ECOLOGICAL EFFECTS OF MARINE PROTECTED AREAS

EMPAFISH PROJECT BOOKLET Nº1

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Project nº SSP8-006539
EMPAFISH
European Marine Protected Areas as tools for Fisheries management and conservation

Specific Programme “Integrating and strengthening the ERA” (6th Framework Programme), under the activity “Scientific Support to Policies” and the research priority for “Modernisation and sustainability of fisheries, including aquaculture-based production system”

Ecological effects of Atlanto-Mediterranean Marine Protected Areas in the European Union

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Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Contents

Forewords

Marine Protected Areas (MPAs) are critically important to the conservation of marine biodiversity and ecological processes and to achieving a sound basis for sustainable use and development of marine environments and resources. This is clearly reflected in the statement from World Summit on Sustainable Development (Johannesburg): "*MPAs are the key to achieving at least 10% of each of the world's ecological regions effectively conserved - the target established at the 6th Conference of Parties to the Convention on Biodiversity*". At the same time, it is widely considered that MPAs can make a significant contribution to regional economic development and to improving the well-being of local communities. Fisheries are one of the main threats to marine biodiversity and ecological processes and MPAs are therefore important for conserving ecosystem services provided by the sea and sustaining tourism that depends on these. By restricting damaging activities, MPAs offer protection for marine natural resources and provide them with critical habitats they need at key times, e.g. for breeding or feeding. MPAs benefit species and habitats of regional interest and may also help to avoid or at least limit the deleterious effects of non-sustainable uses and activities, including pollution and other sources of degradation, in favour of the local economy.

However, MPAs, by definition, protect only a defined area and there is a risk that damaging activities may be intensified or inadequately controlled in areas outside the MPA. Establishment of MPAs should therefore be part of a wider strategy for managing marine resources with clearly defined objectives. Effective management of a complex ecosystem under human pressure is not possible without science. The natural sciences are needed to understand the functioning of the ecosystem. MPAs have to be selected, designed, managed and networked in such a way to ensure the maintenance of ecological processes to sustain ecosystem functioning (e.g. connectivity through adult movement and larval dispersal of marine species, habitat representation and replication, preservation of spawning aggregations, recruitment and nursery grounds). Since the first MPA was declared in the Mediterranean, more than 40 years ago (Parc national de Port-Cros, France), a great deal of research has been conducted to describe, characterize and model the ecological effects of protection from fisheries.

The EMPAFISH project (European Marine Protected Areas as tools for FISHeries management and conservation), supported by the European Commission, has as general objectives: 1) to investigate the potential of different regimes of MPAs in Europe as measures to protect sensitive and endangered species, habitats and ecosystems from the effects of fishing; 2) to develop quantitative methods to assess the effects of marine protected areas and 3) to provide the EU with a set of integrated measures and policy proposals for the implementation of MPAs as fisheries and ecosystem management tools. The first step to reach these objectives is to know the ecological processes involved in the functioning of a MPA and to understand how ecological networks and relationships between species within an ecosystem reorganize after protection from fishing. From the fisheries point of view, there is an urgent need to know how the behavioural and population responses of individual species and ecological interactions among species may translate into recruitment subsidy and 'spillover', which in turn may lead to sustained or enhanced fishery yield in the surrounding region. This cannot be done without well-designed scientific research. Within the EMPAFISH consortium, the 20 case studies included have been the subject of detailed, long-term research.

The general objective of EMPAFISH Work Package 1 (WP1: "Ecological effects of Marine Protected Areas") is to identify and quantify ecological effects of MPAs and to organise the findings in a database for subsequent global meta-analysis and modelling. This booklet constitutes deliverable nº 3 of the EMPAFISH project, under WP1. The present document begins with a brief overview of the ecological processes important for conservation and what are, generally speaking, the expected ecological effects of MPAs. The core of the document is devoted to descriptions of the research done to date at each EMPAFISH case study site to document and understand the ecological effects of protection measures. In chapter 4, a summary of former EC FP5 research project BIOMEX is included; in this project, a consortium of 9 labs (most of them included in EMPAFISH) collected data on 5 out of the 20 cases studies included in EMPAFISH (plus one, Cabrera Archipelago National Park, not included) in order to estimate spillover from MPAs to neighbouring unprotected areas. The majority of these data (using visual census, baited video, ichthyoplankton surveys, and both experimental and onboard commercial fisheries) are to be used within EMPAFISH. Finally, a succinct summary of data available for first analyses within the WP1 is done in chapter 5, including a brief description of new data collected in the framework of EMPAFISH. The bibliography incorporated at the end of this document gives an updated list of articles/references on all ecological studies at the 20 case study sites included in the EMPAFISH project.

