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Ecological mapping and data quality assessment for the needs of ecosystem-based marine spatial management: case study Greek Ionian Sea and the adjacent gulfs

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Abstract

Mapping of ecosystem components (natural and socioeconomic) is a prerequisite for ecosystem-based marine spatial management (EB-MSM). To initiate the process of EB-MSM in the Greek Ionian Sea and the adjacent gulfs, the main relevant ecosystem components were mapped based on existing spatial information and expert judgment. The natural components mapped included habitat types and species targeted for conservation, according to national and European legislation and international agreements. Main human activities/pressures related to fisheries, aquaculture, tourism, and industry were also mapped. In order to assess the quality of data used to map ecosystem components and therefore take into consideration the inherent uncertainty, an assessment of 5 semi-quantitative data indicators based on a pedigree matrix was conducted. Through this qualitative approach we gained information related to the sources, acquisition and verification procedures, statistical properties, and temporal & geographical correlation, along with the collection process quality of the ecosystem components under study. A substantial overlapping between ecological features and human activities was identified, confirming the need for a well-planned approach to marine space management, in order to mitigate conflicts for marine resources and conserve marine ecosystems and their associated goods and services.

Keywords: Ecosystem components, marine spatial planning, conservation, human uses, quality assessment, uncertainty, Ionian Sea.

Introduction

Much of the rapid economic and technological development of the last century has been achieved to the detriment of natural systems and the sustainability of resources and ecosystem functioning. The marine environment, in particular, has been heavily affected by anthropogenic activities, which have caused widespread degradation of marine habitats, depletion of resources and loss of biodiversity at ecosystem, species and genes level (Halpern *et al*., 2008). Fisheries, aquaculture, coastal defence systems, shipping, offshore wind farms, the gas and oil industry, tourism activities, and the need for marine conservation all compete for the same valuable space and resources. Now, more than ever, a well planned approach to marine spatial management is required in order to maintain marine ecosystems in a healthy, productive and resilient condition, so that they can provide goods and services to satisfy human needs.

Conventional sectoral management and piecemeal governance are considered all the less appropriate in pursuit of sustainable development, as the interaction between activities and their cumulative impacts are ignored (Halpern *et al*., 2008; Foley *et al*., 2010). Ecosystem-based marine spatial management (EB-MSM) is a place-based environmental management approach that recognizes the full array of interactions within a marine ecosystem, including humans, rather than considering single issues, species or ecosystem services in isolation (Katsanevakis *et al*., 2011). The definition and mapping

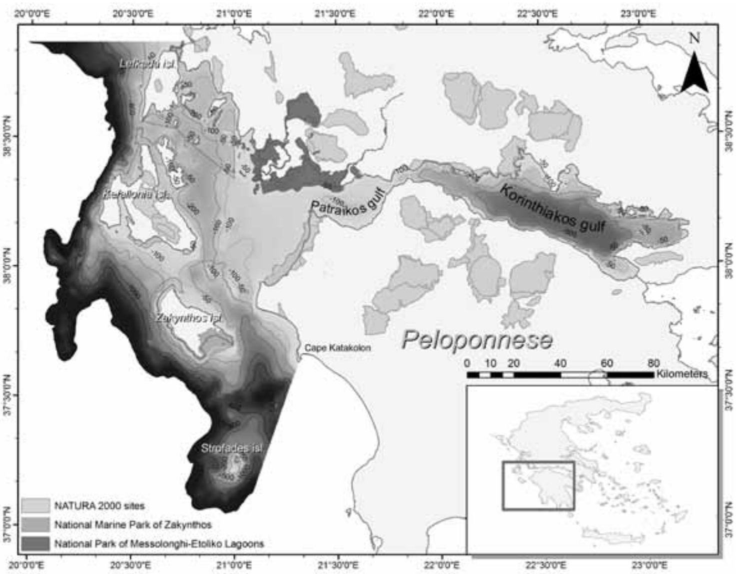

Fig. 1: Bathymetric map of the study area with special areas of conservation.

of ecosystem components and a defined set of operational objectives in particular, is an important part of the scoping process of a management plan based on EB-MSM. These ecosystem components include both natural components, such as habitats, species, or processes describing the ecosystem, and socioeconomic components i.e. different human uses and sectors. Ecological mapping is viewed as the creation of appropriate geographical information systems that allow the collation, visualization, and analysis of spatial information for all relevant ecosystem components.

Acknowledgement and management of data quality assessment in environmental science for policy has become a key factor during the last decades. During the mapping process for the ecosystem components, the quality of information sources should be evaluated. This process can shed light on the uncertainty inherent in the data addressing cognitive constraints in decision-making. Uncertainty assessment has been implemented to a broad range of research fields such as maritime management, environmental and biological modelling, climate change modelling and water management modelling, adding further credibility to the studies' results (Maxim & van der Sluijs, 2011).

In the framework of the MESMA (Monitoring and Evaluation of Spatially Managed Areas) FP7 project, an effort has been made to initiate the EB-MSM process in the Greek Ionian Sea and the adjacent gulfs, a region situated in Western Greece. Part of the study area (Fig. 1), especially the semi-enclosed Korinthiakos Gulf, has limited connectivity with the open sea, making it vulnerable to intense human activities. Anthropogenic activities (fisheries, aquaculture, tourism, shipping, and industry) occur along the coasts of the study area and in offshore waters. Growing conflicts exist between human uses and nature conservation, as well as among the human uses themselves; nevertheless, there is currently no integrated spatial plan for managing the entire study area. This study can be considered as a step towards meeting the goals set by the EU 2020 biodiversity strategy, aiming at halting the loss of biodiversity, the degradation of ecosystem services in the EU by 2020, and restoring them as far as feasible. As a first step for EB-MSM, several relevant ecosystem components along with selected human activities were mapped, addressing issues of information quality. The results of this exercise are presented in this paper. It is pointed out that, in certain cases, due to lack of information, surrogate approximations were used, based mainly on expert judgement. In that sense, it is by no means claimed that these results provide a conclusive depiction of all ecosystem and socioeconomic components in the study area, but rather a first analysis of the available information, which can and should be continuously improved and updated.

