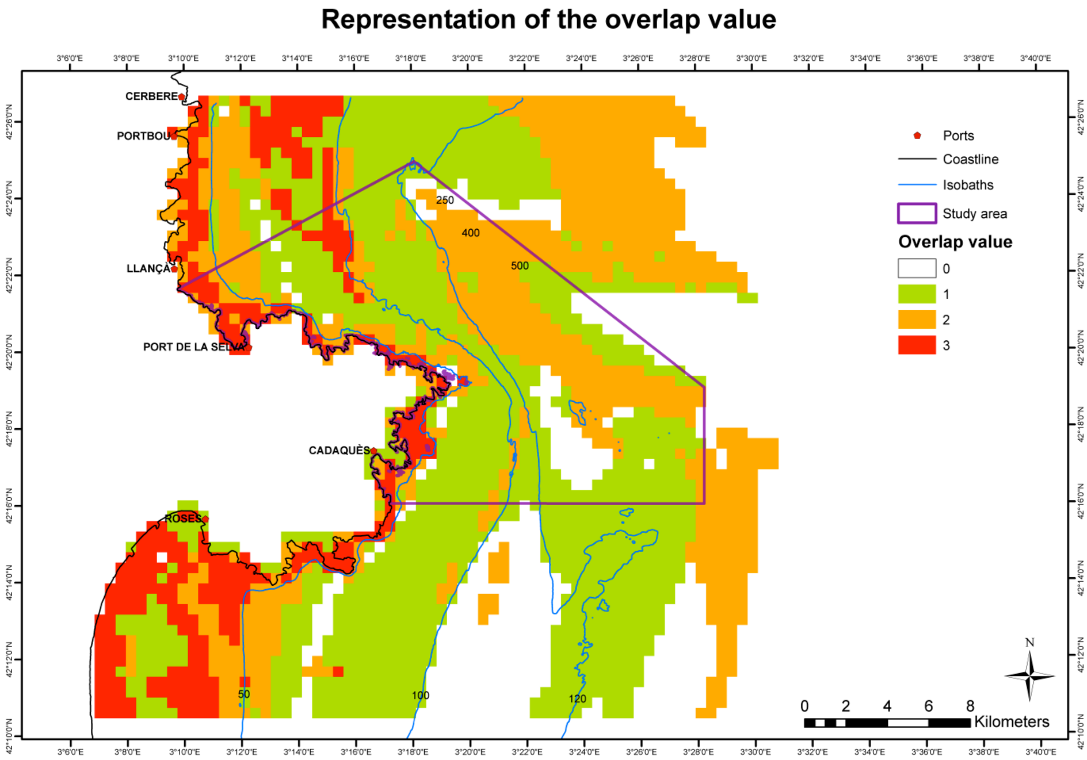

Figure 19. Resulting map once added the overlap value

Key communities

Once the spatial distribution of fishing types and the value regarding the degree of impact of such activities were set, it was time to assess the local communities. The existent major communities to preserve include coral reefs, sponge gardens or maërl beds (calcareous algae) as other hard substratum communities (Figure 20). Figure 21 is intended for comparing in the same area of study for the LIFE+INDEMARES Project, the overlap value with the benthic map.

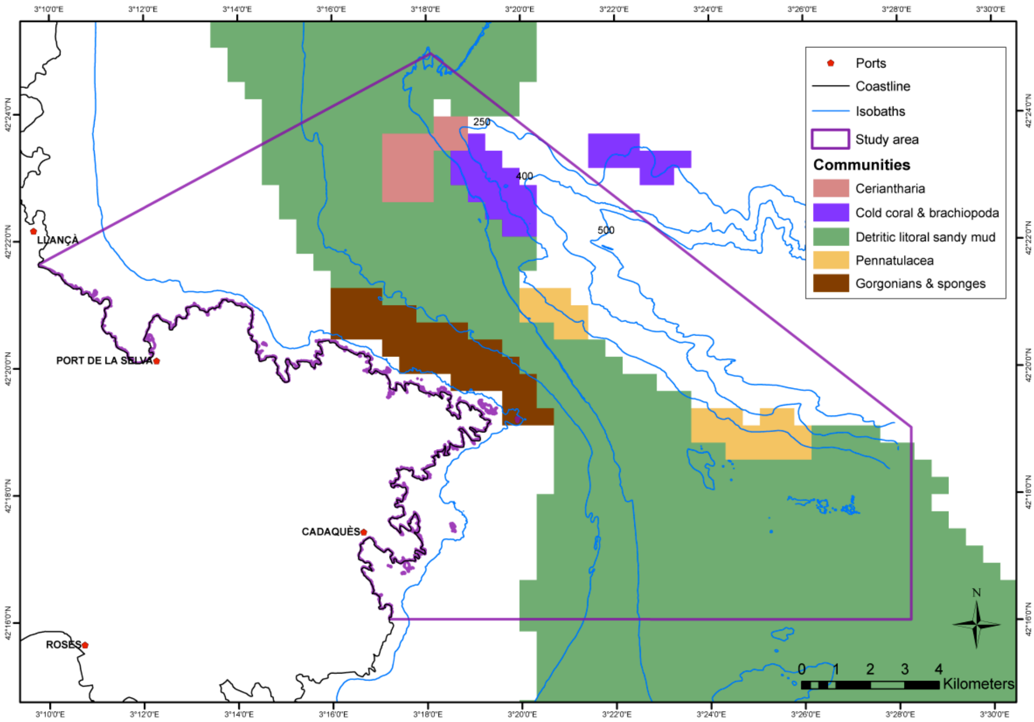

Figure 20. Representation of key communities in the study area for the LIFE+Indemares Project

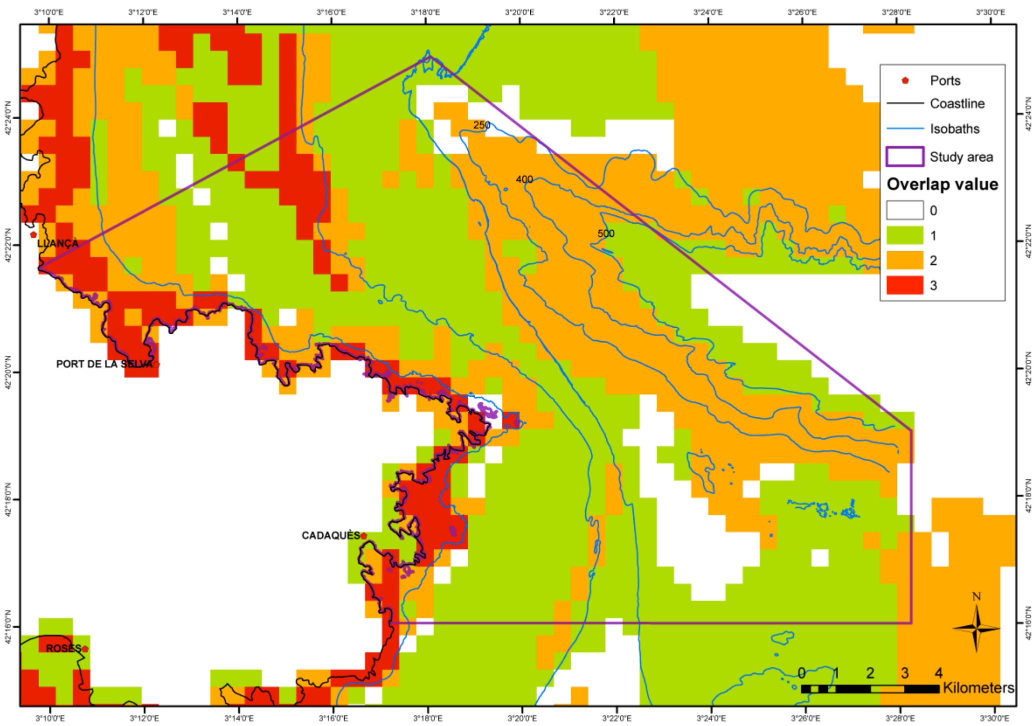

Figure 21. Overlap value in the study area for the LIFE+Indemares Project

Georeferencing older data

These results were raised from the exercise of compiling previous information regarding fishing grounds and target species in the area. In 1955, a very complete detailed book (Bas et al. 1955) containing information of target species and fishing grounds among other fishing details came out. From the provided map, data regarding Cap de Creus area was georeferenced, in order to compare with data from the FAO-COPEMED Project (Annex IX, Figures 20, 21).

DISCUSSION

A significant number of métiers have been used for this study encompassing both passive and active gears. Minor gears act close to the coast whereas gears comprising broader geographic scales extend to the shelf and even at depths from the canyon. Accordingly, the composition of artisanal fisheries in the Mediterranean is commonly dominated by trammel nets, gillnets and longlines (Table 5) as it has also been stated in other studies (Tzanatos et al. 2006, Cadiou et al. 2009). The use of one versus the other may vary in relation to the fishing season, target species' behavior and the seasonal environmental predictability, responsible of a high spatial heterogeneity in the area. Hereby, the provided data by métiers was considered to be more accurate when spatially distributing their action of activity because it encompasses local tradition. Notwithstanding, to generally assess the potential influence of fishing activities, the métier concept has been eventually categorized by gear type when analizing the results. Complementarily, this study was accompanied by information regarding the fishing fleet in each port location, target species and seasonality supporting the métier components' concept. The variety of gears employed on each port presents interesting results (Annex V, Figure 19). Trammel nets and gillnets perform activities in almost every port, whereas longliners are more characteristic of certain ports. In Cadaquès, currently known to have lost almost completely their fishing tradition, comprised a wide variety of gears employed at the time when the data was collected. This division by ports has more interest for the activity of minor gears due to their limitation of movement; but for the other gear types, where are they based is rarely significant because of their wider range of movement.

The role of substrate type in determining fishing location is quite noteworthy. Bottom longlines are exclusively found in sandy and sandy-muddy bottoms from around the canyon. Gillnets are distributed mainly along bottoms with sand and mud although they can also be found in other substrate types (in less than 12%). On the other hand, surface longliners are equally allocated between sand and rock (both around 40%) and less importantly distributed into gravel and muddy bottoms; whereas trammel nets represent a broader coverage, dominated by rock, mud and sand substrates. In Annex VII, a spatial heterogeneity representing each of the four major gear types considered in study are shown according to the substrate granulometry. Through observation experience (Figure 19; Annex VI –substrate type-), prevailing sandy and muddy bottoms host abundant fishing activity evidencing lack of biogenic habitats; nevertheless, if they could reside, trawling would have most likely impacted on them. In a high energy environment, particularly in the northern part of the study area, sandy substrates are less impacted by fishing gears although the same response does not occur in stable muddy sediments. Some of the gear can be classified as having a lighter impact in turn of others such as bottom longlining, trawling and purse-seining which clearly have a major physical impact; despite, species such as erect sponges and other biogenic structures can be detached from both lighter and heavy gears (Kaiser et al. 2002).

In the case of fishing zone ranges, the dominance of certain depths is certainly correlated with the presence of specific fishing gear types (Annex VIII). Bottom longliners mostly move to the confluence of medium range-deep waters, acting significantly as well in deeper and deep canyon waters. Surface longliners cover dominantly coastal water ranges, however they can also move over all fishing ranges. The reason why this might be due is found in the lack of detail when classifying longliners from query surveys, which occasionally included under the same name, both surface and bottom longline gears (field experience). Coastal waters are also covered by gillnets and trammel nets as well as almost in exclusivity by minor gears (Annex VIII). It is important to note that due to the use of the métier concept when displaying the data; more than one factor can justify the final distribution per gear type.

The aim when georeferencing older information has been both to state the limited availability of data regarding fishing distribution and to compare it with the study results.

Although information from Bas et al. (1955) included the trawling fleet at the time, the coincidence of some target species allows observing broad similarities and dissimilarities in their location. Annex IX (Figure 20) pretends to show the distribution in the area of four of the species' domains from the FAO-COPEMED Project which are also recorded in Bas et al. (1955). These species are *Mullus spp.*, *Phycis spp.*, *Octopus vulgaris* and *Merluccius merluccius*. Despite *M.merluccius* which is located in a southern position off the map, the other species are still present; this fact and the whole target and accessorized species from the diverse métiers reproduce the multispecies' fishery tradition. On the other hand, by georeferencing the areas catalogued as fishing grounds in the past, one can notice how especially those areas with high energy regimes such those surrounding the canyon grounds maintain the fishing tradition (Annex IX, Figure 21). Updating information in a similar dimension (i.e. GIS software) will make data comparable on spatial basis and information more available.

An adaptive ecosystem based fisheries management would help to understand the way ecosystems respond to alternative fishing strategies (Gell & Roberts 2003, Pikitch et al. 2004). By ecosystem approach one includes ecosystem considerations into future fisheries management (Kaiser et al. 2002). Management regimes, incorporating both fisheries and habitat conservation goals by using approaches such as total or partial exclusion of bottom fishing gears, or even seasonal and rotational fishing closures are needed (Kaiser et al. 2002); it has been seen that fishing pressure coinciding with important periods of the life history of target species (i.e. spawning) have negative impacts on the stocks (Tzanatos et al. 2006). This is the case of *M.merluccius*, not only exploited by artisanal but also trawling fisheries. This integration would assess the impact of a management action with respect individual species but also ecosystems; interestingly, overfishing in an ecosystem might be considered even when at a single species context is not (Pikitch et al. 2004). To determine ecological constraints, it is quite significant to establish a degree of impact in the ecosystem. Assigning an overlap value in the area (Figure 19) indicates the limitations in the coexistence of particular fishing types, i.e. trammel nets and longlines hardly coincide due to the conflict of interest of both fishing techniques (Annex II -detail of domain of the fishing types-). A spatial overlap displays the degree of impact caused by destructive gears over habitats, implying a greater impact onto the carrying capacity of the system and an impoverishment of the seabed. Contrarily, by analyzing those areas with less confluence of fishing gears, a higher abundance of key communities for protection is seen.

The important role played by benthic communities in areas with high flow velocities and wave-exposed is predicted to be reduced by disturbances from bottom fishing activities (Thrush et al. 1998). The effects of storms and increased flow velocities are in risk to unstabilize the seabed, reason why surface-dwelling organisms act significantly in reducing this process. The requirement of recovery periods ranging from 3 months to up to few decades has seen as necessary for benthic communities' restoration (Kaiser et al. 2002); even so, short term fishing closures can serve as temporal relief from disturbances on the seafloor habitats and communities due to fishing. Nevertheless, maintenance of more structured systems requires longer closing periods (Kaiser et al. 2002). Some benthic communities characterized in providing abundant biogenic structures are considered rich epifauna and thus, target species for conservation (Kaiser et al. 2002) ; in Cape Creus, cold coral, brachiopoda, ceriantharia, pennatulacea, gorgonians, sponge gardens and detritic littoral sandy mud habitats are well-conserved, representative and emblematic communities (Figure 20). Increasing fishing pressure has been demonstrated to be a significant factor in the loss of epifauna (Thrush et al. 1998).