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WP1 leader	Researcher	Coordinator

1 Ecological processes important for marine protection

1.1 Ecological features of marine ecosystems affecting the biodiversity - ecosystem functioning relationship

A number of characteristics distinguish marine from terrestrial ecosystems, regarding the aspects affecting the biodiversity–ecosystem functioning relationship (Carr *et al.* 2003; Giller *et al.* 2004). Probably the most fundamental feature of the marine realm is the prevalence of the aquatic environment in which the organisms live. The properties of seawater determine the physical and chemical features of marine ecosystems, and ecosystem functioning is often forced by physical variations. Environmental gradients are frequently very sharp (especially in coastal areas). The aquatic environment facilitates the assimilation and transformation of materials by marine organisms. The faster rates of transfer across membranes and of transformation of nutrients and energy make bio-geochemical dynamics more active and turnover consequently tends to be higher in the sea than in terrestrial ecosystems. Most primary producers are small in size, and are highly dependent on the combined influence of hydrodynamics (e.g. diffusion, turbulence, advection), locally forced by upwellings, vertical mixing due to wind action, and sedimentation (gravitational).

Microorganisms play a fundamental role in the functioning of marine ecosystems, especially regarding the importance of the “microbial loop”, which permits part of the primary production initially lost from the “classical” pathway from phytoplankton to suspension-feeding herbivores to re-enter the food chain. Some functional groups only exist in the sea (e.g. filterers). Predation is often size-dependent in the aquatic environment. Also, “cascade effects”, or systems with “top-down” control are much more frequent in marine ecosystems.

Barriers to dispersal are typically weak, so that materials and energy fluxes are relatively fast within and between habitats. Habitat patches can be quickly recolonized by recruits after local disturbance or extinction events. In addition, the physical nature of aquatic environments and hydrological processes assure strong inter-connections among different domains of the ecosystem (e.g. between benthic and pelagic realms), or different habitats (e.g. among seagrass meadows, rocky reefs and coastal lagoons) at various spatial and temporal scales. In summary, marine systems are generally more “open” than terrestrial ones. The mosaic of marine habitat patches is often more compact than in terrestrial environments, and makes it easier to carry out experiments at the landscape (or seascape) scale.

1.2 Marine connectivity

The predominance of external fertilization in marine organisms and the production of a huge number of extremely small and highly dispersive propagules mean that exchange of organisms among local subpopulations through the dispersion of eggs and/or larvae, and the migration of subadults and adults, are fundamental to patterns of marine biodiversity.

The very small size of propagules of most marine species makes them particularly susceptible to variations of the physical environment. On occasion, the dispersive phases can travel great distances at sea. The propagation distance, however, is very variable among taxa. For example, a recent review of dipersal distance in benthic marine animals (Shanks *et al.* 2003) establishes a modal propagation distance of <1 km for some sessile taxa (corals, tunicates, bryozoans), and another mode exceeding 20 km, which is the typical dispersal distance for larvae of molluscs, crustaceans and fish. In principle, it might seem as if it would be rare for populations to be self-replenishing, but recent studies (Jones *et al.* 1999; Swearer *et al.* 1999) indicate that it is more common than previously thought. Different degrees of openness of local subpopulations are possible and understanding the underlying processes is crucial for the successful management of marine species and habitats.

The replenishment of a marine area depends on three main processes: colonisation, settlement, and recruitment. Both larval density and diversity can have a critical influence on local species richness and thus on ecological interactions within the community. Marine ecologists have long recognised the key role of temporal fluctuations of settlement and post-settlement events in the regulation of the dynamics of marine communities (Underwood & Fairweather 1989).

Mobility of marine organisms, beyond their home range, can also influence marine connectivity. There is evidence that some demersal fish species can move hundreds or thousands of metres in short periods of time, by, for example, using different habitats for feeding, resting or spawning, or by ontogenetic changes in the use of space, or even by home-range relocation phenomena (Mathews 1990; Kramer & Chapman 1999; Gillanders *et al.* 2003; Lowe *et al.* 2003; Egli & Babcock 2004; Topping *et al.* 2005).

Therefore, in endeavouring to discover the biological and environmental factors that determine the spatial and temporal patterns of abundance of a given species, it is important to have information about the connectivity of its populations, i.e. the degree to which sub-populations living in different parts of the species' geographical range are related, through the exchange of larvae, recruits, juveniles or adults. It was previously generally agreed that populations in spatially separated areas are more connected in the sea than on land, but recent studies have prompted a reappraisal of this notion (Palumbi 2003).

Connectivity among marine areas for a given species can be studied by a variety of recently developed techniques (Palumbi *et al.* 2003), such as remote sensing, marine circulation modelling, tagging, including external (natural or artificial), chemical (trace elements or stable isotopes in otholiths) or genetic (Pérez-Ruzafa *et al.* 2006) methods, and Geographical Information Systems (GIS).

1.3 The importance of habitat structure

The habitat of an organism can be intuitively defined as the place where it lives and which provides food, shelter and living space to the organism (Chabanet *et al.* 2005). More formally, a habitat can be defined as a spatially-bounded area, with a subset of physical and biotic conditions, within which the density of interacting individuals, and at least one of the parameters of population growth, is different than in adjacent subsets (Morris 2003). Habitat must be defined in relation to the species and populations of interest, and in a manner that reflects underlying processes operating at appropriate spatial and temporal scales.

Potential habitats for a species (at a given spatial scale) vary with respect to both quality and quantity of available resources (food, refuge, etc.), predation risk, or resource requirements by organisms from the same or different species leading to competitive interactions. Therefore, the question to address is: what habitat features are relevant for these organisms and what are the ecological functions provided by these features, which are to be measured and, ultimately, protected (García-Charton *et al.* 2000). The concept 'habitat' encompasses not only the substratum (rock, sand, etc.), but also habitat 'formers' (e.g. coral reefs, seagrass meadows, gorgonians, vermetid reefs, maërl beds, or macroalgae); moreover, habitat 'determiners', i.e. organisms able to modify the physical structure of habitat by their individual activity (e.g. by grazing, scratching, scavenging), should be considerded.