Materials and Methods

Study area

The eastern boundaries of the study area were defined by the coastline; the entire Patraikos and Korinthiakos Gulfs were included (Fig.1). Since the conservation of the cetacean populations in the area is one of the priorities foe management (ACCOBAMS, 2007), and as sperm whales and Cuvier's beaked whales actively forage down to 2000 m depth, we have included the entire distributional range of these species in the study area, by defining the 2000 m depth contour as the natural western and southern boundaries of the study region. Southwards, we extended the study region to include Strofades Islands, a protected area of high conservation value, in which is part of the National Marine Park of Zakynthos. The northern limits of the study area were defined by 38° 53′ latitude and the

Table 1: Conservation importance and population status of habitat types and species present in the area according to relevant international Conventions, EU Habitat Directive, EU Birds Directive and the Red Book of Endangered Animals of Greece (GREEK RED BOOK, 2009). The asterisk in the Habitats Directive tab refers to priority habitat types or species, while the Arabic numbers refer to the code of each habitat type. Latin numbers in all tabs refer to the relevant Annexes of the respective Directive/ Convention. Greek Red Book abbreviations LC, NT, VU, EN, CR, DD stand for the relevant species' population status of "Least Concern", "Nearly Threatened", "Vulnerable", "Endangered", "Critically Endangered" and "Data Deficient" respectively.

		Habitats Directive	Birds Directive	Barcelona Convention	Bern Convention	Bonn Convention	Greek Red Book
Habitat Types	*Posidonia oceanica* seagrass meadows	*1120					
	Coastal lagoons	*1150					
	Coralligenous and deep corals	1170					
	Submarine structures made by leaking gases	1180					
Species	*Monachus monachus*	*II, IV		II	II	I, II	CR
	Tursiops truncatus	II, IV		II	II		VU
	Stenella cueruleoalba	IV		II	II		VU
	Delphinus delphis	IV		II	II		EN
	Physeter macrocephalus	IV		II	II	IV	EN
	Ziphius cavirostris	IV		II	II		DD
	Caretta caretta	*II, IV		II	II		EN
	Savalia savaglia			II	II		N/A
	Hippocampus spp.			II	II		DD
	Pinna nobilis	IV		II	II		VU
	Phalacrocorax aristotelis desmarestii		I		II		NT
	Calonectris diomedea		I		II		LC

south-eastern limits by a straight line joining Cape Katakolon on the western coast of the Peloponnese with the 2000 m contour south of Strofades Islands.

Overall, the study area comprises 10 marine NATURA 2000 sites and includes two national parks: the aforementioned National Marine Park of Zakynthos and the National Park of Messolonghi - Etoliko Lagoons (Fig. 1).

Ecosystem and socioeconomic components

Habitat types and species considered in this analysis were selected based on their conservation importance, as defined by European legislation or international agreements (Table 1). Habitat types of high conservation value include *Posidonia oceanica* meadows, coastal lagoons, and submarine structures formed by leaking gases. The Habitat Type "Reefs" is also a widely distributed ecological component in our study area. However, due to its extremely bulky nature - currently consisting of a large variety of natural habitats, which may differ significantly in terms of their ecological and conservation aspects (Salomidi *et al.*, 2012) - we hereby chose to address only the deepest counterparts, in our case represented by coralligenous formations and deep-water corals. These marine biogenic habitats are well recognized for their high conservation value and vulnerability (Ballesteros, 2006; UNEP, 2007), but have long been neglected by Greek conservation and management plans, due mostly to their deep and thus fairly unknown distribution in the Greek Seas and the wider Eastern Mediterranean. The list of species utilized in the study includes the Mediterranean monk seal *Monachus monachus*, the common bottlenose dolphin *Tursiops truncatus,* the striped dolphin *Stenella coeruleoalba*, the short-beaked common dolphin *Delphinus delphis*, the sperm whale *Physeter macrocephalus*, Cuvier's beaked whale *Ziphius cavirostris*, the loggerhead turtle *Caretta caretta*, the gold coral *Savalia savaglia*, the short-snouted seahorse *Hippocampus hippocampus* and the long-snouted seahorse *H. guttulatus*, the fan mussel *Pinna nobilis*, the Mediterranean shag *Phalacrocorax aristotelis desmarestii*, and Cory's shearwater *Calonectris diomedea*. The human activities taking place in the study area and analyzed herein are: fisheries, aquaculture, tourism, and industry.

Existing spatial information was implemented in a unified geographic information system, using ESRI

ArcGIS 9.3. Most polygon shapefiles, representing the spatial distribution of habitat types and species, were created from scratch, using available information from various sources. Details on the sources, assumptions made, and data quality for each layer are given below:

- *Posidonia oceanica* meadows: Layers of their spatial extent are based on data gathered from local surveys within the framework of research projects carried out by the Institute of Oceanography, Hellenic Centre for Marine Research (HCMR), scattered information from various sources (i.e. grey literature) and expert judgment. Detailed mapping of *Posidonia oceanica* meadows was only available for some of the existing NATURA 2000 sites of the study area.
- Coralligenous formations and deep corals: The current extent of coralligenous formations (up to 60 m depth) in the Korinthiakos Gulf has been roughly estimated based on several scattered groundtruthing surveys (Salomidi *et al*., 2006, 2009, 2010). Slope and shelf surveys (video), experimental trawling (fishing by-catch) and fishermen questionnaires have revealed the presence of deep water corals on sediments, crusts and rock outcrops, in the Greek Ionian Sea at depths of 400-800 m (Mytilineou *et al.* 2011; Smith *et al.* 2010, 2011).
- Submarine structures formed by leaking gases: A number of marine seismic surveys in the past have revealed the presence of gas seeps from benthic sediments in the study area. Geophysical studies in the Patraikos Gulf by Hasiotis *et al*. (1996), and in Elaiona Bay and Aigio, in the south-western part of the Korinthiakos Gulf, by Soter (1999), Papatheodorou *et al*. (2002), and Trombouki (2005) have identified the presence of three pockmark fields.
- Cetaceans: Spatial distribution of all cetacean species is based on habitat/area use produced from presence data gathered by means of systematic field surveys and cetacean strandings during the last 15 years (Frantzis & Herzing 2002; Frantzis & Alexiadou, 2003; Frantzis *et al.*, 2003; Frantzis, 2009).
- Mediterranean monk seals: The spatial distribution of the species is based on habitat/area use produced from data gathered by (a) systematic and sporadic habitat use surveys and mapping of seal sightings during the period 1985-1998 (Jacobs & Panou, 1988, 1996; Panou *et al*., 1993; Panou, 1998), (b) mapping of seal sightings during the period 2007-2008 (Panou, 2009) and (c) collection of seal sightings mainly through the local port police authorities (MOM, 2009). The critical habitat for the species was defined as the area located between the coastline and the 200 m isobath, having considered the coastal habits of seals, their home range and the maximum depth they are known to be able to dive at in search of food (127m, Dendrinos *et al.,* 2007).
- Loggerhead turtles: Data consist of information regarding the location and extent of the species' nesting beaches, as provided by the Management Body of the National Marine Park of Zakynthos (NMPZ).
- Seabirds: Marine Important Bird Areas (Marine IBAs) were based on preliminary results from seabird colony data, boat-based, at-sea, seabird recording and telemetry surveys carried out under LIFE Project "Concrete conservation actions for the Mediterranean Shag and Audouin's gull in Greece, including the inventory of relevant marine IBAs", LIFE07 NAT/GR/000285, 2009-2012 and the "Survey and Conservation of Seabirds in Greece", 2007-2010, project.
- Seahorses: The only distribution and abundance data available for the entire study area come from a specific site in the eastern Korinthiakos Gulf where thriving populations of both the short-snouted seahorse *Hippocampus hippocampus* and the long-snouted seahorse *H. guttulatus* exist (Issaris, unpublished data), but it is believed that both species are present at many other coastal sites of the wider marine area.
- Fan mussel: Spatial distribution of the species in the area is based on a critical compilation of relevant literature (e.g. Katsanevakis *et al*., 2008), reports, unpublished data, and personal observations of experts.
- Gold coral: Their spatial distribution has been estimated from scattered preliminary studies (Salomidi *et al*., 2006, 2009, 2010) and expert judgement.
- European hake nursery grounds: The European hake *Merluccius merluccius* is one of the main target species of demersal fisheries. Its nursery grounds were investigated using experimental bottom trawl survey data (MEDITS) during the period 1998-2008. Details on the sampling protocol for the MEDITS surveys are described by Bertrand *et al*. (2000). The MEDITS survey stations are widely distributed in the study area and have a relatively high density. Catch rates (expressed as catch per unit of effort km^{-2}) of juvenile hakes were modelled as a function of Latitude, Longitude, Year, and Depth, applying Generalized Additive Modelling techniques (GAM). GAM outcomes generated hake nursery grounds in high spatial resolution, covering the entire study area. We considered all young-of-the-year specimens as juveniles. According to the most recent age & growth estimates for the region, this corresponds to fish of less than 100 mm in total length. Spatial estimations of catch rates were derived in the form of gridded matrices for the entire study area, with a spatial resolution of 100 m x 100 m. The map layer produced was based on cells with catch rates of juvenile hakes > 200 per km^2.
- Fishing activity: According to the fleet register, 1959 fishing vessels have been recorded in 23 ports within the study area (23 trawlers, 30 purse seiners, and 1906 coastal fishing vessels using static nets and long lines). Fishing activity was divided into three sectors: trawlers, purse seiners and small-scale coastal fisheries that nets or long-lines. The spatial distribution of the trawler and purse seiner fleets was analyzed using