When comparing bionomy with the overlap value (Figures 20, 21) it is manifested how areas with higher ecological interest coincide with less overlapping of fishing gears (with ranging values from 0 to 2). By looking at the major area of study from the LIFE+Indemares Project, the percentage of coverage of either one or none type of fishing reach a 60%, the confluence of 2 fishing gear correspond to one third of the area, whereas only an 11% show the potential activity of three gear types. Therefore, a relationship of well-conserved communities known from this area and the incidence degree of fishing activities is suggested. Predicting spatial patterns from available fisheries' data has been the main tool in order to evaluate the impact onto resident benthic communities. The corridor between the continental shelf and the canyon to be proposed for conservation by the LIFE+Indemares Project is home to juveniles of demersal fish found mainly on continental shelves and which find refugee and benefit from rocks and other small physical features such as sponges (Salat 1996, Orejas & Gili

2009). The shelf break area associated with the shelf-slope hydrographic front has been surveyed to support large concentrations of zooplankton (Palomera & Ana 1990).

Because of the extent of fishing activities in the local economy and the urgency in protecting certain marine habitats and species, MPA planning and management should be conducted on a multidisciplinary basis (Badalamenti et al. 2000). This approach is specially suitable in fisheries sensitive to ecological changes such as declining stocks, socio-economic evolution of coastal communities and fishery regulations (Colloca et al. 2004). The lack of participation of fishermen in the policy making process is threatening this system. Fisheries system transformed into a complex system with difficulties in reaching information, mainly due to: complexity, incoherence and excessive number of laws; incomprehensive fish market's laws from fishermen perspectives; and the increase of administrations having competencies in fisheries management (Alegret 1996b). The deficient transparency when information is passed from the Administration to the users generates not only distrust but also ignorance in terms of ecological concerns by the fishers. For fishery managers to be concerned with habitat protection either they have to be forced throughout legislation or the loss of yield caused by a bottleneck in the life history has to be exposed; thus, it is critical to evidence the effect of fisheries (Stelzenmüller et al. 2008).

Nonetheless, fishing industry will oppose to any total area of exclusion to certain fishing types (Kaiser et al. 2002). To enforce the need for establishing large size MPAs, as seen in modeling studies by Walters et al. (2000, 2007), the success of small areas seems to be reduced when spatial use of fishing activities is revealed. Additionally, fewer large MPAs have been suggested to contribute to cost-effective benefits towards ocean and fisheries conservation (Cullis-Suzuki & Pauly 2010). Studies on seasonal fishing ground closures of trawling as effective measures to minimize benthic communities' degradation have been assessed (Demestre et al. 2008). By aiming to particularly protect certain stages of life history of commercial species, not all species coincide in time for such processes. Communities respond to effort patterns, thus intensity and frequency of fishing activities determine the degree of disturbance in which a community is subjected to, and the time that would need for a potential recovery (Thrush et al. 1998, Kaiser et al. 2002, Micheli et al. 2004).

Often, management measures for a MPA have resulted into the loss in fishing yields and the decrease of fishing pressure. Due to the selectivity of fishing gears and the suggestion of taking measures such as parceling or seasonality, a recovery of species would arise as would also become a tangible benefit in terms of spillover for the fisher's community (Forcada et al. 2009, Stobart et al. 2009, Goñi et al. 2010). Restrictions on fishing gears concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea are already contained in the Council Regulation (EEC) No 1967/2006[10] of the European Union. The biological enrichment of adjacent fishing grounds can occur due to density-dependent movement of species by ensuing an export of biomass in terms of both egg and larvae recruitment and emigration of adults (Goñi et al. 2010).

Examples of fisheries benefits in other marine reserves have been seen, i.e. trammel nets have benefit in a 66% of CPUE increase when a fishery ground was protected for five years in Egypt (Galal et al. 2002). Abundant evidence in the literature regarding spillover is recorded; the first recent empirical study comprising a decade of results of *Palinurus elephas* inside and outside a marine reserve, a valuable species in the northwestern Mediterranean and that is the main target for trammel net fisheries (Goñi et al. 2010) is a prove of it. The spatial extent of spillover is dependable on the fishing pressure surrounding the area (Goñi et al. 2008). According to the suggested management, by combining a no-take zone and by diminishing overlapping fishing activity areas, benefits might be greater. Long-term measures of ecological resources' protection and economic benefits at the short or medium-terms should be seen as the trade-offs of MPA profits (Claudet & Pelletier 2004). In addition, MPAs can be rewarding serving somehow as control areas when comparing with similar overfished areas. It is not easy to state with certainty that establishing marine protected areas may turn into a favorable impact to artisanal fisheries and other activities but certainly involving fishermen and other stakeholders through integrated coastal zone management plans should be accompanied.

Due to the social conflicts between recreational fishing and artisanal fishing, limiting recreational activities would help to make restrictions on artisanal fisheries acceptable

[10] Corrigendum to Council Regulation (EC) No 1967/2006 of 21 December 2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea, amending Regulation (EEC) No 2847/93 and repealing Regulation (EC) No 1626/94

and included as a management tool (Cadiou et al. 2009). Conflicts existing amongst resource users, in particular, spearfishing need to be taken into account as an activity affecting the structure of fish populations and thus, ecosystem functioning (Lloret & Riera 2008, Cadiou et al. 2009). This battle could be solved by applying to recreational fishing activities competing with the same resources than artisanal fisheries, the equivalent fees and regulations. Nonetheless, sustainability can be reached by maintaining artisanal fisheries. In studies by Cadiou et al. 2009 in a MPA in the North Western Mediterranean have suggested the compatibility of artisanal fisheries with conservation aims, possibly explained by the specificity of this type of fishery by the practice of métiers in which various species are targeted seasonally (Figures 9-17). This has been supported by the banning of recreational activities, trawling and restriction on fishing practices.

One of the outputs to highlight when regulating the activity of boats (commercial and recreational) is the better quality supply offered to the community and at the same time, it rises the idea of open tourism-based activities as a powerful trade-off. As seen in the Italian case (Colloca et al. 2004), fishing tourism cooperatives could be raised to better manage tourism activities in which not only recreational boats but also artisanal fishers could benefit from. In Catalonia, this situation could occur by owning two types of license to be able to exert both activities divided in time, or by creating such organizations enhancing fishing and tourism with specific regulations. As a result, the decrease of fishing effort in turn of tourism gains would be the solution of artisanal fisheries to adjust to the dimensions and availability of resources by exercising a healthy activity.

To conclude, marine reserves have a great potential in maintaining or enhancing fishery catches, it will depend on the level of enforcement that this can turn into a sustainable increase (Gell & Roberts 2003).

CONCLUSION

This study is intended to be an approach for the assessment of artisanal fisheries' impact onto benthic communities; however, for more concise results regarding global fishing activities, log book records or vessel monitored system data (VMS) to assess fishing by semi-industrial and industrial fleets should be recovered. Due to delays in administrative and bureaucratic measures this information has not been available on time. Notwithstanding, it is important to note that most of the semi-industrial fleet move away from Cape Creus, off to waters from the Gulf of Lions. In addition, environmental (i.e. currents), socioeconomic (i.e. type of fishing gear) and geophysical (i.e. narrowness of the shelf) components in the area, make of artisanal fisheries the prevailing activity over semi-industrial and industrial fisheries.

To protect not only species but also communities there is a need to know those habitats exposed to more exploitation than others. In this study one can see how the seabed experiences different levels of fishing activity; those areas subjected to a greater effect correspond to areas relatively undisturbed by natural perturbations (i.e. muddy areas) unlike areas suffering of high environmental influence with unconsolidated sediment being predominant. It is essential knowing the benthic characteristics to ensure that fishing closures in no-take or partially protected areas do not cause a displacement to other vulnerable areas. An opportunity for protection of particular areas where ecologically important species have been recorded is by taking into consideration spatial distribution when managing.

The partition of fishing activities seems to be an effective approach for habitat conservation in Cap de Creus. Both, areas used exclusively by unique fishing gears (i.e. parceling) and areas shared seasonally by two or more participants (i.e. considering target species' behavior) have seen to work and to avoid conflict among the several sectors (Kaiser et al. 2002). Thus, this is an excellent consideration when managing areas where ecologically important species have been recorded, to ensure their protection and the sustainability of the ecosystem. This seems to work well for benthic communities; nevertheless, to fully protect mobile species and their habitats it is urgent to identify the so-called Essential Fish Habitats, which not only encompass areas for nursery and spawning, but areas as relevant to keep up other stages of their life cycles such are food or predator avoidance sites (Kaiser et al. 2002).

There is an ongoing need to review artisanal fisheries in the Mediterranean through recurring debates on the future status of fisheries. Bearing in mind that data used for this case study was collected between December 2000 and March 2001 and that fishing activity's consequences are observable on a large-scale, continuous monitoring must be highlighted in order to promote a responsible development respecting both the environment and fisheries. The approach given here should be tested in adjacent areas and different situations to confirm the usefulness of a spatial tool and the knowledge of the benthos to carry out habitat impact estimates; studying fishing functioning onto benthic systems has the potential to be applied at both local and international scales.

Conservation needs to be seen from a more integrated and proactive perspective, assuming the relation of protected spaces with the surrounding territories and with human uses. Looking for coherent ways of territorial ordination will keep the functions and natural services. Involving local communities in taking the most profit of the economic potential of MPAs, needs to be highlighted when planning with the stakeholders (Badalamenti et al. 2000).

ACKNOWLEDGEMENTS

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ANNEX I

Images of the impact of fishing activities

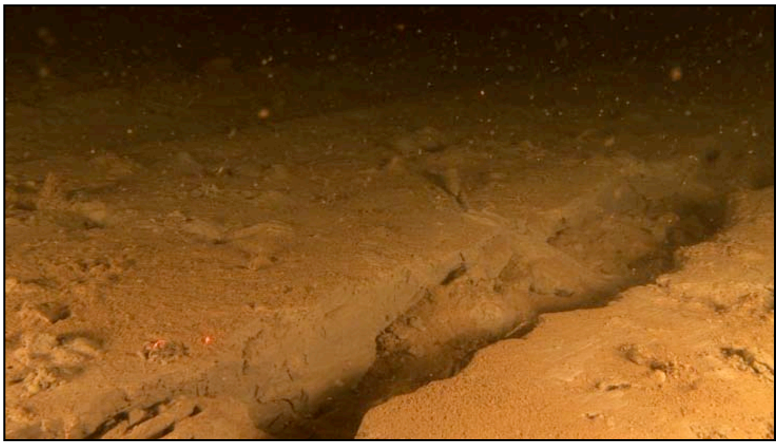


Figure 1. Trawling marks

Figure 2. Abandoned bottom longlines

ANNEX II

Complementary information

Questionnaire

FAO COPEMED Artisanal Fisheries Inventory 2000. Metier Form

Metier code				
Gear. Local name				
Spp 1 T/A				
2 T/A				
3 T/A				
4 T/A				
5 T/A				
6 T/A				
Nb. Boats / Fishermen				
Fishing season	E F M A M J J A S O N D	E F M A M J J A S O N D	E F M A M J J A S O N D	E F M A M J J A S O N D
Fishing Zone description				
Depth Min / Max				
Dist. Left / Right				

Port Name	
Port code	
Date	
Lat.	
Lon.	
Road Access	Y N
Cold Room	Y N
Market	Y N
Infraestructures	Y N
Other Activities	Y N
Port authority	Y N
Port.doc=	
Photo=	

Figure 3. Questionnaire model employed for the FAO-COPEMED Project

Description of fishing ports

- Cadaquès

Small village situated in the Eastern side of the peninsula formed by Cap de Creus. The natural port is opened to a South-East direction and it is quite protected from winds. Since the old times conditions in this area have been rough for the fishermen; the poor methodology that historically characterized them together with the presence of southern currents and high bottom depths has not allowed to strongly exploit the area (Bas et al. 1955). The most represented catches are hake, lobster, octopus, scorpion fish and seabream which are sold at the auction in Roses (Boix 2003). Nowadays, the economy of this old fishermen’s town is mainly supported by tourism.

- L'Estartit

It is not considered a big port and because of the sea conditions, a refuge was built favoring the few fishermen in the area. Looking at the past, fishing has not been essential for the subsistence of the village as other activities in the area such as farming had been present. Most fished species are sole, monkfish, red mullet, hake, European seabass and cuttlefish (Boix 2003). Due to its small dimensions, catches are sold in l'Escala and Palamós (a southernmost port).

- L'Escala

South from Gulf of Roses one can find L'Escala, where no refuge is found. Meteorology conditions of this area are particularly tough especially during winter season. Fishermen are able to sustain themselves. Representative catches are sardine, anchovy, hake, tuna, cuttlefish and red mullet (Boix 2003). Auction occurs twice a day, one at 8am (for blue fish) and at 3pm.

- Llançà

Llançà locates its fishermen village in a small beach not fully protected, reason why obliges some of them to anchor in Port de la Selva. The recent rough winter weather conditions (2009 and 2010), one of which destroyed the fish market, calls for reinforcement constructions such is the proposal of a counter dike. The guild includes the towns of Colera and Portbou, with little fishing importance (Bas et al. 1955). The first founded association seems to be documented in 1817 whereas *confraries* started to settle in 1913. Throughout the years, tourism activities have been eclipsing agriculture, fishing and mining exploitation. Most representative catches are hake, scorpion fish, lobster, sole and prawns (Boix 2003). The auction is hold at 17.15 in the afternoon.

- Port de la Selva

This village was founded by the fishermen of the area. Situated just north from Cap de Creus, it is found in an extended bay protected from eastern winds, although strongly affected by northerly winds, forcing to suspend fishing activities during some periods of the year. Its Bay is oriented north-northeast and comprising around 2Km length and 1.4 Km width (Bas et al. 1955). The first fishermen Union documented was in 1792. At the beginning of the 20th century the number of fishermen was 278, whereas nowadays barely reach the 20. The most representative species are hake, monkfish, prawns and scorpion fish. Auction occurs twice per day at 8am and 6pm (Boix 2003).

- Roses

Located in the southern part of Cap de Creus, there is a Gulf giving the name to this south-west oriented Bay. The first union was created in 1913 named the Fishermen's society. In 1920, coral was highly exploited and represented a high economic source. The fishing development in the area grew strongly when agriculture practices were not succeeding (Bas et al. 1955). The port which traditionally had been a fishing and commercial harbor, is nowadays an important recreational fishing port as well. During the last years, immigration has brought many fishermen from North Africa replacing the local and traditional fishermen. Today Roses represents the port with the most significant fleet and of highly economic importance of fishing in the area. Most fished species are sardine, hake, anchovy and blue whiting (Boix 2003). Fish markets are hold at 8am (bluefish) and at 4.45pm.