In studies of habitat structure, the distinction is often made between habitat complexity – the absolute quantity of each element type, which represents the degree of variation in the orientation of the three-dimensional surface per unit of seabed area (vertical component), and heterogeneity – variation attributable to the relative abundance of the different structural elements of habitat (horizontal component), at each spatial scale of interest (García-Charton & Pérez-Ruzafa 2001; García-Charton *et al.* 2004).

Marine habitats can be classified according to the ecological function they provide (e.g. habitat for spawning, recruitment, nursery, etc.). Futhermore, a particular organism can occupy different types of habitat during the day (e.g. for resting and feeding), and particularly at different stages of their life cycle. On the other hand, habitats can be described at different spatial scales of observation, which will also depend on the organism of interest (García-Charton *et al.* 2000; Chabanet *et al.* 2005).

Marine habitats are being altered by physical disturbances of human origin (coastal works, dredging, dumping, spilling, trampling and other tourist impacts, trawl fishing, anchoring, etc.), which generate a variety of negative effects (siltation, occupation of the coastal fringe, destruction of erect organisms, etc.) (Chabanet *et al.* 2005). Ultimately, the effects of these disturbances are the degradation, fragmentation and destruction of habitats and the ecological functions they provide to marine species and ecosystems.

1.4 Marine protected areas as tools for ecosystem management and conservation

In recent decades, marine protected areas have been established around the world at a rapid rate (Lubchenco *et al.* 2003). Some offer protection to pristine natural communities (Kelleher *et al.* 1995), while others attempt to halt further deterioration of sensitive habitats, or serve as fisheries management tools for long term sustainability of fisheries (Rowley 1994). Marine protected areas with similar objectives have been established along the Mediterranean coast (Harmelin 1990; Ramos & McNeil 1994; Harmelin *et al.* 1995).

MPAs have been proposed as an optimal way to protect marine ecosystems and associated fisheries in tropical and temperate waters (Lubchenco *et al.* 2003). Two main objectives have been identified when addressing the purposes of MPAs: ensuring sustainable use of economic resources, and protecting biodiversity – valuable species, habitats and landscapes (Salm *et al.* 2000), although the two are not mutually exclusive. From a fisheries perspective, MPAs have been advocated as an insurance against uncertainties faced by traditional management measures, which have contribued to the collapse of several fisheries (Pauly *et al.* 2002). However, there are conditions under which MPAs may be ineffective in sustaining or enhancing fishery yields (Hilborn *et al.* 2004), or, worse, may lead to reduced yield (Holland 2000; Smith & Wilen 2003; Gårdmark *et al.* 2005) or greater environmental damage outside protected areas (Dinmore *et al.* 2003). In addition, most ecological, fisheries and socio-economic effects of MPAs lack of sufficient empirical evidence (Pelletier *et al.* 2005). To be effective, MPAs have to be properly managed; this task includes defining objectives and goals from the outset, site selection, zoning, planning and implementing a surveillance and enforcement system as well as monitoring actions (Kelleher 1999). In the modern conception of MPAs, local communities have to be effectively involved, as public participation and awareness are essential if proper environmental management is to be implemented.

2 Ecological effects of MPAs: a brief review

2.1 Reserve effect

Fishing reduces population abundance, preferentially removing larger and older fish, thus changing the size and age structure of exploited populations (e.g. Goñi 1998). The cessation or reduction of fishing promotes an increase in abundance as well as the mean size and age of the protected populations, a subject that has been thoroughly investigated both in the Mediterranean (Bell 1983; García-Rubies & Zabala 1990; Francour 1994; Dufour *et al.* 1995; Harmelin *et al.* 1995), and in other marine regions (e.g. Dugan & Davies 1993; Jones *et al.* 1993; Ferreira & Russ 1995; Jennings *et al.* 1995; McClanahan & Kaunda-Arara 1996; Russ & Alcala 1996). Most studies show that the species more likely to respond to the cessation of fishing in marine reserves ("reserve effect") are large, long-lived predators (e.g. Serranidae, Lutjanidae, Balistidae, Scaridae, Acanthuridae, Haemulidae), species highly vulnerable to fishing and those whose populations are overexploited (PDT 1990; Roberts & Polunin 1993; Bohnsack 1996). Other species may not show effects or may show the inverse effect (lower abundance or biomass in the reserve), presumably due to interespecific relationships. In the Mediterranean, sparids, labrids, serranids and sciaenids appear to have benefitted most from protection (e.g. Bell 1983; García Rubies & Zabala 1990; Bayle & Ramos 1993; Harmelin & Marinopolous 1993; Francour 1994; Dufour *et al.* 1995; Harmelin *et al.* 1995; García-Charton *et al.* 2004; Claudet *et al.* 2006; Guidetti 2006).

Despite the popularity of MPAs, there is little clear empirical evidence currently available of their effectiveness (Russ 2002; Halpern 2003).