data from a GPS vessel monitoring system (VMS) operating on board fishing vessels, which at regular intervals (2h) provides data to the fisheries authorities on the location, course and speed of vessels[1]. For this study, VMS data provided by the Hellenic Ministry of Maritime Affairs, Islands and Fisheries (October 2008 until May 2011) were used to estimate the fishing effort, expressed in number of fishing days (days at sea) per year. For trawlers, it was assumed that records with speeds between 0 and 4.5 knots correspond to fishing, while those with records > 4.5 knots correspond to steaming and were excluded. For purse seiners, it was assumed that each vessel performs one haul per day. Based on the above, one signal per day and per vessel has been selected having a recorded speed of zero. To estimate the fishing pressure of small-scale fisheries, a multi-criteria decision analysis has been applied, mainly based on expert opinion. The criteria used included: depth (based on the assumption that the fishing pressure is greater in shallower waters); banning period for trawlers (it varies in the study area, and affects the activity of the coastal fleet; when trawlers are banned, small-scale fisheries are generally more active); fishing effort of trawlers (it is negatively correlated to the fishing effort of the coastal fleet); distance from coast (the fishing effort of small-scale fisheries is reduced with the distance from the coast); fleet distribution (based mainly on the distribution and capacity of fishing ports; the larger the fleet in a locality, the larger the fishing effort).

- Aquaculture: Point distribution of aquaculture farms within the study area was produced using Google Earth satellite images as a reference. Recently, Google Earth has proven to be a valuable scientific tool for confirming fish farming capacity in the Mediterranean Sea (Trujillo *et al.,* 2012). The number and the size of each cage in each aquaculture farm was measured within the Google Earth environment and by using the approximate depth of each cage (derived from the type and size of the cages), the total volume of the farm was estimated. Additionally, each farm's capacity was calculated, based on the total farm volume and the mean fish density.
- Urban development: Population density patterns in the coastal areas surrounding the case study area were mapped based on 2012 population census of EL.STAT. (Hellenic Statistical Authority).
- Industry: The major industry in the area affecting the marine environment is an industrial plant (Aluminium of Greece S.A.) located on the north-eastern coast of the Korinthiakos Gulf, which produces aluminium from bauxite ores, and discards residues known as "red mud". For several decades, red mud had been directly disposed in the Korinthiakos Gulf through underwater pipelines. This practice was recently stopped but a large part of the seabed has already been covered. The affected area was mapped based on systematic geophysical survey, sampling and visual observation of the seabed performed three times during the last decade (HCMR data).
- The analysis of the tourism sector was mainly based on the General Framework Plan for Sustainable Tourism Spatial Planning in Greece (MEECC, 2009) and on the supply of recreational services provided in the marine environment such as yachting, sailing, swimming and diving.
- Marinas: Boating activity was based on the existence of marinas along the coastal area according to the recent Greek National Tourism Organization (GNTO, 2011) data.
  - Blue flags: Blue Flags are used to indicate the well-organized beaches of the case study, which comply with the appropriate criteria and requirements of the Blue Flag accreditation system (FEE, 2012). Data were obtained from the Hellenic Society for the Protection of Nature, the official representative of Blue Flags accreditation of the EU for Greece (HSPN, 2011).
  - Diving centres: The list of diving centres operating in the area was acquired from the relevant online database of the Hellenic Association of Recreational Divers "Tethys" (TETHYS, 2011).
  - Spatial Management Plan for Tourism: This is a 15-year Action Plan that aims to provide clear rules for spatial planning, organization and development of tourism in Greece (MEECC, 2009). In this respect, it paves the way towards improving the competitiveness of the tourism product, sustainable use of resources, as well as spatial planning and development for tourism accommodation units and enterprises. The Management Plan categorizes Greek areas according to the viability and dynamics of tourism in each area, the contribution of the tourism industry to the local economy and the existing tourism market in each case.

Data quality assessment

In order to communicate the soundness of scientific knowledge, qualitative strategies have been developed. One of these approaches includes a qualitative assessment of semi-quantitative data indicators based on a pedigree matrix that describes those aspects of data quality influencing the reliability of the overall result, developed by Pedersen Weidema & Wesnaes (1996).