Older data information

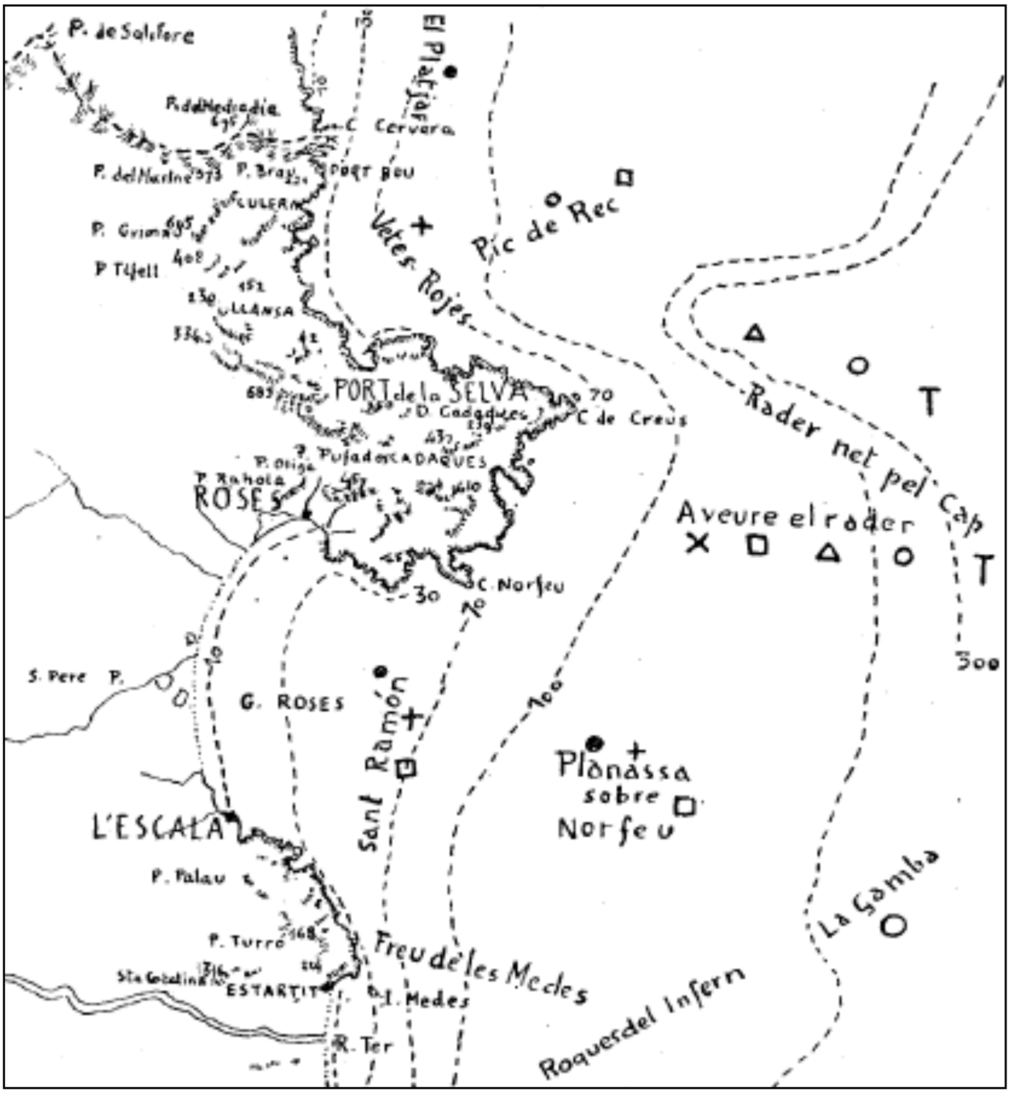


Figure 4. Old data of fishing ground and target species (Bas et al. 1955)

Description of fishing gears

- Gillnets

Type of gear used to gill, entangle or enmesh the fish in single nettings (Figure 5). Gillnets are kind of nets which may be fixed at the bottom or at a certain distance above it. To neutralize the buoyancy of the floats either anchors or ballast are sufficiently used. The length can reach between 60-100m and height ranges from 1.5 to 6 m (FAO 1990).

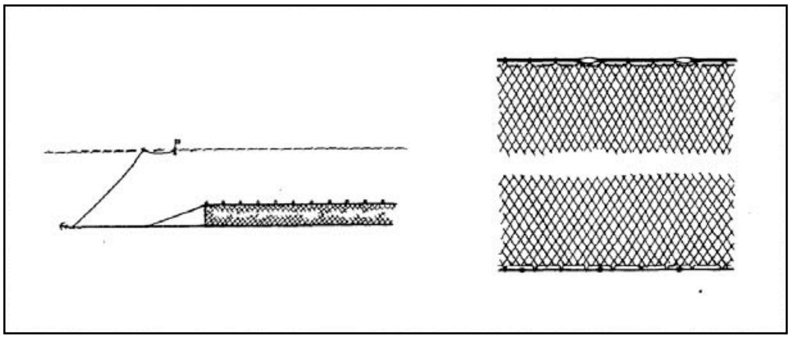


Figure 5. Gillnet (FAO 1990)

The main target species are mackerel and mullet. This gear is set close from the coast at variable depths according to the continental shelf; in Costa Brava, they are usually released between 50-70m at sunset and always collected before the sun rises.

- Trammel nets

This popular gear is made of three walls of netting, the outer wall ones are of a larger mesh size than the inner ones from the panel, which are loosely hung. It is a bottom-set kind of net where fish get entangled in the inner small meshed wall once they have passed throughout the outer wall (Figure 6). At night, it is displayed at the bottom like a wall helped by the buoyancy at the top of the net and the weights that reach the bottom (Figure 7). The net is collected the next day before the sun rises when the fish will follow the light towards the surface. Its height is approximately of 1.5m and a length of between 80-100m. It is a very selecting fishing gear which does not damage the fish. It is popular to fish mullet, cuttlefish, spiny lobster and sole.

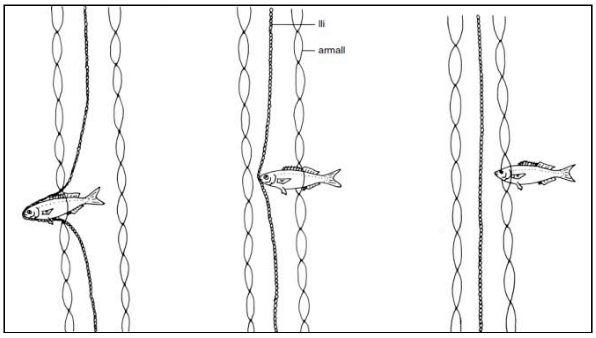


Figure 6. Entanglement of fish (Del Cerro & Portas

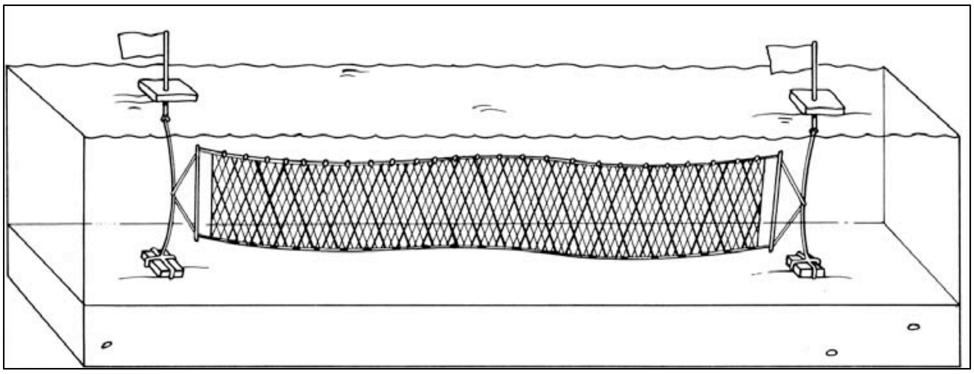


Figure 7. Trammel net (Del Cerro, 2006)

- Combined Gillnets-Trammel nets

It is a bottom set gear consisting of a gillnet in which the lower part is replaced by a trammel net (Figure 8). The advantage is that bottom fish might be caught in the lower trammel net part whereas together, semi-demersal and pelagic fish can be caught in the upper gillnet's part. It was first used in the Mediterranean, where it was discovered the capacity that both benthic and pelagic type of fish get entangled.

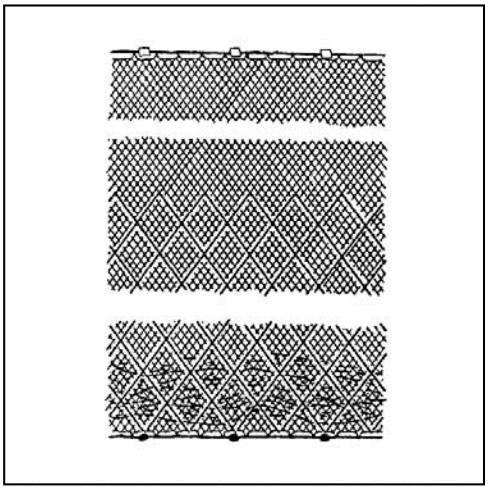


Figure 8. Combined gillnet-trammel net (FAO

- Pots

Mainly designed to catch fish or crustaceans, pots are found in the shape of cages or baskets made with several materials such as wood, wicker, metal rods, wire netting and so on, having at least one entrance (Figure 9). They are usually set on the bottom, might or not have bait, can be found singly or in rows, and showing their position on the surface by a connection of ropes to buoys (buoy-lines).

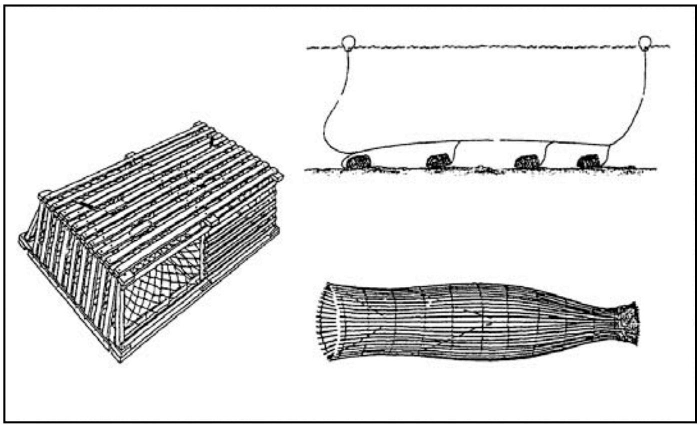


Figure 9. Pots (FAO 1990)

- Nansa

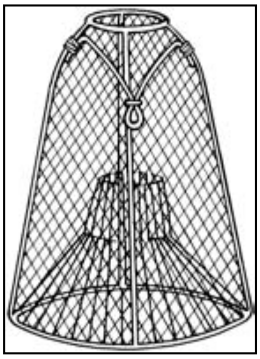


Figure 10. Nansa (Del Cerro & Portas 2006)

This type of gear traditionally made of reed, nowadays is made with plastic. It has a triangular shape reaching an average height of one meter; there is a circular opening known as mouth where the bait is settled and where the fish are taken out. The bottom presents an inner funnel-like shape which opens to the inside but does not allow escaping from it (Figure 10). The amount of *nanses* used at the same time depends on the boat size; they are kept most of the time in the sea connected by approximately 3 meters rope and only taken out once per day to extract the fish caught and to fill in with new bait (Figure 11). Several specializations in size and morphology are made according to the target species (Bas et al. 1955).

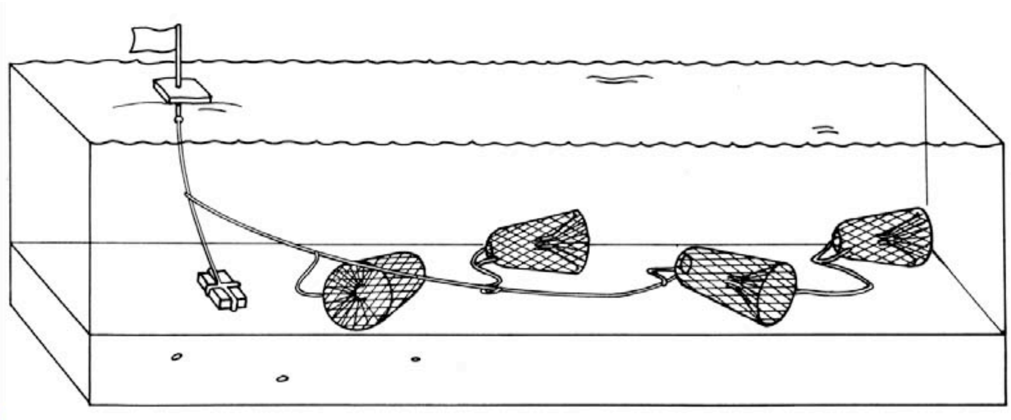


Figure 11. Set of nanses (Del Cerro & Portas 2006)

Cadup o catúfol

It is designed to target the common octopus (*Octopus vulgaris*) because of its hiding capacity and low movement. This gear serves the octopus to hide inside without being needed the bait. There is a main rope from which secondary ropes are tied and these ones are linked to the cadups (Demestre 1995). Several shapes and mostly clay materials compose a cadup; this fragile material for rough weather conditions determines the abandonment of this type of gear.

- Handlines and Pole-lines (hand operated)

Handlines may be used with or without a pole or rod (Figure 12). When fishing in deep waters, lines are frequently operated using reels and either natural or artificial bait. Jigging lines operated by hand and used in small boats are included in this category. They are mainly used to catch cephalopods: squid, octopus and cuttlefish.

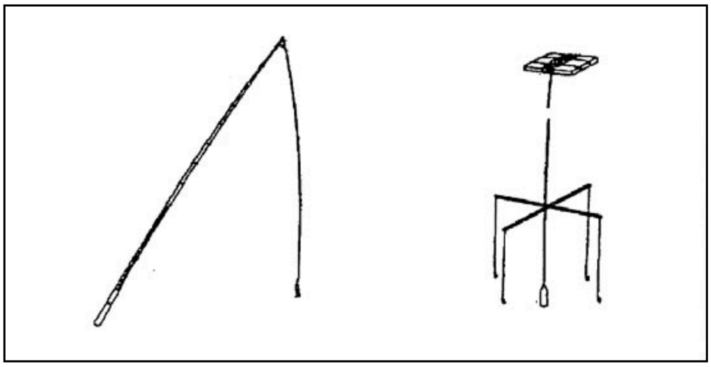


Figure 12. Handlines (Del Cerro & Portas 2006)

Each one has around 25-50 m of ressitant hemp thread with a colourful painted lead at the end (with fixed hooks facing up), which is constantly moving up and down to get the attraction of the fish. When ressitance is felt, the thread is pushed away (Bas et al. 1955).

- Set Longlines

Consisting of a main line which can be set either horizontally, near the bottom or less frequently near the surface; it can reach considerable lengths. Snoods with baited or unbaited hooks are fixed at regular intervals. The hook size will depend on the species to target. To avoid the removal from currents, in each of the ends there is an iron weight that gives stability on the bottom.

Normally all longlines have similar dimensions, however, they can vary on the thread's size, and consequently on the hook's size. Thus, distinctions on longlines are measured in weight. In this work, the different designations included in the definition of surface longlines are *palangre* (for greatest weight) and *palangró* (for the lighter ones).