2.2 Fish movement and connectivity

Protection of dispersal and migratory patterns should be based on the recognition of their spatial connections and, in marine ecosystems, local measures are insufficient when the scale of the connections encompasses large areas of territory. The notion of a critical distance representing an organism's ability to travel between habitat patches, sensu D'Eon *et al.* (2002), is a fundamental consideration when establishing an MPA, whether coastal or island, and a relationship between mean dispersal and reserve size could determine the persistence of species within a reserve (Lockwood *et al.* 2002) and the effectiveness of spatial protection as a fisheries management tool. Design of marine reserve systems requires an understanding of larval transport into and out of reserves, whether reserves will be self-seeding, whether they will accumulate recruits from surrounding exploited areas, and whether reserve networks can exchange recruits. Direct measurements of mean larval dispersal are needed to understand connectivity in a reserve system, but such measurements are extremely difficult. Genetic patterns of isolation by distance have the potential to add to direct measurement of larval dispersal distance and can help set the appropriate geographic scales on which marine reserve systems will function well (Pérez-Ruzafa *et al.* 2006).

When the density of a population is higher inside a reserve than in adjacent non-reserve areas, random movements are expected to produce a net emigration from the reserve (Rakitin & Kramer 1996). Furthermore, frequency-dependent models of animal distribution such as the Ideal Free Distribution Model predict that, when the species fitness is affected by the relationship of population density and resource availability, animals will tend to move from areas where their density is high (Rakitin & Kramer 1996). Emigration of individuals from MPAs has been proposed as a potential benefit of reserves for fisheries management and population replenishment (Russ & Alcala 1996), and is expected to produce a gradient of abundance and mean size across reserve boundaries. Kramer & Chapman (1999) examined the implications of fish home range size and relocation on marine reserve function and ability to increase abundance outside reserve boundaries. They predict that species with intermediate levels of mobility and density-dependence of space use will provide the greatest spillover benefits to nearby fisheries. Potential emigration could thus be important for demersal fishes and some invertebrates such as lobsters or shrimps. These species may spend enough time inside the reserve to experience a significant reduction in fishing mortality while having the ability to move outside the protected area. Even though this spillover effect is widely assumed and expected, there is remarkably little evidence of this effect so far (Sanchez-Lizaso *et al.* 2000). Spillover was the main focus of an EU research project recently achieved – BIOMEX (http://biomex.univ-perp.fr) – that provided significant input to EMPAFISH (see section 4 below).

2.3 Other biological effects

The expected higher densities of previously-exploited species in MPAs may produce an augmentation of intraspecific and interspecific competition as biomass of the populations approaches the carrying capacity of the area (Sánchez-Lizaso *et al.* 2000). Life history parameters (such as life-span, growth, natural mortality, age and size at maturity and reproproductive patterns) are thought of as plastic or adaptive (Stearns & Crandall 1984) and could conceivably be easily affected by changes in population density in protected areas after fishing restrictions are put in place if resources become limiting (Sánchez-Lizaso *et al.* 2000). Finally, since protected areas are not closed systems, resource limitation brought about by increased competition in dense protected populations could induce density-dependent emigration from MPAs, leading to spillover.

2.4 Indirect effects

The trophic cascade is a major ecosystem process based on predation interactions, involving at least three or four trophic levels of an ecosystem (Pinnegar *et al.* 2000). Variations in food consumption by one trophic level, usually top-carnivores, cascade down the food web, each trophic level influencing the one below. Whereas the energy transfer propagates upwards through the food web (from primary producers to top-predators, i.e. a 'bottom-up' process), true trophic cascades are generally viewed from the 'top-down' pathway (from top-predators to primary producers). The "true trophic cascades imply keystone species, with such top-down dominance that their removal causes precipitous change in the system" (Menge 2000; Duskalov *et al.* 2007). Nevertheless, the concept of 'keystone' species has been given different meanings and definitions, and has been applied to organisms with very different effects on their communities.

Demonstrating cascading impacts is difficult as reactions down through the food webs progressively decrease. Depending on the complexity of the system and the specialization of the species concerned, changes down the food web could be highly variable and diffuse. The effects of removal of top-predators would be weakened down a species-rich system and/or down a system with abundant omnivores. In an ecosystem, species are interconnected by different types of direct and indirect interactions, the effects of which are intermingled in the ecosystem functioning. Direct predator effectiveness is mediated by various indirect effects (shelter availability, heterogeneity of habitats, variability of recruitment, size refuge, patchiness of resources, disease, stochasticity of abiotic events) which obscure the pure trophic cascading effects. Trophic cascades generally occur when the runaway consumption flow is unified, i.e. specifically directed to some kind of food. According to the numerous papers published about trophic cascades in fresh waters ecosystems, we could hypothesize that a true cascade effect is evident if the number of links in the trophic web is not too large, e.g. when the trophic web is damaged. However, if the number of trophic levels and the number of trophic links increase, a clear trophic cascade effect may probably be impossible to detect. Consequently, are MPA's the best places to study cascade effects? A strict banning of all fishing pressures in an MPA is likely to allow recovery, not to pristine conditions, but to a greater species richness and/or trophic diversity than outside, in unprotected areas. There may therefore be a lower chance of detecting effects of trophic cascades in MPAs, where trophic diversity has increased.