In our case, the specific pedigree matrix has been modified in order to help specify the reliability, completeness, temporal correlation, geographical correlation and data collection process quality of the ecosystem

1. According to the Regulation of the European Commission EC/2244/2003, fishing vessels >15 meters in total length are obliged to be equipped with VMS.

Table 2: Modified pedigree matrix used for the assessment of the semi-quantitative indicators in our case study.

Indicator Score	1	2	3	4	5
Reliability	Measured Data	Verified data partly based on assumptions	Non-verified data partly based on qualified estimates	Qualified estimate (e.g. by scientific expert)	Non-qualified estimate
Completeness	Representative data from all sites relevant for the study area considered over an adequate period to even out normal fluctuations	Representative data from >50% of the sites relevant for the study area considered over an adequate period to even out normal fluctuations	Representative data from only some sites (<50%) relevant for the study area considered OR >50% of sites but from shorter periods	Representative data from only one site relevant for the study area considered OR some sites but from shorter periods	Representa-tiveness unknown or data from a small number of sites AND/ OR from shorter periods
Temporal correlation	Less than 3 years of difference to year of study	Less than 6 years difference	Less than 10 years difference	Less than 15 years difference	Age of data unknown or more than 15 years of difference
Geographical correlation	Data from area under study	Average data from larger area in which the area under study is included	Data from area with similar environmental conditions	Data from area with slightly similar environmental conditions	Data from unknown area or area with very different environmental conditions
Data collection process quality	Data from targeted research conducted by the team involved in the case study	Data from targeted research conducted by other teams not involved in the case study	Data from targeted research conducted with different methodologies	Data from common research conducted with a standard methodology	Data from common research conducted with different methodologies

components (Table 2). Each characteristic is divided into five quality levels with a score between 1 (high quality) and 5 (low quality). The "reliability" indicator relates to the sources, the acquisition methods and verification procedures used to obtain the data. The "completeness" indicator relates to the statistical properties of the data: how representative is the sample, whether the sample includes a sufficient number of data and/or whether the period is adequate to even out normal fluctuations. The "temporal correlation" indicator represents the time correlation between the year of study and the year the data were obtained. The "geographical correlation" indicator illustrates the geographical correlation between the defined area and the location of origin of the data used. Finally, the "data collection process quality" indicator refers to the collection process of the data.

The data quality indicators refer to the origin of the data in the same way as a genealogical table reports the pedigree of an individual. The pedigree matrix can serve as a data quality management tool through which the analyst can survey the data quality, find sources of uncertainty and point out improvements in data quality (Maxim & van der Sluijs, 2011). The quality indicators used are mainly meant to provide guidance in attributing scores to each of the criteria. Therefore, a pedigree matrix should be implemented in a flexible and creative way. As mentioned above, the scores in the pedigree matrix are 'semi-quantitative', but this is actually a qualitative way to assess quality assessment (and therefore the inherent bias) and to indicate, in a transparent way, where there might be a problem. Such being the case, ecosystem components with high scores should be accounted for more cautiously.

Results

Ecosystem and socioeconomic components

Distribution patterns for the respective ecosystem and socioeconomic components are presented below, along with detailed maps, providing a general view of the system under study:

- *Posidonia oceanica* meadows: The meadows are found along most of the coastline in the study area, restricted to shallow waters of less than 45m in depth. They occur to a greater extent in the Ionian Sea where the depth gradient develops gradually and to a lesser extent in the Korinthiakos Gulf where the bottom profile is generally steeper (Fig. 2).
- Coralligenous and deep corals: Three major sites of interest have been identified, the first one in the deep Ionian waters (400-800 m) featuring the cold-corals *Antipathes dichotoma*, *Antipathella subpinnata*, *Desmophyllum dianthus* and *Leiopathes glaberrima*, and another two areas along the southern coast of the Korinthiakos Gulf, where steep rocky cliffs extending to depths often greater than 200 m favour the development

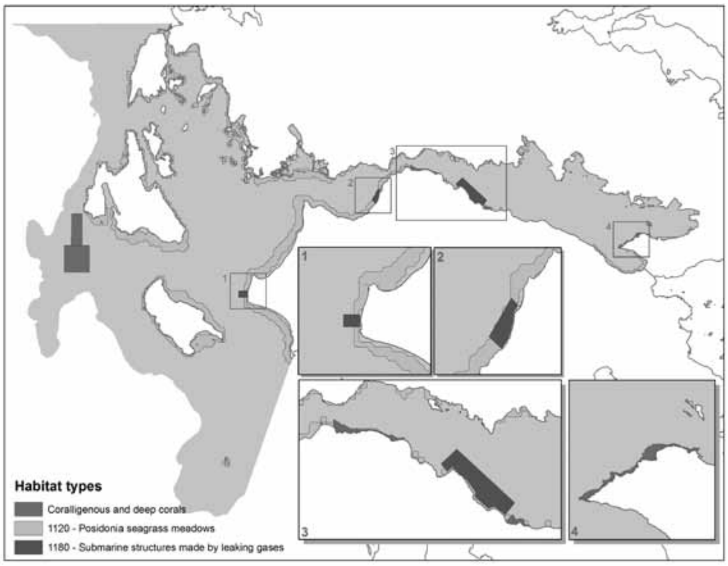

Fig. 2: Spatial distribution and extent of habitat types targeted for conservation.

of typical coralligenous assemblages some of which host rich gorgonian and gold coral facies (Fig. 2). It is expected that more records of coralligenous and deep corals will be obtained with increasing scientific effort within the study area.

- <u>Submarine structures formed by leaking gases</u>: Three sites of interest have so far been identified within the study area; one in the inner Ionian Archipelago, one in the Patraikos Gulf and one in the Korinthiakos Gulf (Fig. 2). These sites have been characterized as cold seeps but only the site in the Korinthiakos Gulf has been studied for the presence of typical assemblages associated with this habitat type.
- <u>Cetaceans</u>: Essential habitats for both coastal and pelagic cetaceans exist in the study area. As a general rule, the common bottlenose dolphin occupies all the waters in depths up to 200 m. Nevertheless, this species seems to be absent in a large part of the south and south-western inner Ionian Archipelagos, between the islands and the mainland. In the Korinthiakos Gulf, it is limited to the shallower, western and half north-western parts (Fig. 3). There are two separate and ecologically different populations of common dolphin in the study area. The "coastal" population occupies the shallow waters of the inner Ionian Archipelagos between Lefkada and Kefallonia Islands and the mainland, as well as the shallow south and south-western coastal waters of Zakynthos Island (Fig. 3). Until 2003, this population covered the entire area, north of the line between the south-western part of Lefkada Island and the southern part of Kastos Island; however, after a dramatic decline, the few individuals left seem to have limited their range to the southern part of Lefkada Island (Bearzi *et al*., 2008). Very recent data indicate that the remaining individuals of this species may still be trying to expand their presence to their previous range (Tethys

Fig. 3: Spatial distribution of cetaceans in the study area.