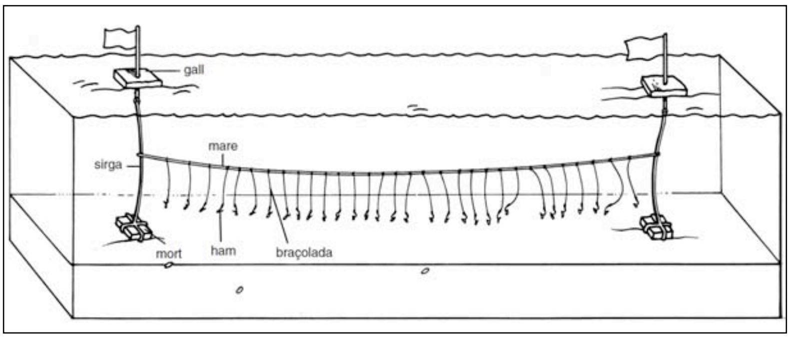


Figure 13. Bottom longline (Del Cerro & Portas 2006)

It is employed during the daytime and it does not need to be draft for more than one hour. The draft can be done either in rocky, sandy or muddy bottoms. They can be settled either at 15m or over 300m deep. Bottom longlines are the most commonly used (Figure 13). See below an example of a vertical longline (when the main line is set vertically); next to it, another one showing the direction of the draft (Figure 14).

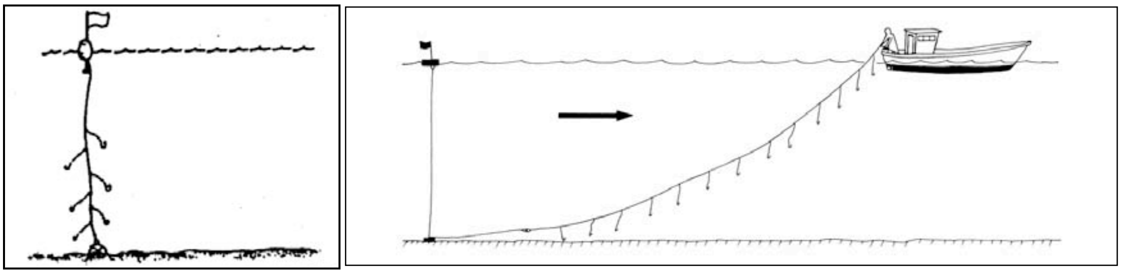


Figure 14. Longline (FAO 1990, Del Cerro & Portas 2006)

- Miscellaneous gears

Sometimes the gears employed are not classified in a particular category, or they are based on mixed principles. This is when they are called miscellaneous gears, and these can comprise a wide range of equipments operated either in shallow waters or from boats.

- Boat dredges

These refer basically to *Gàbies*, which are used for shellfishing by boat. The boat situates at about 100m then it drags the cages back.

Gàbies

They are very simple gears. There is what is called a mouth on the bottom side with some iron spikes to attach to the sea bottom and the cage itself with metal grids on the walls (Figure 15). The importance of the iron material is due to it will facilitate the boat to go back and drag the cages back once the fish are caught; there is a rope from the cage to the buoy. They are rarely used to fish deeper than 15 m and usually near the wave breakers (Del Cerro & Portas 2006).

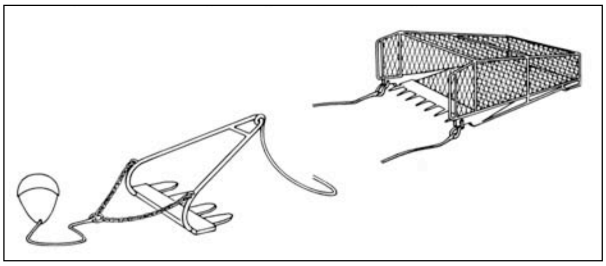


Figure 15. Cage -*gàbia*- (Del Cerro & Portas 2006)

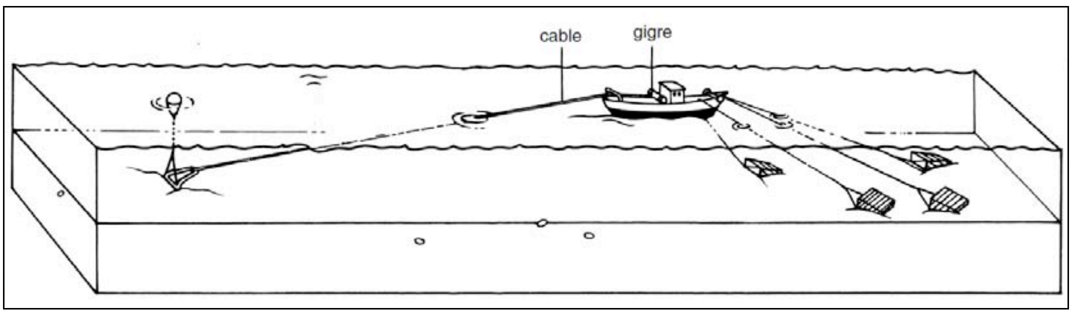


Figure 16. Set of cages (Del Cerro & Portas 2006)

ANNEX III

Provided layers regarding bathymetry, substrate type and benthic communities

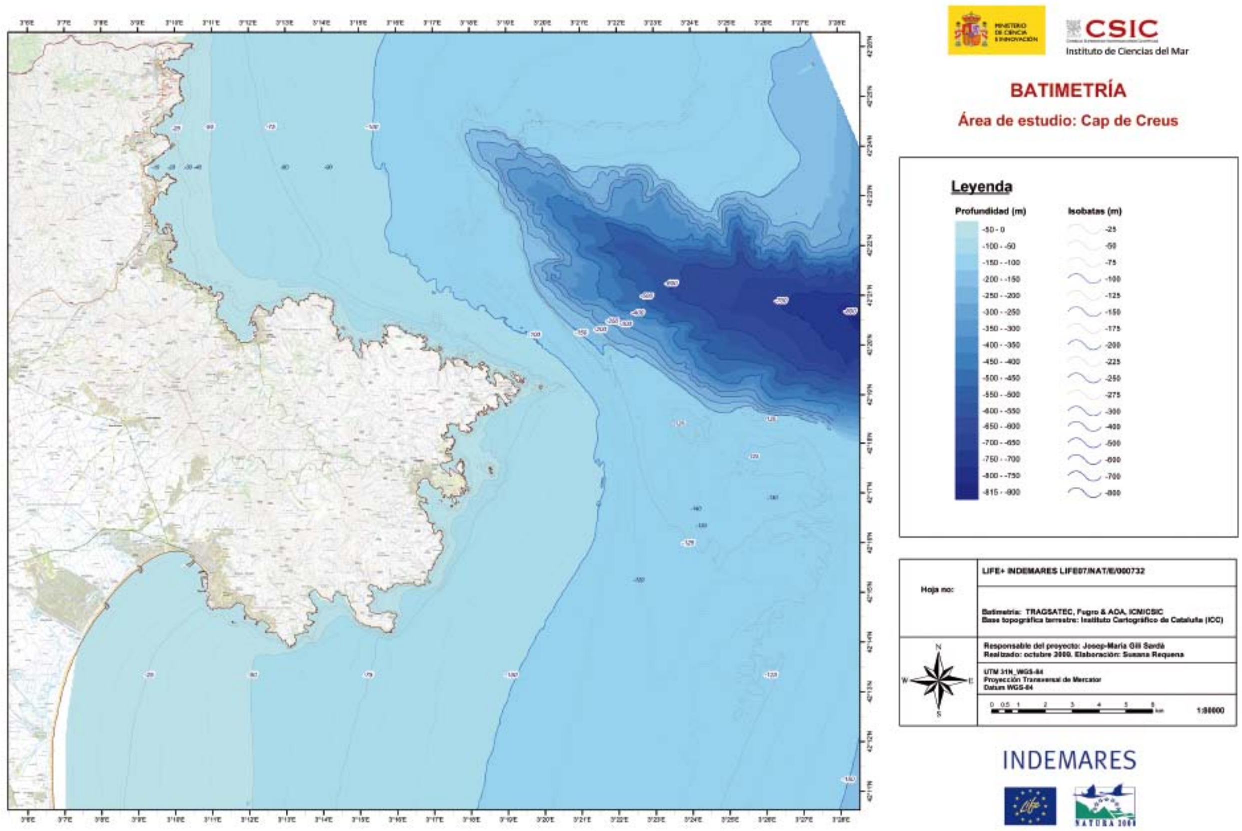


Figure 17. Bathymetry

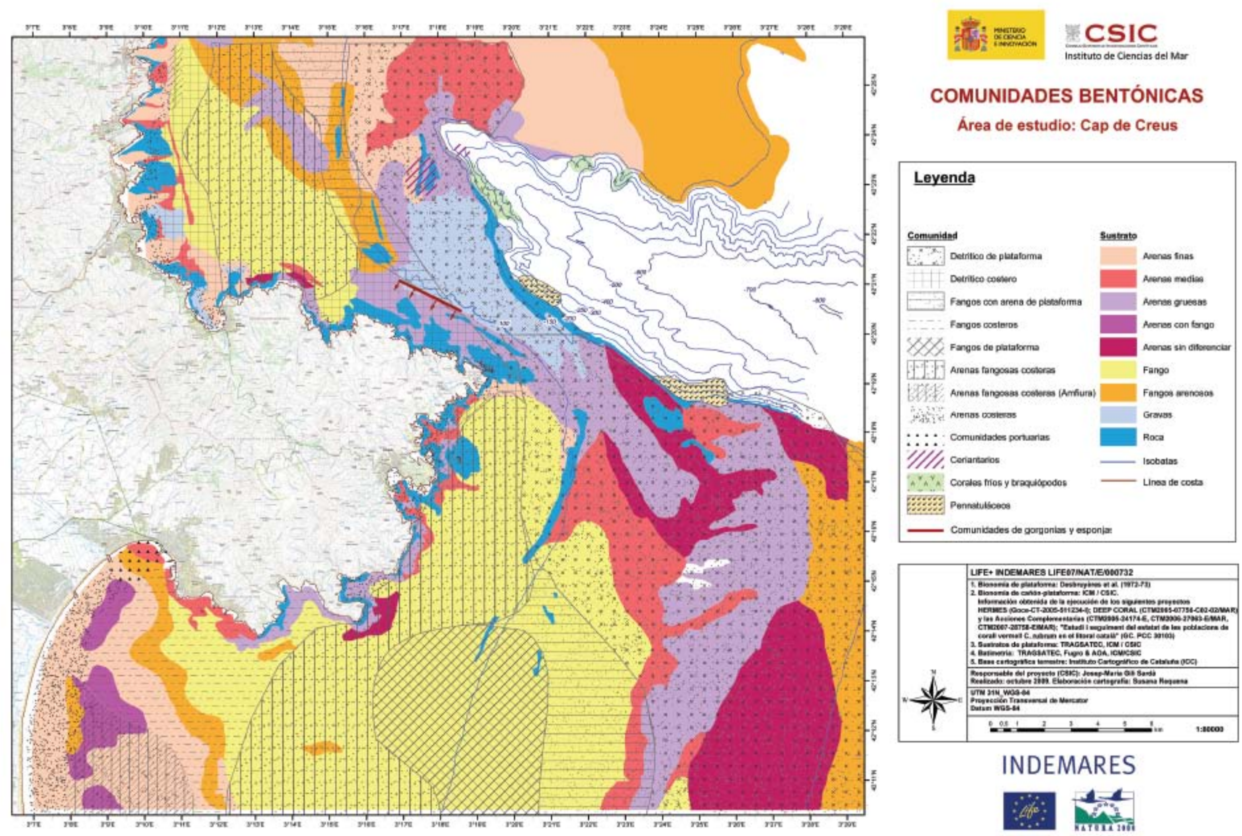


Figure 18. Benthic Communities and substrate type

ANNEX IV

List of target species

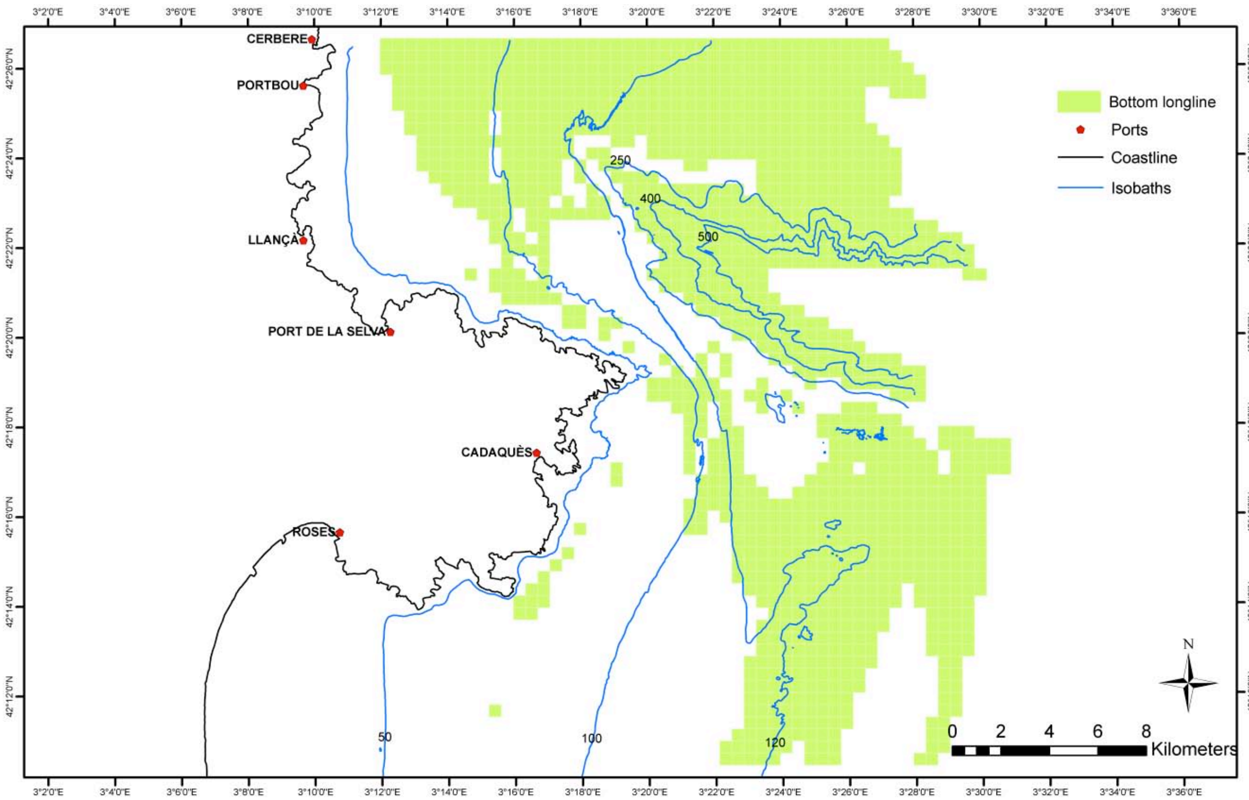
Table 1. List of target species by fishing gear