2.5 The interference of habitat structure

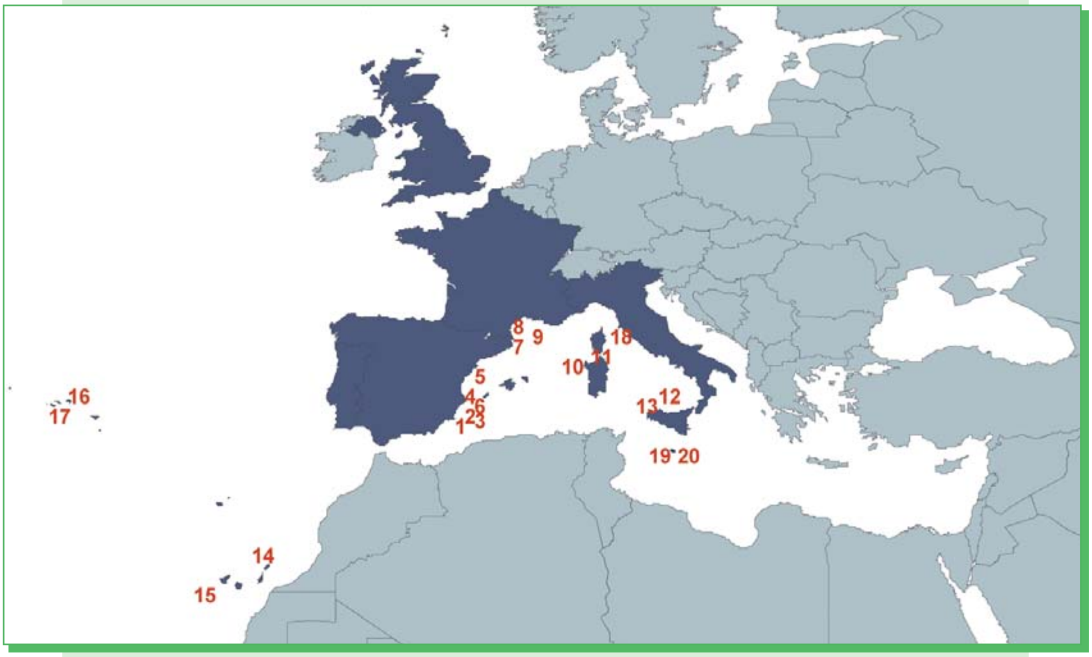
In assessing the effects of MPAs, there is a potential source of confounding in the fact that, usually, marine reserves are established in zones that already harbour structurally complex habitats, which form favourable habitats for the development of a rich and abundant reef fish fauna (García-Charton & Pérez-Ruzafa 1999; García-Charton *et al.* 2000, 2004). Part of the observed variability in fish assemblage structure could be due to selection of areas to be protected that are particularly favourable to high fish abundance and diversity, because they offer predominantly rocky, complex habitats. Nevertheless, the influence of habitat structure seems to be exerted mainly at small-to-intermediate spatial scales, since, isolating the part of variation due to habitat from the variables chosen as indicators of the ''reserve effect'' produces mainly the loss of heterogeneity among sectors and/or zones (García-Charton *et al.* 2004), although in some cases (e.g. Ordines *et al.* 2005) bottom morphology did not exert a detectable effect, probably due to greater habitat similarities among the localities that were being compared. Studies describing fish assemblages at multiple scales (e.g. Williams & Hatcher 1983; Galzin 1987; Holbrook *et al.* 2000; Gust *et al.* 2001) have usually found that habitat type explains small-to-medium patchiness in fish assemblage structure. Distinguishing the relative contribution of habitat structure can help to elucidate the actual effects of protection (Jennings *et al.* 1996; García-Charton *et al.* 2000, 2004).

3 Ecological effects in EMPAFISH case studies

3.1 General view

The analyses to be carried out in EMPAFISH will be based on existing data on ecological, fisheries, and socio-economic aspects of already established, well-studied MPAs selected as case studies (Fig. 1 to 3). It is to be underlined that most of the data available to this project were generated by the participants in previous projects funded by the EU. In addition, some new work is to be done to obtain missing information that is required to perform a more comprehensive analysis. In the following sections, the ecological research on the 20 case studies to date is summarised.

Figure 1. Location of case studies considered in the EMPAFISH project (correspondence of numbers with names of MPAs are indicated below).



- **1** Cabo de Palos - Islas Hormigas
- **2** Tabarca
- **3** San Antonio
- **4** Serra Gelada & Benidorm islets
- **5** Columbretes Islands
- **6** Anti-trawling zones (SE Spain)
- **7** Medes Islands
- **8** Cerbère – Banyuls
- **9** Côte Bleue
- **10** Sinis - Maldiventre
- **11** Bouches de Bonifacio
- **12** Ustica Island
- **13** Gulf of Castellamare / Trawl Ban Area
- **14** La Graciosa e Islotes del Norte de Lanzarote
- **15** La Restinga – Mar de las Calmas
- **16** Monte da Guia - Faial
- **17** Formigas Islets - Dollabarat Bank
- **18** Tuscany Archipelago
- **19** Malta 25 NM Fisheries Management Zone (FMZ)
- **20** Rdum Majjiesa/Ras Ir-Raheb

Figure 2. Location of subregions were case studies considered in the EMPAFISH project are situated: a) Eastern Spain, b) Gulf of Lyon, c) Corsica, Sardegna and Tuscany, d) Sicily and Malta, e) Archipelago of Canary islands, f) Archipelago of Azores islands.