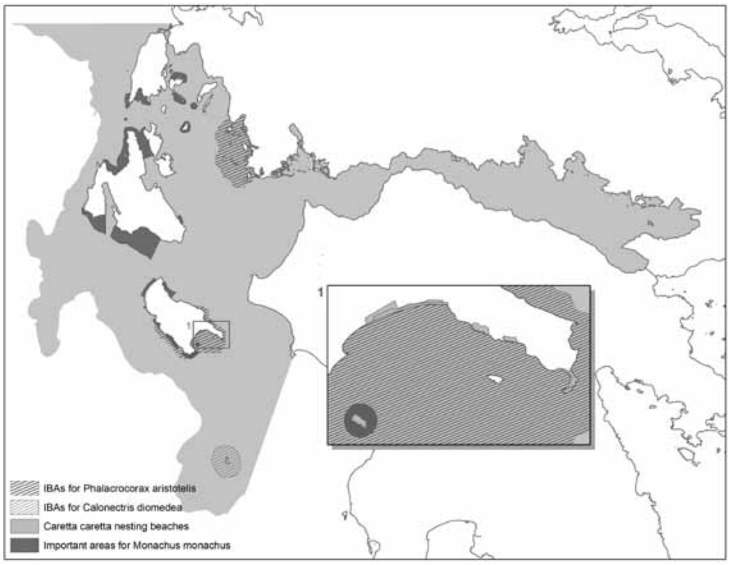

Fig. 4: Important areas for seabirds, monk seals and loggerhead sea turtles.

Research Institute, unpublished data). The “pelagic” population of this species inhabits the deep waters of the Korinthiakos Gulf above depths of 200-900 m, sharing the same habitat and living in common mixed pods with a purely pelagic dolphin species, the striped dolphin (Fig. 3). The striped dolphin is absent from the entire shallow inner Ionian Archipelagos, and is present in all the offshore Ionian waters above depths of > 200 m (Fig. 3). The two deep diving cetacean species inhabiting the study area are Cuvier’s beaked whale and the sperm whale. They both occupy the waters above the continental slope, especially close to the 1000 m bathymetric contour and further offshore (Fig. 3).

- <u>Mediterranean monk seal</u>: Important sites for the conservation of the monk seal have been identified in the islands of the Ionian Sea, mostly associated with the existence of marine caves suitable for the reproduction and resting of the species along the coastline (Fig. 4). The coasts of the Patraikos and the Korinthiakos Gulfs as well as the coast of the western Peloponnese have not been thoroughly surveyed but sporadic sightings of the species have been recorded. However, the shores along the western Peloponnese are mostly sandy beaches; hence they do not favour the presence of monk seals. Furthermore, it is estimated that human disturbance is high within the semi-enclosed Gulfs, again not favouring the presence of seals. The important sites for the species, depicted in figure 4, represent the extent and not the importance of the critical areas.
- <u>Loggerhead turtle nesting beaches</u>: Major nesting sites –among the most important in the Mediterranean Sea– are found within the NMPZ (National Marine Park of Zaktnthos), Laganas Bay, Zakynthos Island (Fig. 4), although a few other minor nesting sites occur in other Ionian islands.
- <u>Seabirds</u>: One marine IBA for Cory’s shearwater and two IBAs for the Mediterranean shag have been identified, all located in the Ionian Sea (Fig. 4).
- <u>Seahorses</u>: One site of high abundance of the short-snouted seahorse and the long-snouted seahorse has been identified in the Korinthiakos Gulf. This information is preliminary since the distribution of both seahorse species in the study area is largely unknown (Fig. 5). The two species are probably abundant in other locations as well, but no information is available.
- <u>Fan mussel</u>: Various important areas for the conservation of the fan mussel that currently sustain a high abundance of the species have been identified in coastal waters throughout the study area, although a targeted survey might help to identify many more such areas (Fig. 5).
- <u>Gold coral</u>: The rare gold coral has been detected within at least two coralligenous sites in the Korinthiakos Gulf, forming at places spectacular facies (Fig. 5). These areas are not conclusive, because the full extent of coralligenous habitats has not yet been mapped in the study area. More records of this species are expected with increasing scientific survey effort.
- <u>European hake nursery grounds</u>: *Merluccius merluccius* nursery grounds are mainly confined to the inner Ionian Archipelago, while a relatively small area is also present in the Patraikos Gulf (Fig. 5). All nursery areas are situated in front of major river mouths.
- <u>Fishing activity</u>: The fishing effort of small-scale fisheries is widely distributed within the shallow waters of most of the study area (Fig. 6). The purse seiners’ effort is mainly focused on the eastern part of the Inner Ionian Archipelago and the southern part of the Patraikos Gulf (Fig. 7), while trawling effort is concentrated in the southern part of the inner Ionian Archipelago, as well as in the Patraikos and the Korinthiakos Gulfs (Fig. 8).

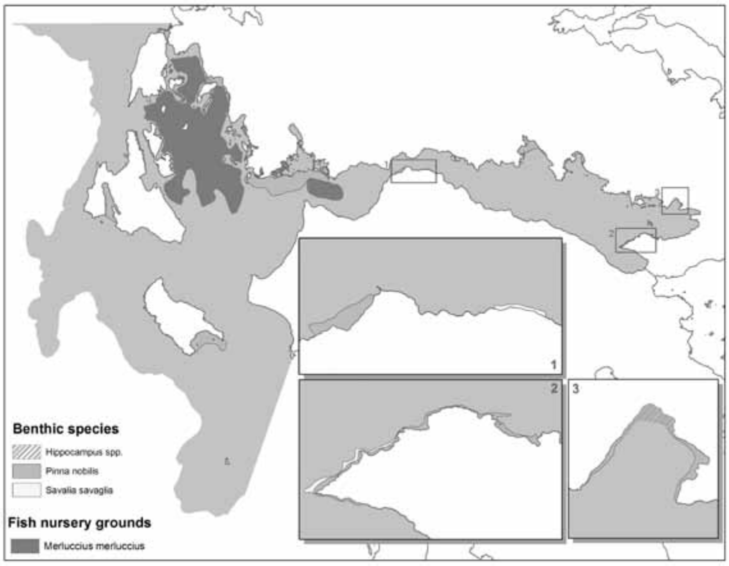

Fig. 5: Spatial distribution of benthic species of special conservation interest and European hake nursery grounds.