Trammel nets	Gillnets	Combined gillnets-trammel nets	Longlines	Bottom longlines	Pots	Miscellaneous gear	Handline-polylines	Boat or vessel seines
Palinurus elephas	*Sarda sarda*	*Sarda sarda*	*Diplodus sargus*	*Merluccius merluccius*	*Octopus vulgaris*	*Paracentrotus lividus*	*Loligo vulgaris*	*Gymnammodytes cicerellus*
Homarus gammarus	*Diplodus sargus*	*Lichia amia*	*Dentex dentex*	*Conger conger*	*Conger conger*	*Mytilus galloprovincialis*		*Donax trunculus*
Lophius piscatorius	*Sparus aurata*		*Dicentrarchus labrax*	*Lepidopus caudatus*	*Sepia officinalis*	*Corallium rubrum*		*Acanthocardia tuberculata*
Trisopterus minutus	*Atherina boyeri*		*Diplodus cervinus*	*Pagellus bogaraveo*		*Nereis spp.*		*Chamelea gallina*
Scorpaena scrofa	Fam. Mullidae		*Pagellus erythrinus*	Fam. Triglidae				*Callista chione*
Fam. Soleidae	*Merluccius merluccius*		*Sparus aurata*					
Psetta maxima	*Pagellus acarne*		*Diplodus vulgaris*					
Lithognathus mormyrus	*Scomber scombrus*		*Pagrus pagrus*					
Citharus linguatula	*Citharus linguatula*		*Conger conger*					
Fam. Mullidae	*Scyliorhinus canicula*		*Epinephelus guaza*					
Pagellus acarne	*Trisopterus minutus*		*Phycis phycis*					
Sepia officinalis	*Trachurus trachurus*		*Trisopterus minutus*					
Spicara smaris	*Pagellus erythrinus*		*Merluccius merluccius*					
Scorpaena spp.	*Dicentrarchus labrax*		*Lepidopus caudatus*					
	Seriola dumerili		*Pagellus acarne*					
			Polyprion americanus					
			Raja asterias					
			Pomatomus saltatrix					