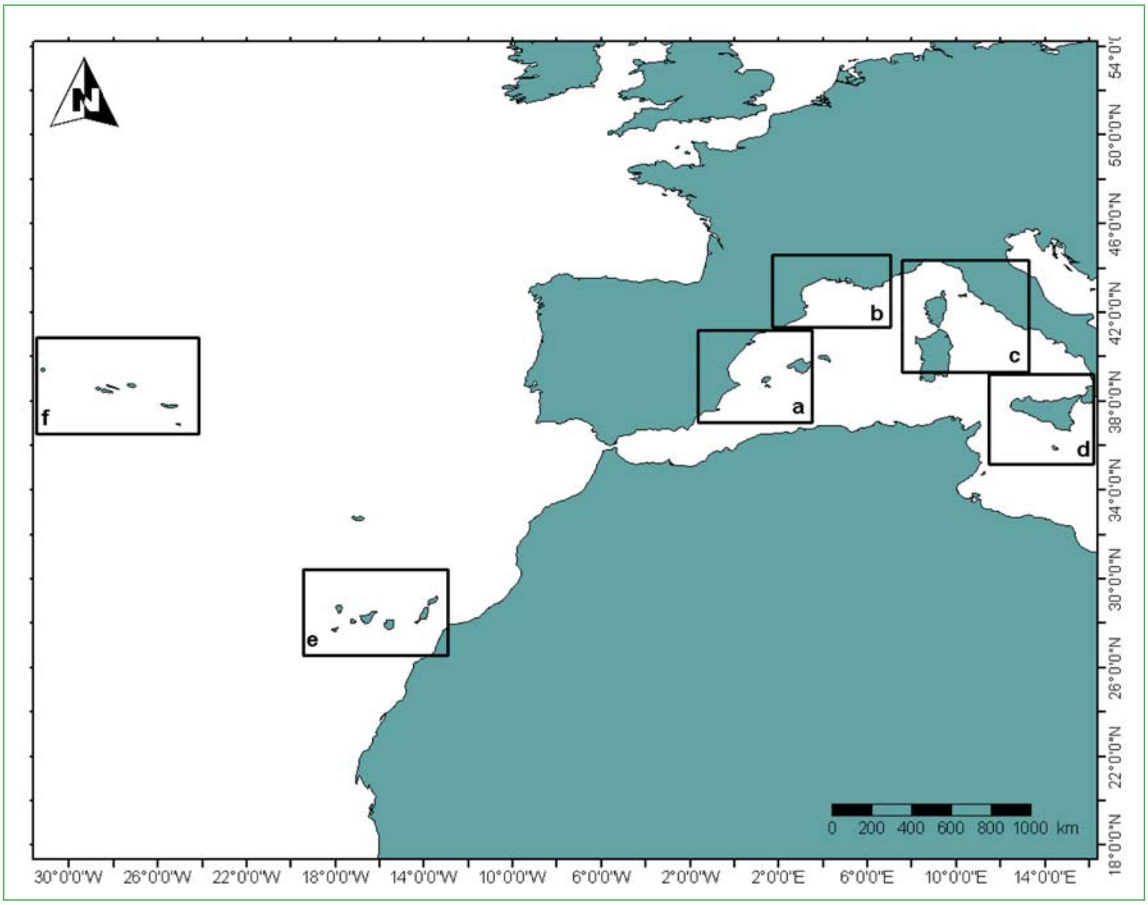
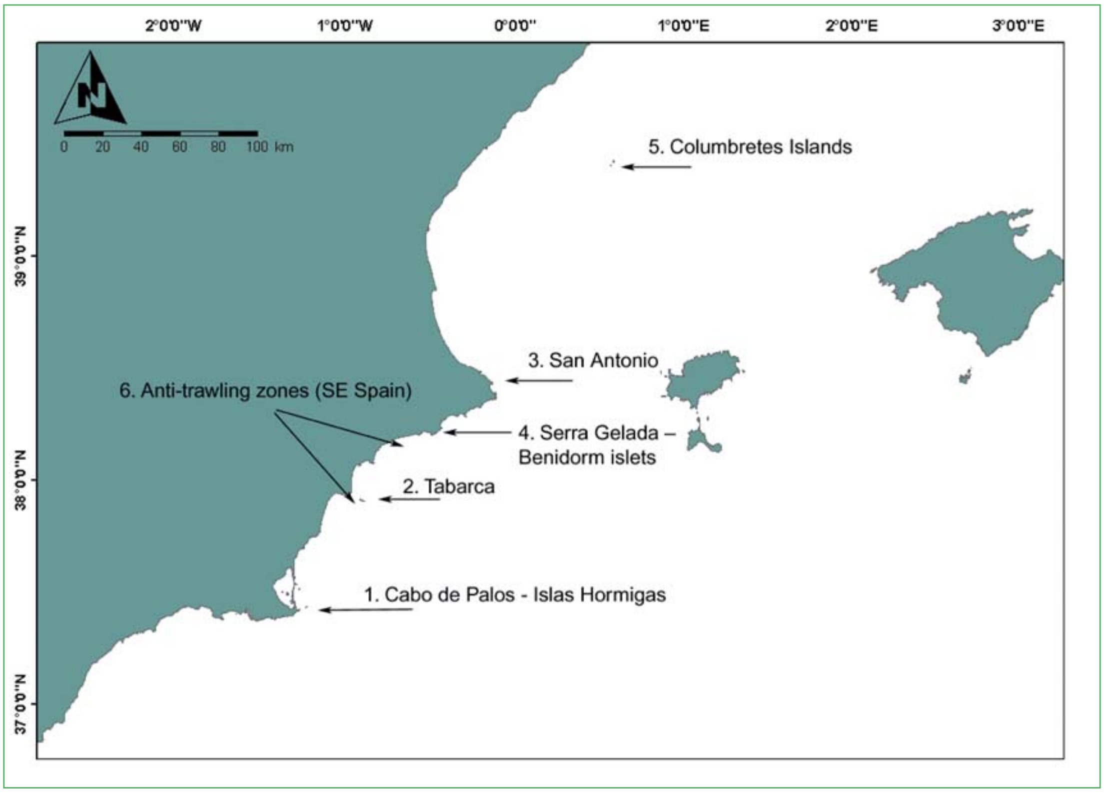