- Aquaculture: Aquaculture farms are mainly found in the north-western part of the study area - Ionian Sea - around the north-western coastline of mainland Greece and around the island of Kefalonia in particular, as well as along the northern coastline of the Korinthiakos Gulf. In contrast, no aquaculture farms exist along the southern coastline of the Korinthiakos Gulf or around the islands of Zakynthos and Lefkada. The biggest farms in terms of capacity are located in the Ionian Sea (Fig. 9).
- Urban development: Population is evidently concentrated along the coastline of the study area, with a few exceptions (Fig. 9).
- Industry: The area of the sea bottom affected by the former deposition of red mud by Aluminium of Greece S.A. is situated in the central Korinthiakos Gulf (Fig. 9).
- Tourism:
  - Marinas: Seven marinas officially designated for leisure boats are present in the wider study area, one in the Korinthiakos Gulf, two in the Patraikos Gulf and five in the Ionian Sea (Fig. 10). However, it should be stressed that leisure boats often use small fishing ports or even bays without human settlements.
  - Blue flags: Blue flags indicating beaches used for tourism are distributed throughout the study area (Fig. 10).
  - Diving centres: Diving centres are present throughout the area, although most of them are situated on the three large islands of the study area, in the Ionian Sea (Zakynthos, Kefalonia, and Lefkada islands) (Fig. 10).

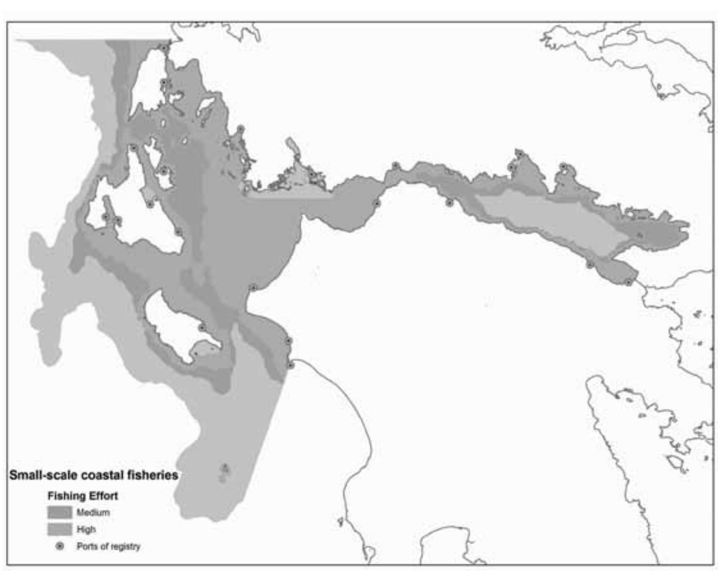

Fig. 6: Fishing effort of small-scale coastal fisheries fleet.

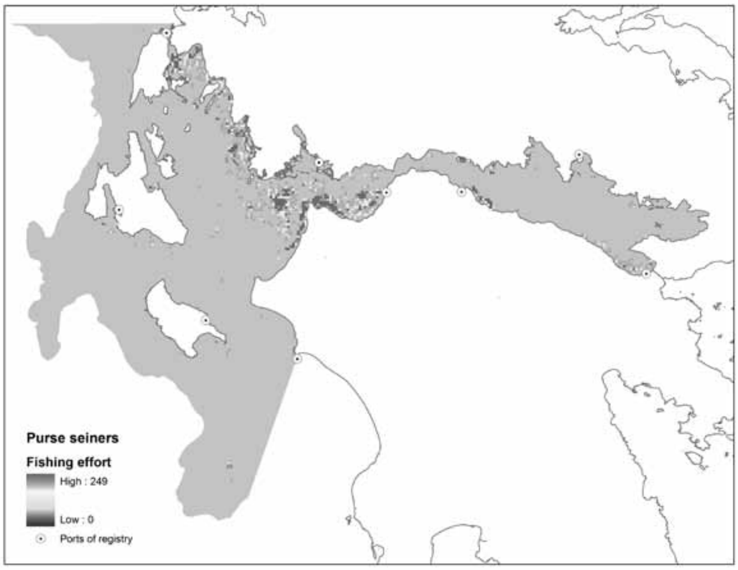

Fig. 7: Fishing effort of purse seiners fleet.

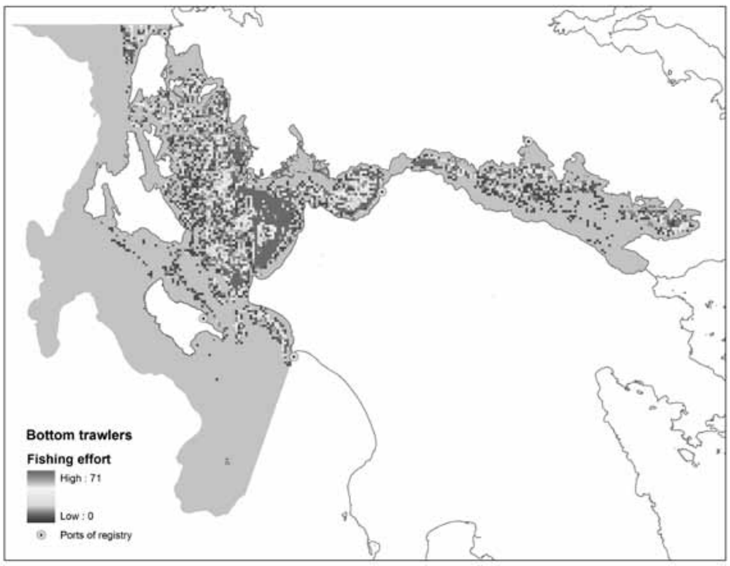

Fig. 8: Fishing effort of bottom trawling fleet.

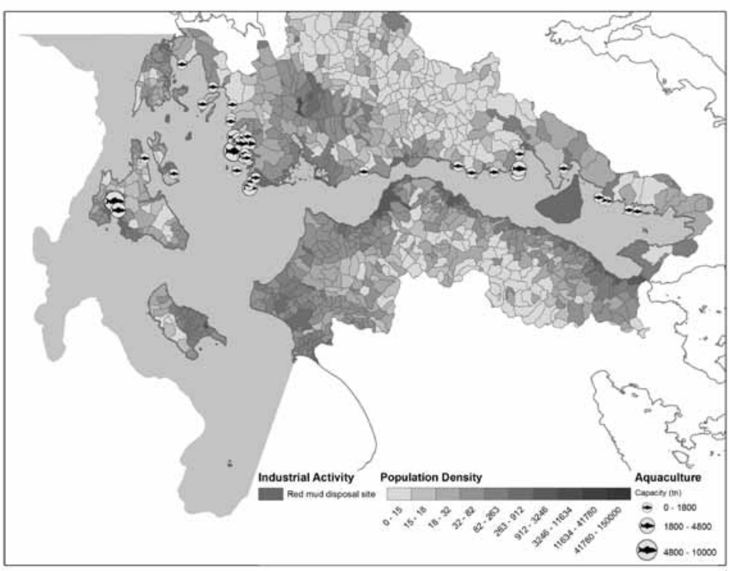

Fig. 9: Aquaculture, urban development and industrial waste.