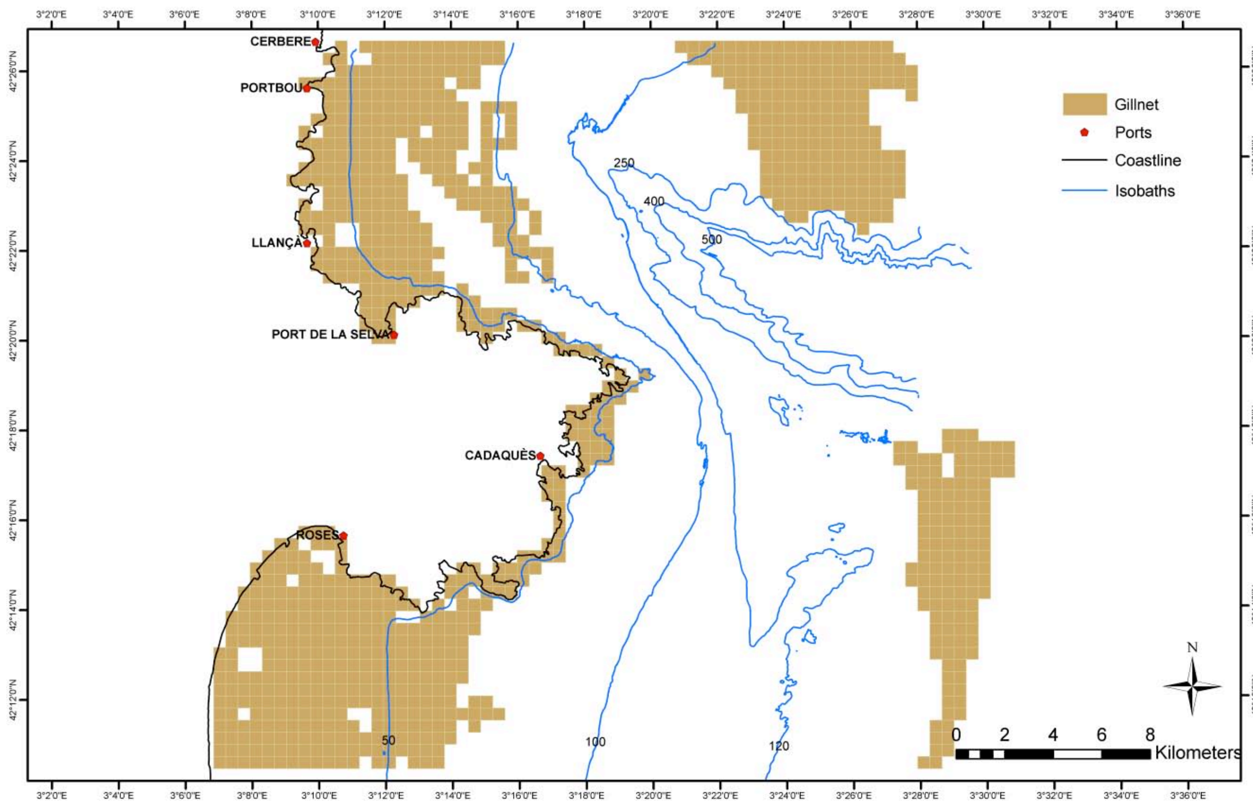
ANNEX V

Maps of the activity area for each fishing type

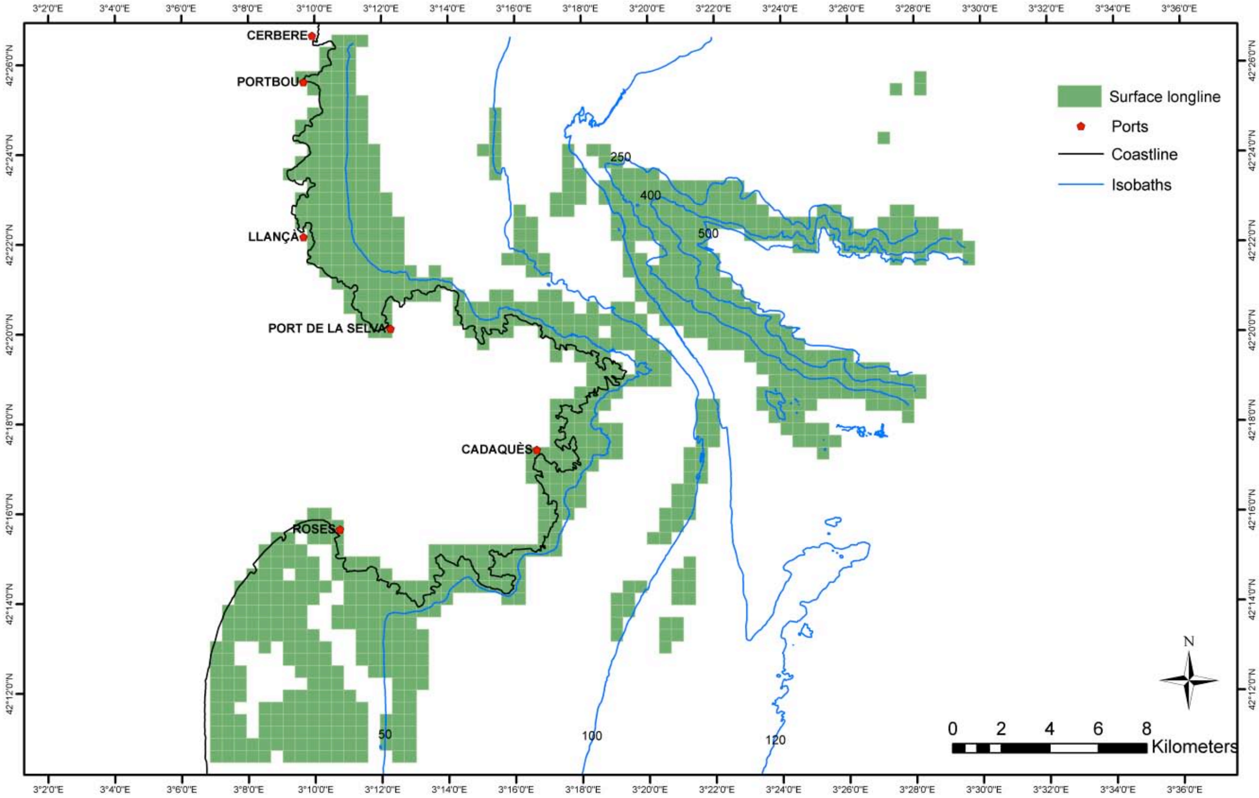
Bottom longline



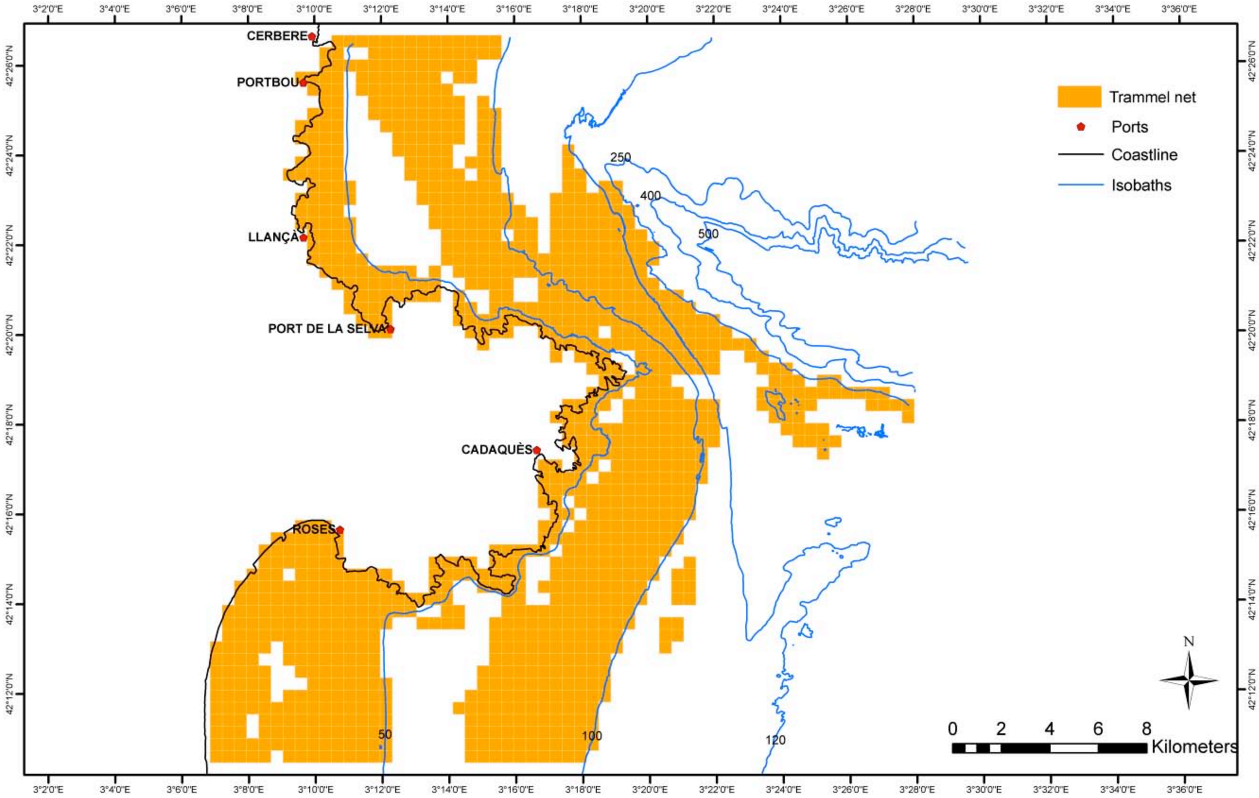
Gillnet



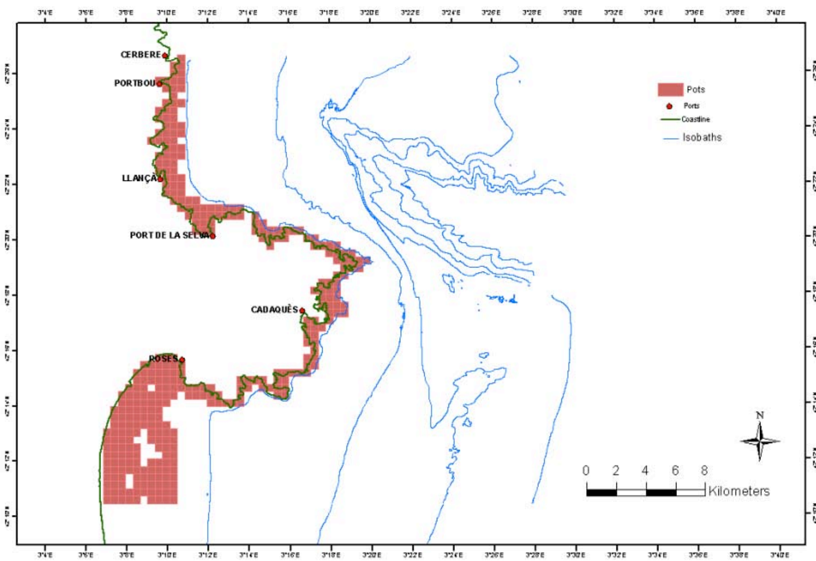
Surface longline



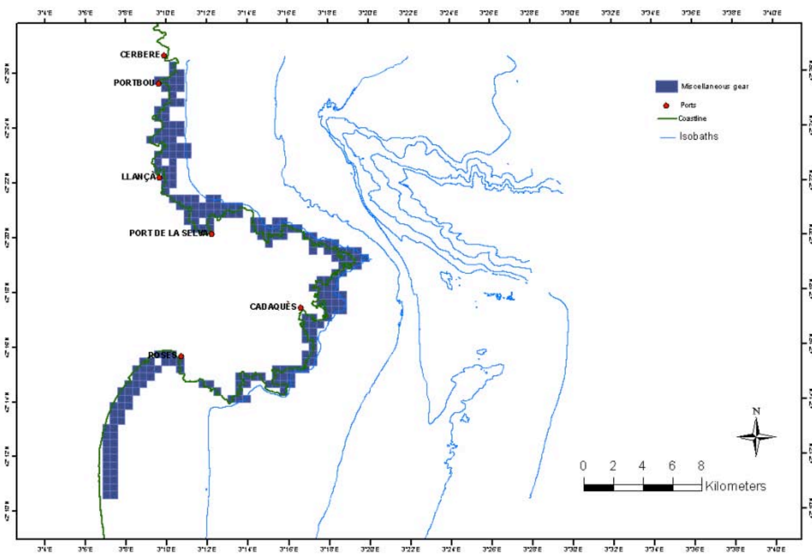
Trammel net



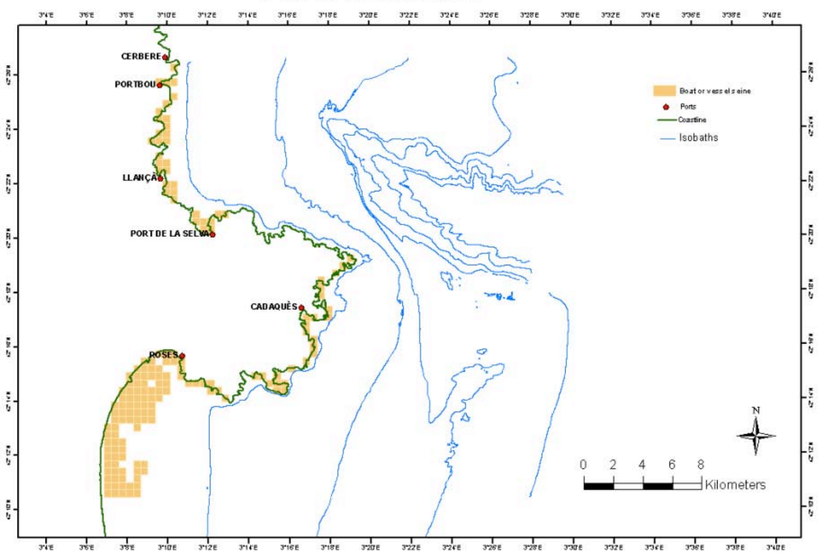
Pots



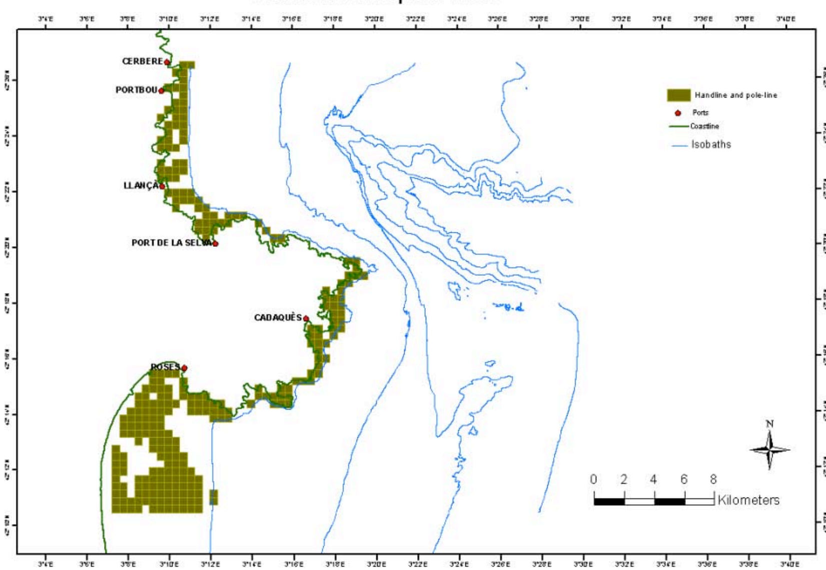
Miscellaneous gear



Boat or vessel seines



Handline and pole-lines



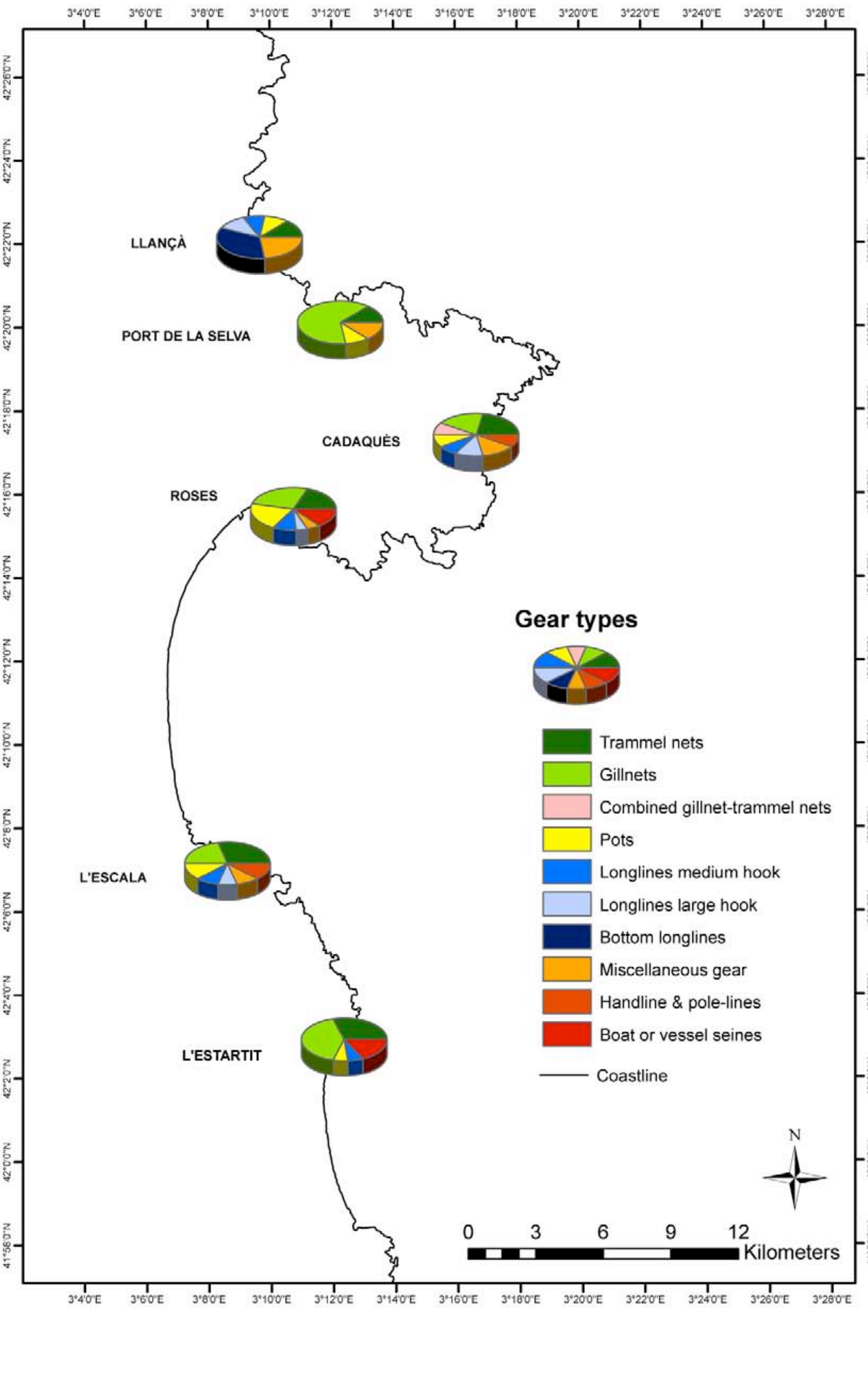
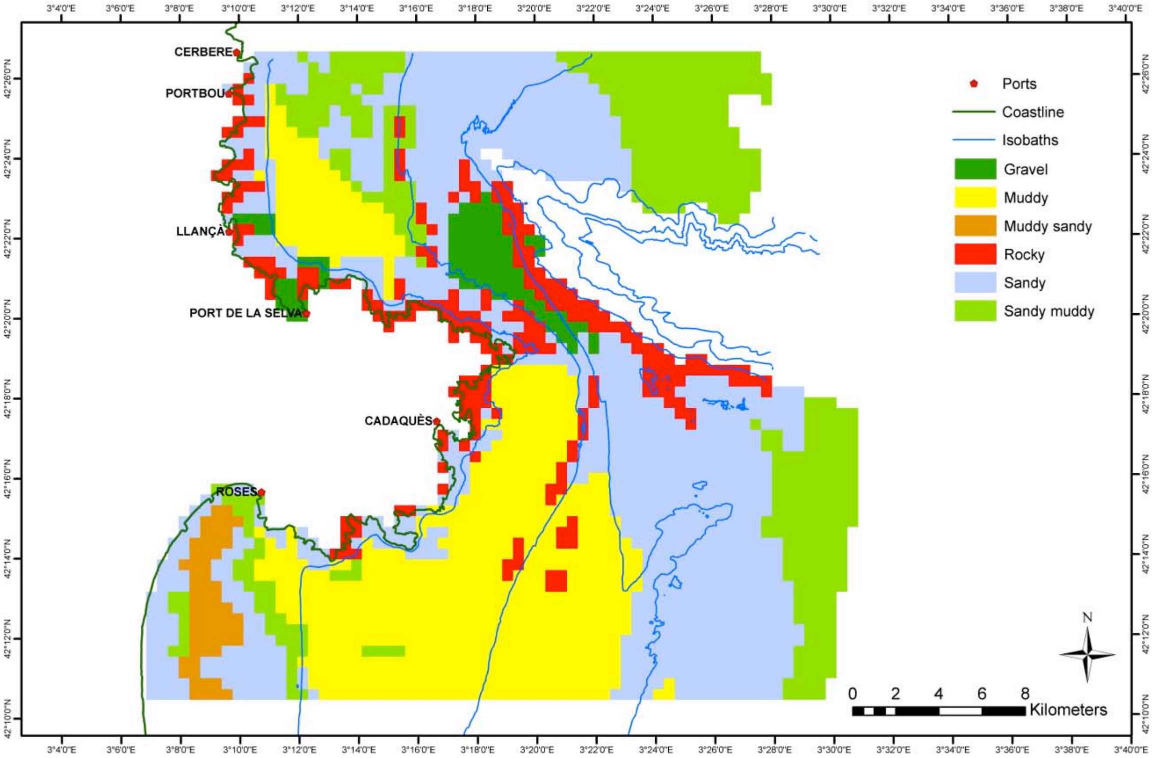