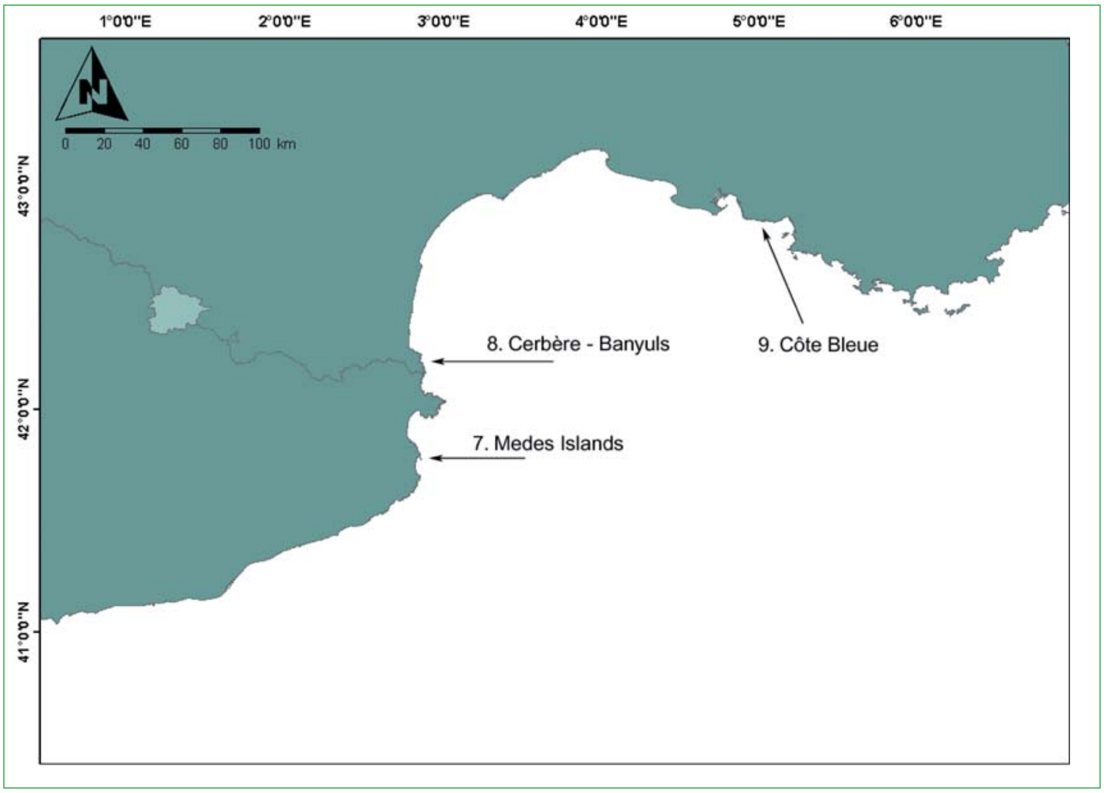