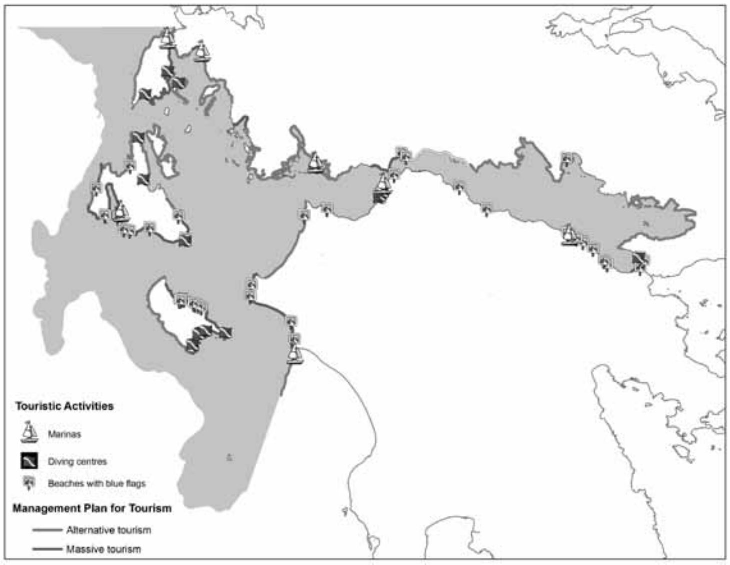

Fig. 10: Existing touristic activities and future touristic development plans.

❍ Spatial Management Plan for Tourism: Although most of the Ionian Islands are included in the tourism development plan, plans for the development of tourism in the study area are focused mainly on the development of alternative tourism.

Data quality assessment

An evaluative account of different qualitative aspects of the data (Funtowicz & Ravetz, 1990) describing the environmental components has been attempted using the modified pedigree matrix presented above (Table 2). The attributing scores for each of the qualitative criteria used are presented in Table 3.

The pedigree matrix reveals that the weakest indicators of the data under study were: completeness and data collection process quality, since quite a small number of ecosystem components were scored with high values for these attributes. Obviously, for the relevant ecosystem components, the representativeness of their samples and the different methodologies applied to research should be taken into consideration in decision-making. However, the strongest indicators were temporal and geographical correlation, underlining that the study was based mainly on recent data obtained from the study area.

Finally, in an attempt to visualize the qualitative information gained from implementation of the pedigree matrix, radar diagrams were produced (Fig. 11), presenting each indicator's score for every ecological component. From the study of the aforementioned radar diagrams, one can conclude that data corresponding to the following ecosystem and socioeconomic components: coralligenous and deep corals, fan mussel, gold coral and small-scale fisheries, exhibited low quality assurance (high uncertainty) mainly due to the lack of completeness or to low data collection process quality. On the other hand, the ecosystem

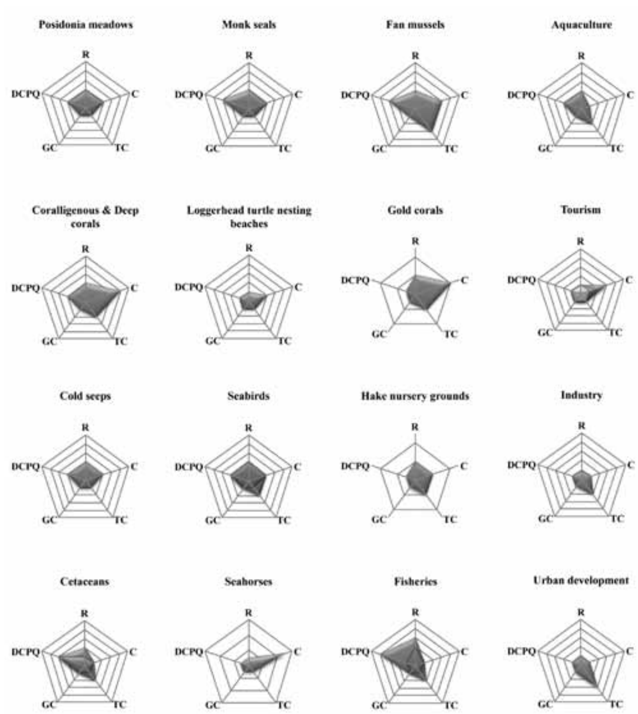

Fig. 11: Radar diagrams for the ecosystem and socioeconomic components, showing the scores for each indicator (R: Reliability, C: Completeness, TC: Temporal correlation, GC: Geographical correlation and DCPQ: Data collection process quality). For the ecosystem component: Tourism, the blue pentagon corresponds to marinas, the red pentagon to diving centres and the green to blue flags. For the ecosystem component: Seabirds, the red pentagon corresponds to the species *C. diomedea* and the blue to the species *P. aristotelis desmarestii*. For the ecosystem component: Cetaceans, the red pentagon corresponds to the species *P. catodon, Z. cavirostris, T. truncatus,* & *S. coeruleoalba* and the blue to the species *D. delphis*. For the ecosystem component: Fisheries, the blue pentagon corresponds to the coastal fleet and the red corresponds to the purse seiners & trawlers fleet.

Table 3: Pedigree matrix presenting the corresponding scores of each data quality indicator for all ecosystem components.

Data		Reliability	Completeness	Temporal correlation	Geographical correlation	Data collection process quality
Posidonia meadows		2	2	1	1	2
Coralligenous and deep corals		2	4	2	1	2
Cold seeps		2	2	1	1	2
Cetaceans	Delphinus delphis	2	1	2	1	3
	Physeter catodon	1	1	1	1	3
	Ziphius cavirostris	1	1	1	1	3
	Tursiops truncatus	1	1	1	1	3
	Stenella coeruleoalba	1	1	1	1	3
Monk seals		2	2	1	1	3
Loggerhead turtle nesting beaches		1	2	1	1	1
Seabirds	Calonectris diomedea	2	2	1	1	2
	Phalacrocorax aristotelis desmarestii	2	2	2	1	2
Seahorses		1	5	1	1	1
Fan mussels		2	3	3	1	3
Gold corals		2	4	2	1	1
Hake nursery grounds		2	2	2	1	1
Fisheries	Trawlers	2	1	1	1	1
	Purse seiners	2	1	1	1	1
	Coastal	3	1	2	1	4
Aquaculture		2	1	2	1	2
Tourism	Marinas	1	3	1	1	1
	Blue flags	1	1	1	1	1
	Diving centres	1	2	1	1	1
Industry		1	1	2	1	1
Urban development		1	1	3	1	1

and socioeconomic components: loggerhead turtle nesting beaches, trawlers, purse seiners, industry, and tourism (blue flags and diving centres), exhibited high quality assurance and therefore low uncertainty.