Figure 19. Composition of gear types by port

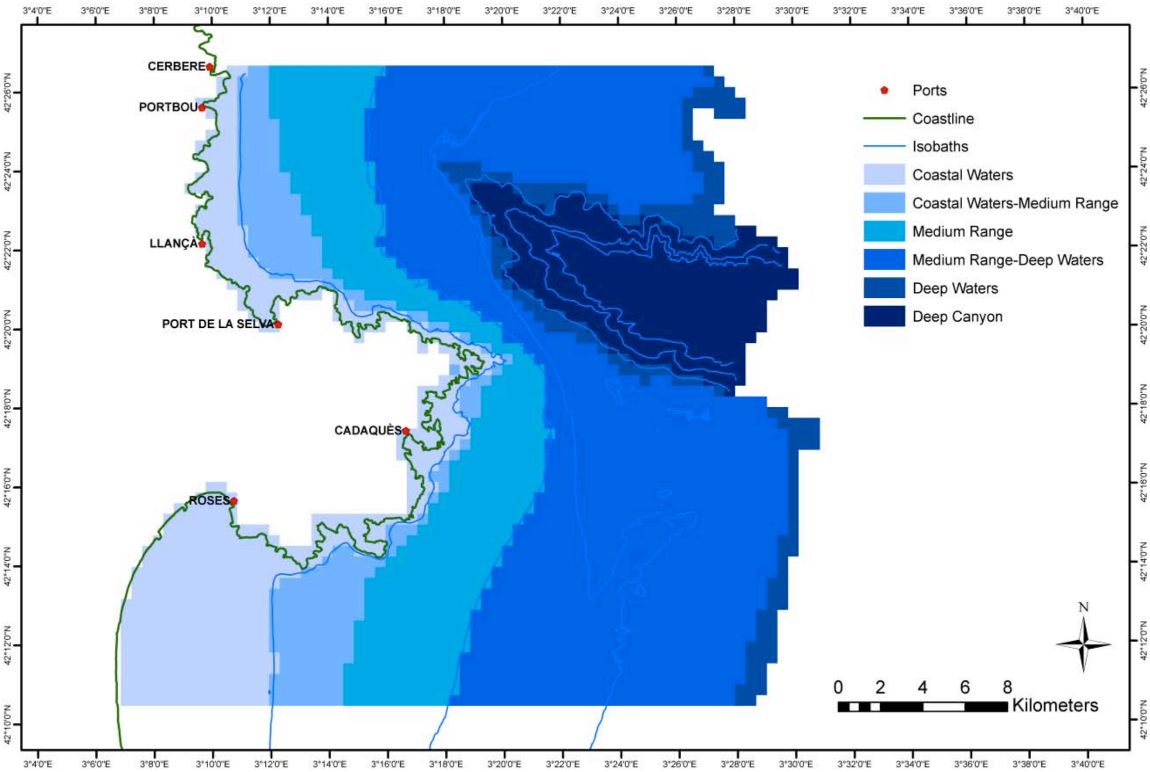
ANNEX VI

Maps of the substrate type and the fishing zone

Substrate type



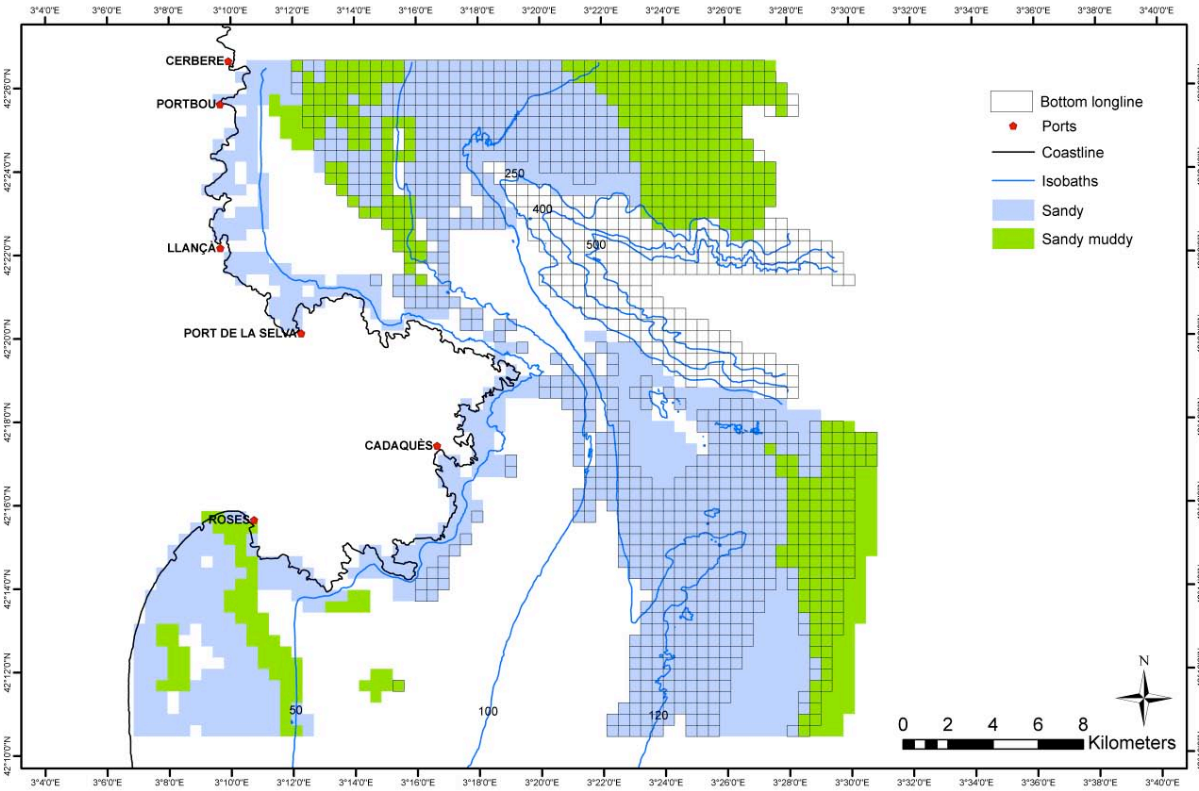
Fishing zones



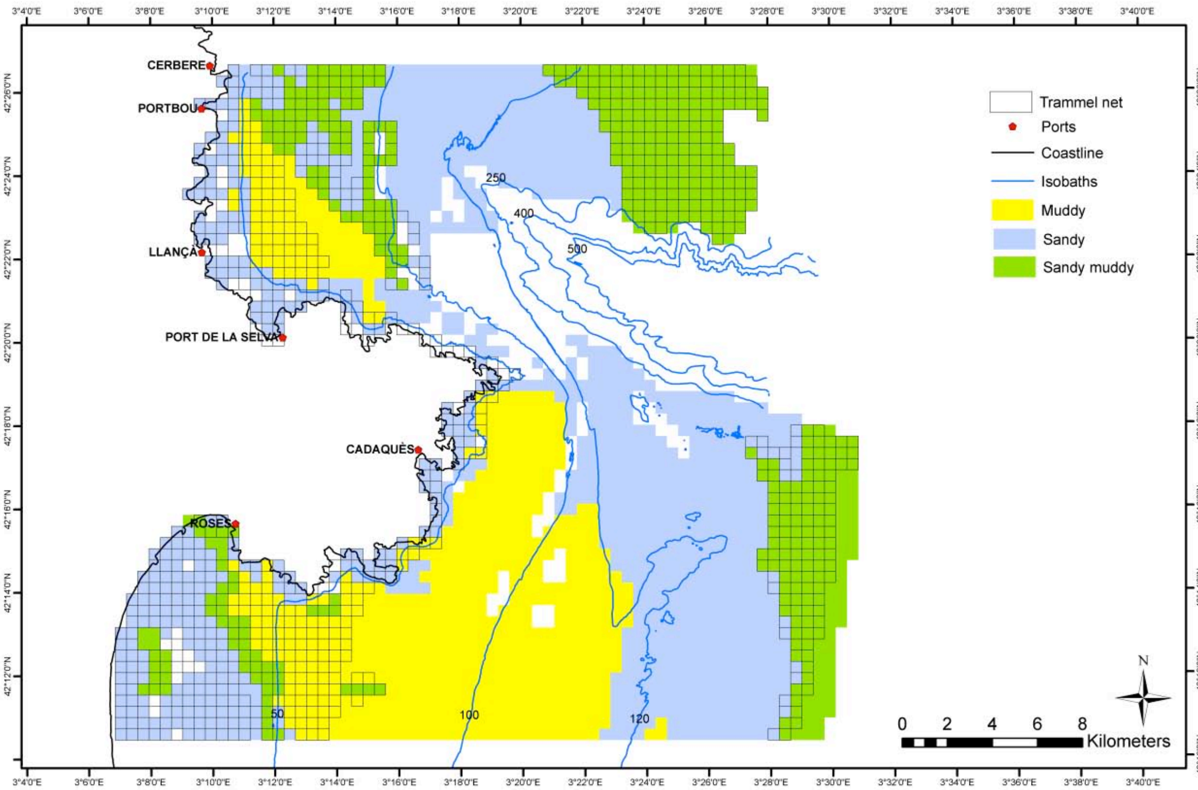
ANNEX VII

Maps of the activity area for each main fishing type regarding fishing zone

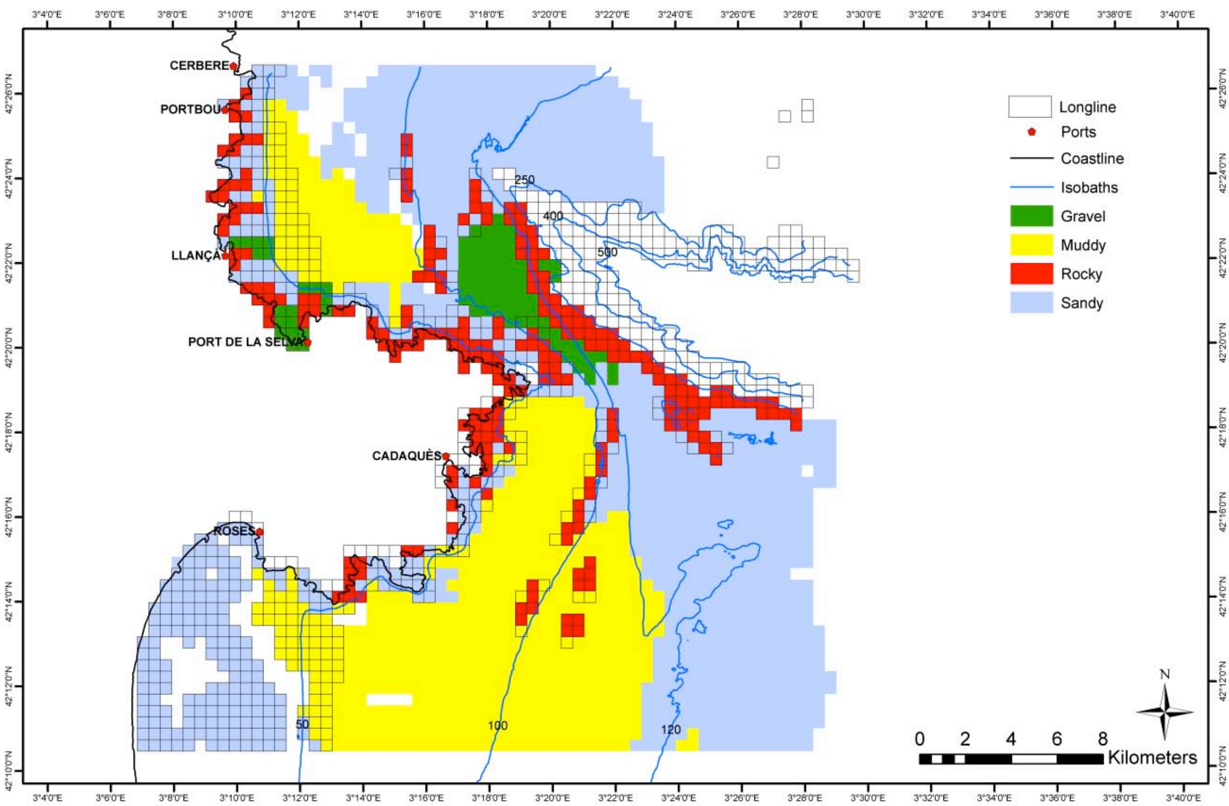
Bottom longline in sandy and sandy muddy substrate



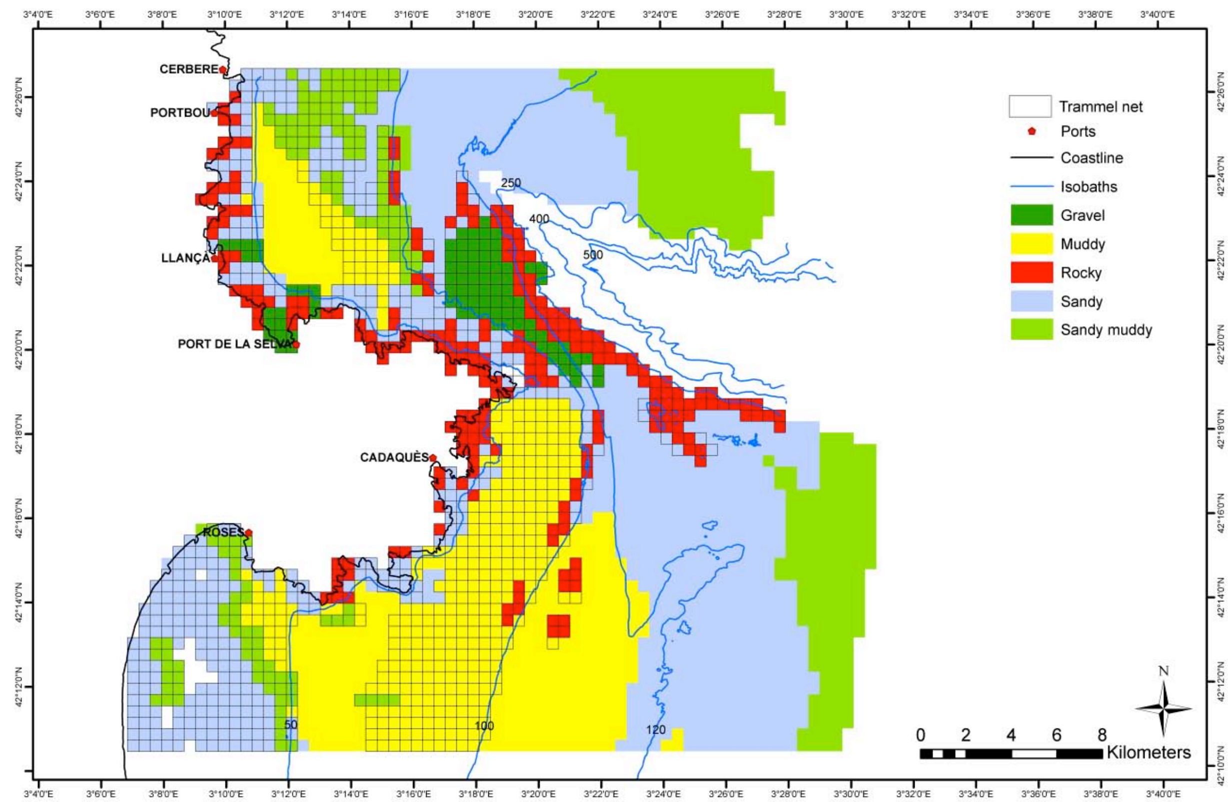
Gillnet in sandy, muddy and sandy muddy substrate



Longline in sandy, muddy, rocky and gravel substrate



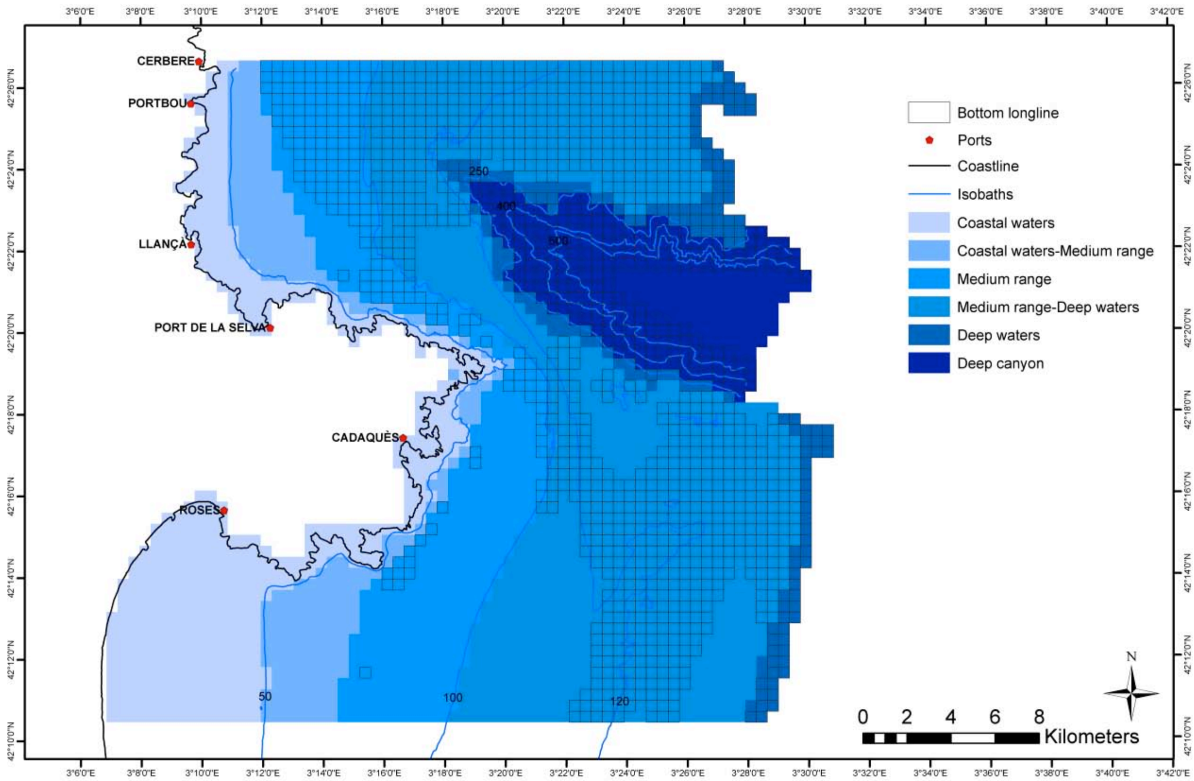
Trammel net in sandy, muddy, sandy muddy, rocky and gravel substrate



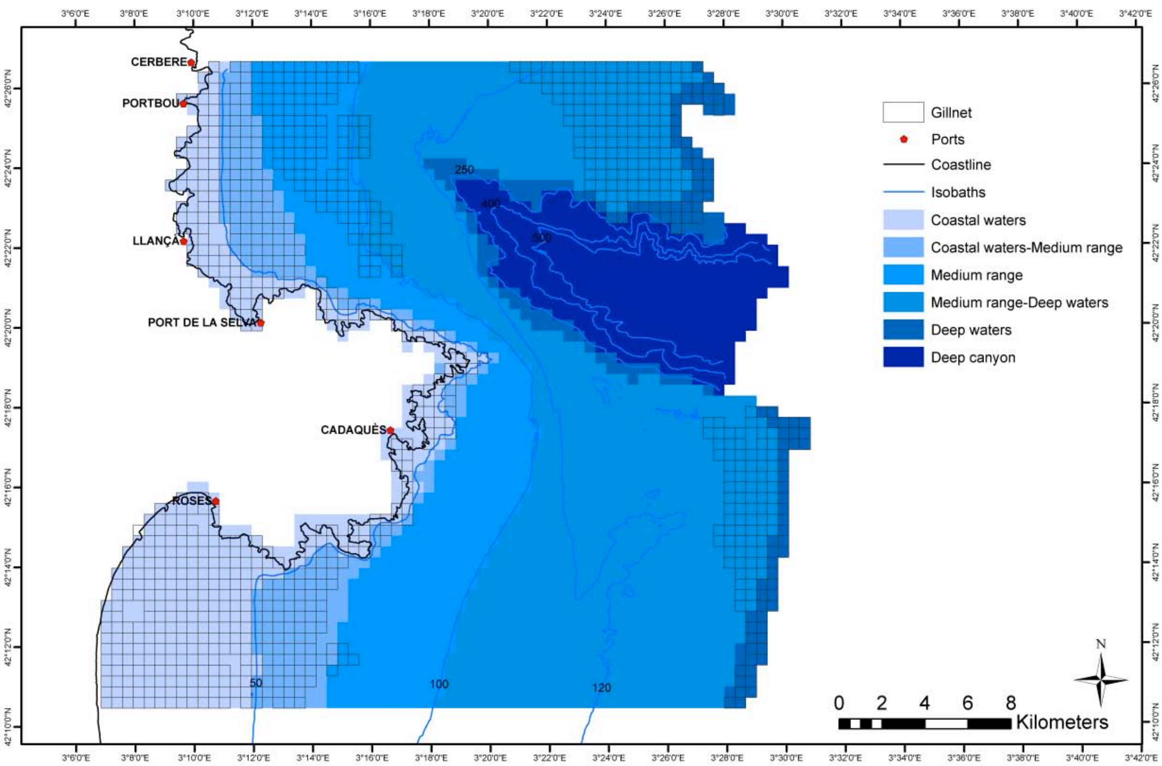
ANNEX VIII

Maps of the activity area for each main fishing type regarding fishing substrate

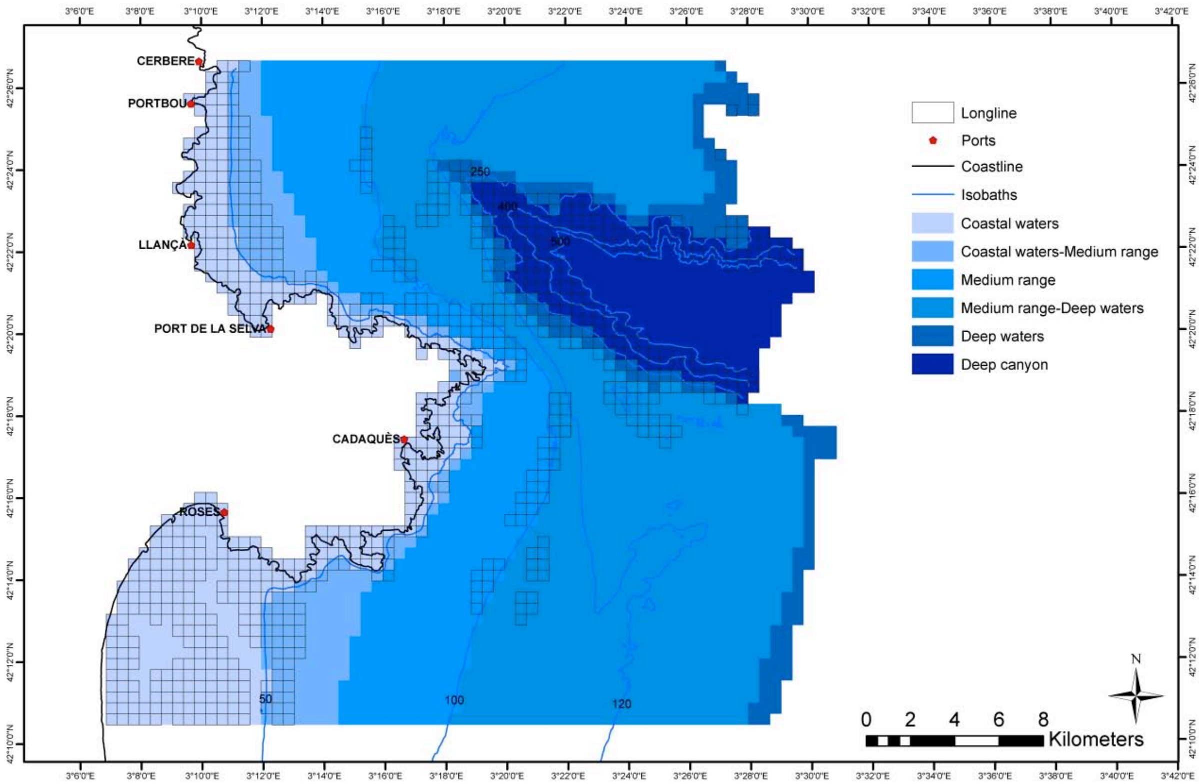
Bottom longline and fishing zones



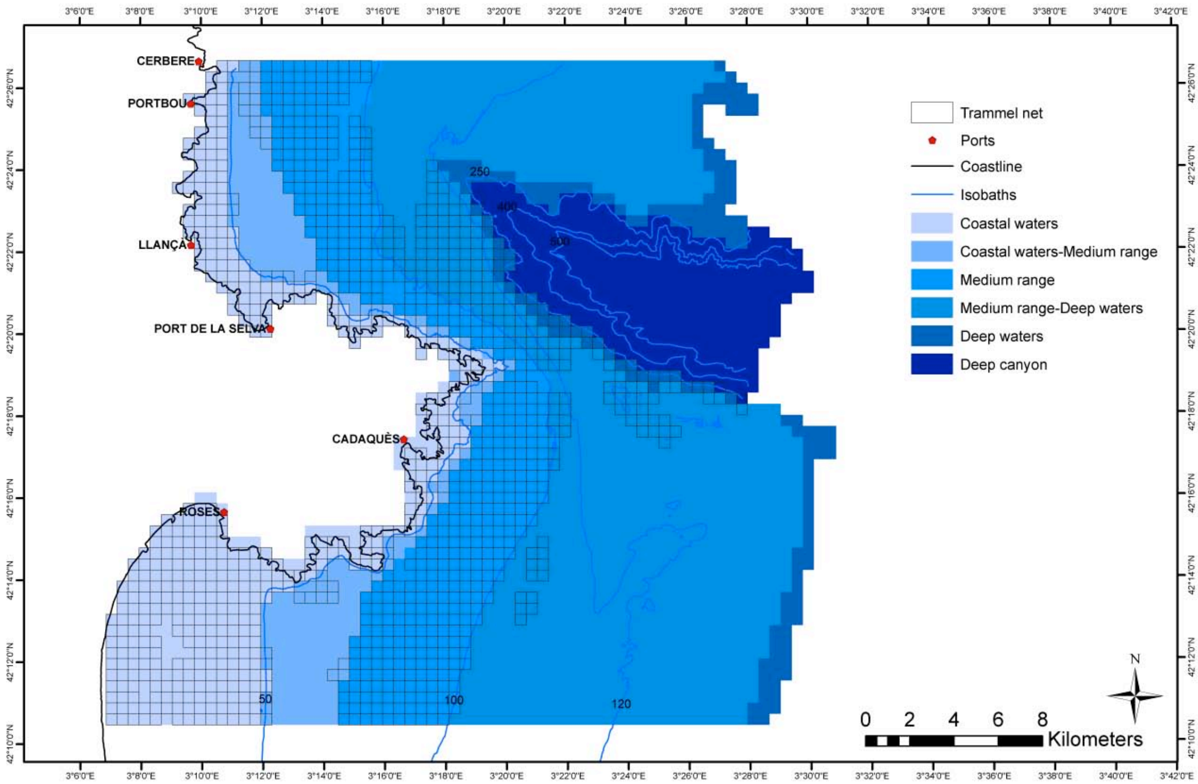
Gillnet and fishing zones



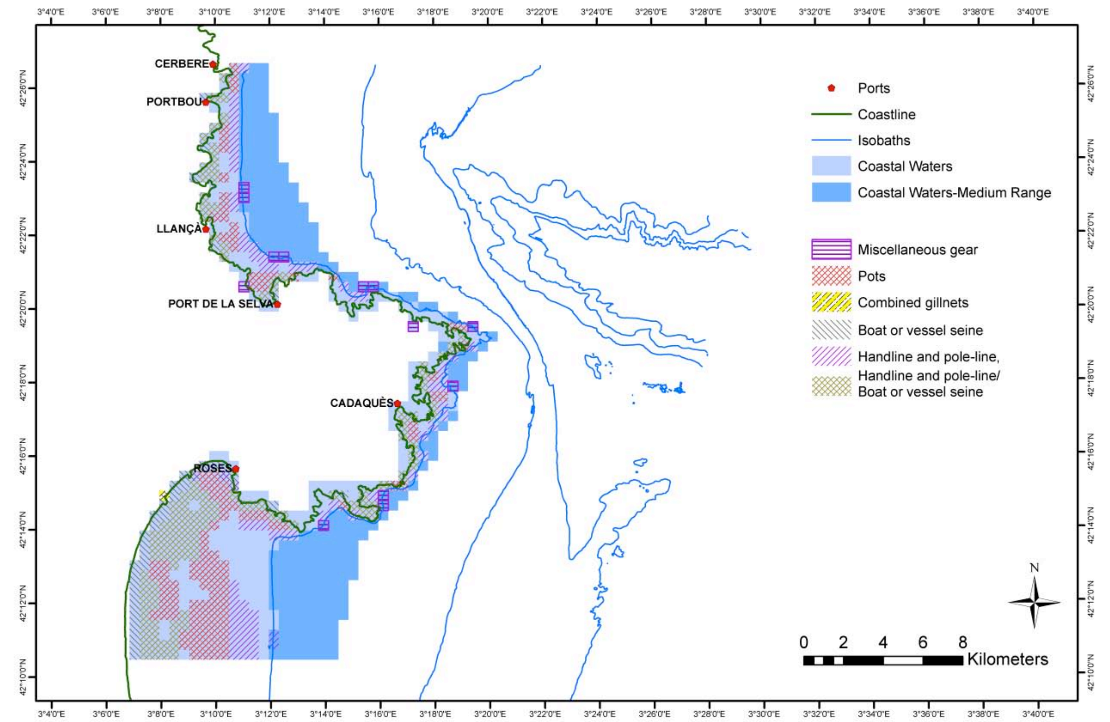
Longline and fishing zones



Trammel net and fishing zones



Minor gears and fishing zones



ANNEX IX

Maps of georeferenced older data in comparison with the existent one

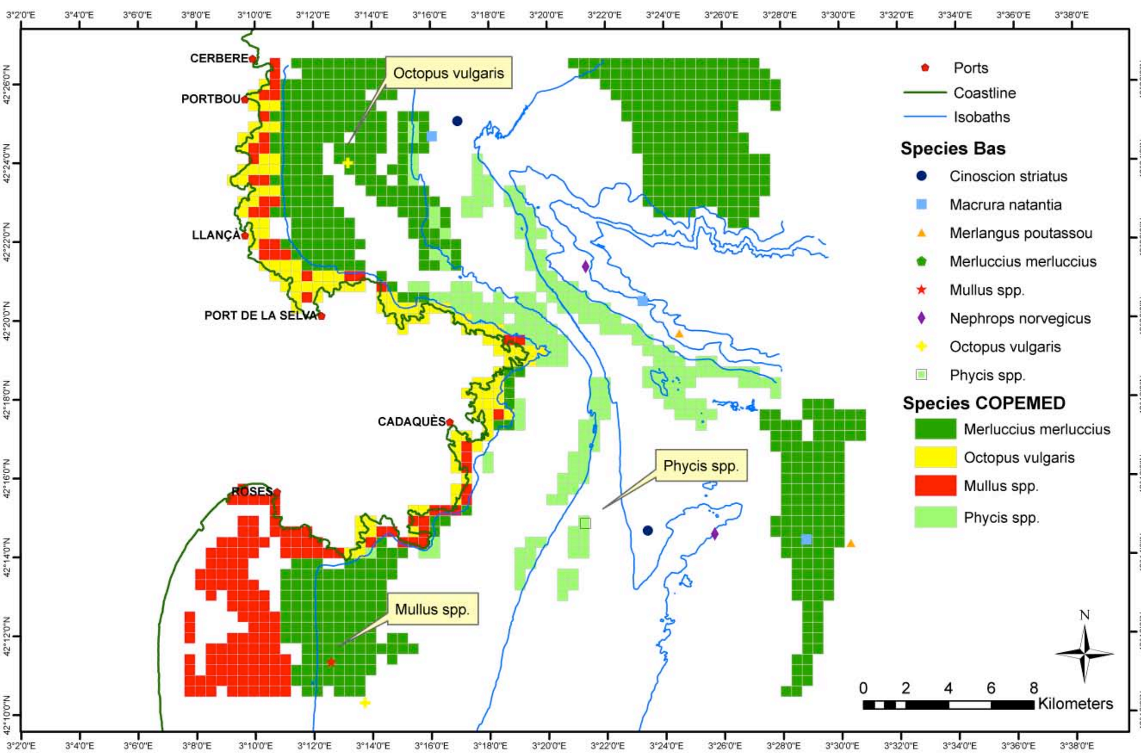


Figure 20. Comparison of target species from data by Bas et al. (1955) and the COPEMED Project

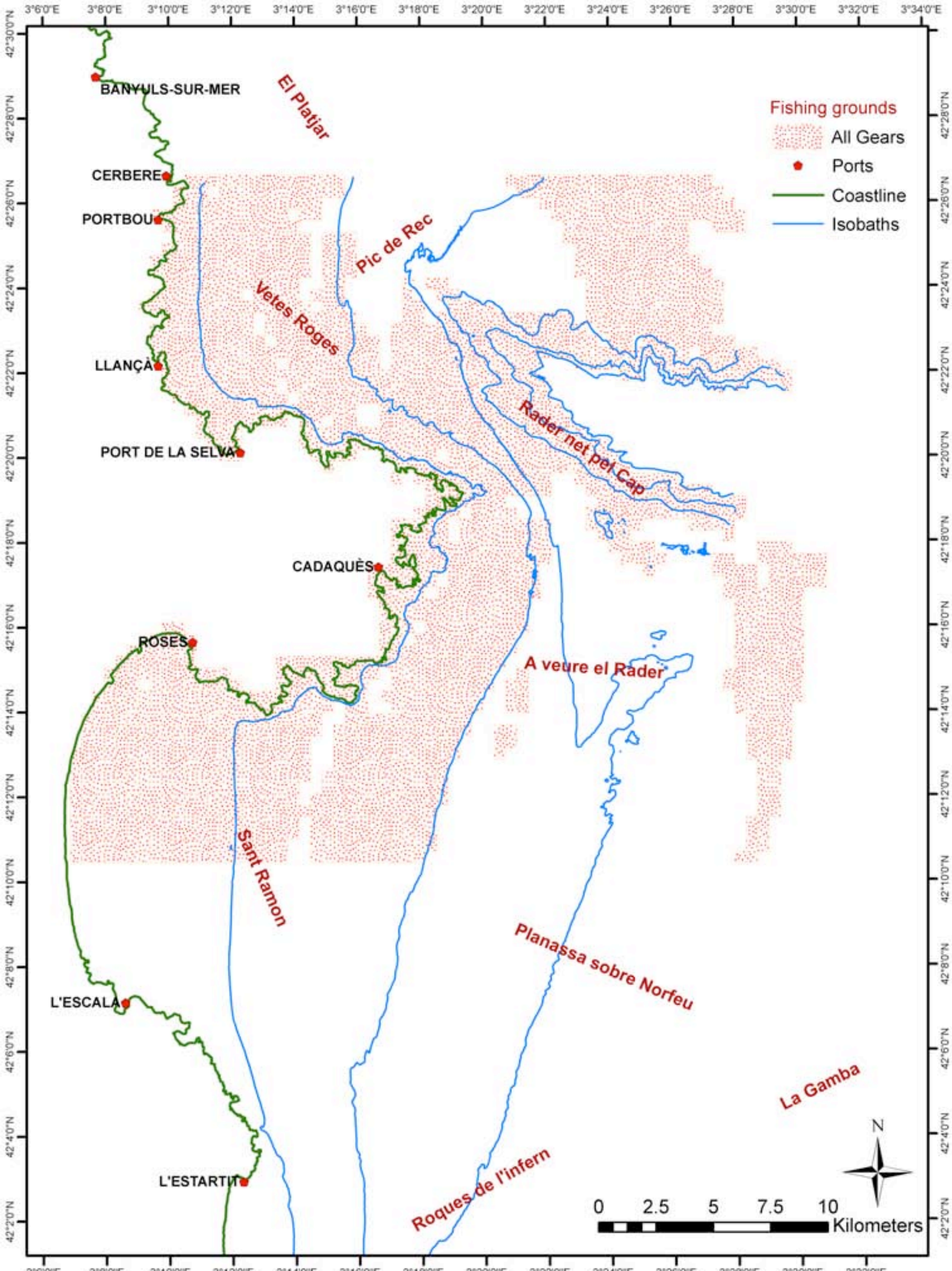


Figure 21. Fishing ground results compared with the ones from Bas et al. (1955)