Discussion

This study constitutes the first effort to accumulate and combine all available ecological and socioeconomic information referring to a highly valuable ecological region in the Mediterranean (CIESM, 2011). The study area includes one of the most crucial nesting sites for the critically endangered loggerhead turtle, it hosts a large population of the critically endangered Mediterranean monk seal, and has been suggested by the 3rd Meeting of the Parties of ACCOBAMS as the only area of special importance proposed for an MPA for the Mediterranean sperm whale (ACCOBAMS, 2007). Furthermore, both the northern Inner Ionian Archipelago and the Korinthiakos Gulf have been proposed as MPAs for the endangered common dolphin. Our study area encompasses –some fully, others partly– three of the fourteen MPAs proposed by ACCOBAMS for the protection of cetaceans in the Mediterranean Sea. Therefore, this study should be considered as a baseline, upon which future scientific efforts should build.

As highlighted by mapping in the study area, ecosystem components and human activities often compete for the same marine space. There is a sizeable overlap between important conservation areas for the monk seal, the common dolphin, the bottlenose dolphin on the one hand, and fishing grounds for small-scale fisheries on the other hand, as well as between important areas (nesting beaches) for the loggerhead turtle and massive tourism (in the National Marine Park of Zakynthos), but also between grounds shared by the various fisheries sectors (mainly between trawlers and small-scale fisheries).

A well-documented case is the interaction between the highly endangered Mediterranean monk seal and small-scale fisheries in the study area. Monk seals damage the gear used while feeding on fish and octopus caught by all types of static nets, and also by bottom long lines (only beach seines are not affected). Quantitative and qualitative data on catch losses per unit of effort and gross production due to seal damage on an experimental trammel net revealed a drastic reduction of 67% and 80% respectively with accumulating seal damage, while the reduction was even more severe for catches of mullets alone (*Mullus surmuletus* and *M. barbatus*), the preferred prey of seals and -at the same time- the most valuable catch and main source of income for coastal fishermen(Panou, 1998). Seal damage and the associated loss of income is the main reason for deliberate killings of seals by fishermen and other coastal inhabitants throughout Greece. Information obtained through questionnaires answered by local fishermen in the study area during specific targeted studies, revealed that in 85% of known cases of dead seals the cause of death was either deliberate killing or accidental death in fishing gear (Cebrian & Vlachoutsikou, 1993; Karavellas, 1995; Jacobs & Panou, 1996; Panou, 1998).

Sea turtles are also affected by fisheries through incidental catches by all types of gear and through the reduction of prey availability due to overfishing. A study of incidental catches of loggerhead turtles in surface long lines used for catching swordfish in the entire Ionian Sea (1989-1995) revealed a catch frequency of 18.1% of the fishing trips performed, while 7.7 turtles were caught per year and vessel with 77% of the animals being small-sized or subadult (Panou *et al*., 1999).

Another well documented conflict in the form of resource overlap between socioeconomic and ecosystem components in the study area is the population decline of the common dolphin in the Inner Ionian Archipelago, between the islands of Lefkada and Kastos and mainland Greece. About 150 common dolphins were present in 1996, but after 10 years of gradual population shrinking, only 15 animals had remained in 2007 (Bearzi *et al*., 2008). Bearzi *et al.* (2008) carried out a subsequent assessment of fishing effort and catch and suggested that the decline was largely caused by prey depletion due to overfishing, especially by local purse seiners and beach seiners.

A recent study for the evaluation of seabird by-catch mortality in the Southern Ionian Sea, based on an interview-orientated methodological approach, showed that commercial longlines and to a lesser extent gillnets cause incidental catches mostly of Cory's shearwater and the Mediterranean shag (Karris et al., 2012). More specifically, the estimated annual incidental mortality of 6.3 Mediterranean shags in bottom longlines and nets represents approximately 3.0-5.1% of the 31-53 pairs breeding in the southern and central Ionian Sea (Hellenic Ornithological Society, unpublished data). Similarly, 495 Cory's shearwaters were estimated to be caught in longlines, a number of birds that represents 1.7-2.0% of their local population, since the Strofades Islands host 5,000-6,000 breeding pairs (Karris *et al*., 2009).

The necessity of an integrated approach to management, such as EB-MSM, appears to be the only way to effectively mitigate such conflicts for marine space and resources and achieve sustainability of marine ecosystems and their services to humans. An important aspect when applying EB-MSM is the assessment of the credibility of the scientific approaches used in decision-making, taking into consideration the uncertainty of the final results (van der Sluijs, 2002). The process of uncertainty analysis not only helps in the identification of knowledge gaps, but it can also increase the decision-makers' confidence in the robustness of scientific results, strengthen stakeholders' and public confidence in science and further improve the quality of decisions (Maxim & van der Sluijs, 2011). There are multiple types and sources of uncertainty that one should take into account in environmental decision-making, such as knowledge uncertainty, variability uncertainty and linguistic uncertainty (Ascough II *et al*., 2008). Here, we dealt only with knowledge uncertainty and specifically with data/parameter uncertainty.

The results of the data quality assessment indicated that the sampling effort was not evenly distributed throughout the study area; thus for many ecosystem components the accuracy of the final maps is hindered by lack of completeness in the data collection process. In terms of data reliability and specifically for small-scale fisheries, it should be stated that the frequent use of expert judgment in the analysis process along with low data collection process quality constitute further sources of unmeasured bias. However, it should be noted that the geographical and temporal correlation of the overall ecosystem components exhibited high quality assurance.

Our findings highlight the need for more targeted surveys for specific species and habitat types, especially at the understudied sites of the study area. Nevertheless, the rapid degradation of marine ecosystems dictates the urgent need for management measures that can be modified at a later date through adaptive management, upon acquisition of new information (Katsanevakis *et al*., 2011; Parravicini *et al*., 2012). In general, adaptive management incorporates initial uncertainty, treats decisions as hypotheses to be tested, and demands that managers learn from the consequences of their decisions and alter them (or implement new ones) accordingly (Ascough II *et al*., 2008; Parravicini *et al*., 2012). The lack of high quality spatial information cannot be an excuse for non-action, especially when crucially endangered species and habitats are at stake.

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