Figure 3. Location of case studies considered in the EMPAFISH project, by subregions:

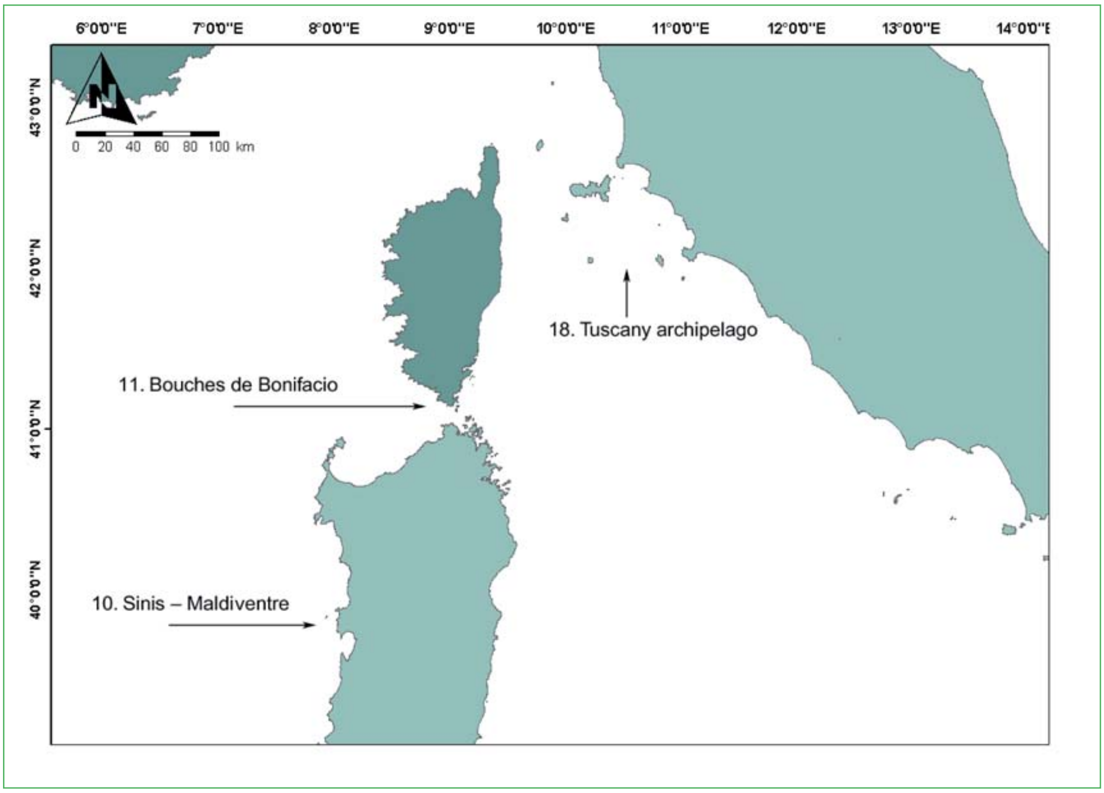
a) Eastern Spain



b) Gulf of Lyon

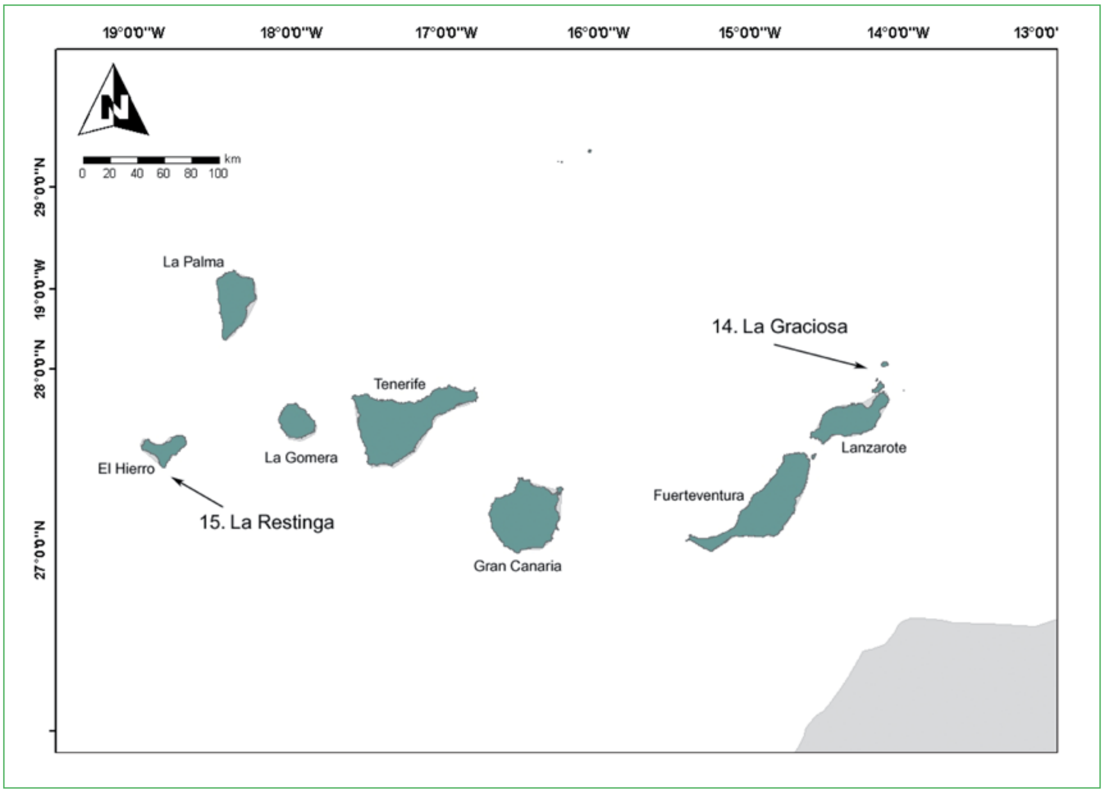


c) Corsica, Sardegna and Tuscany

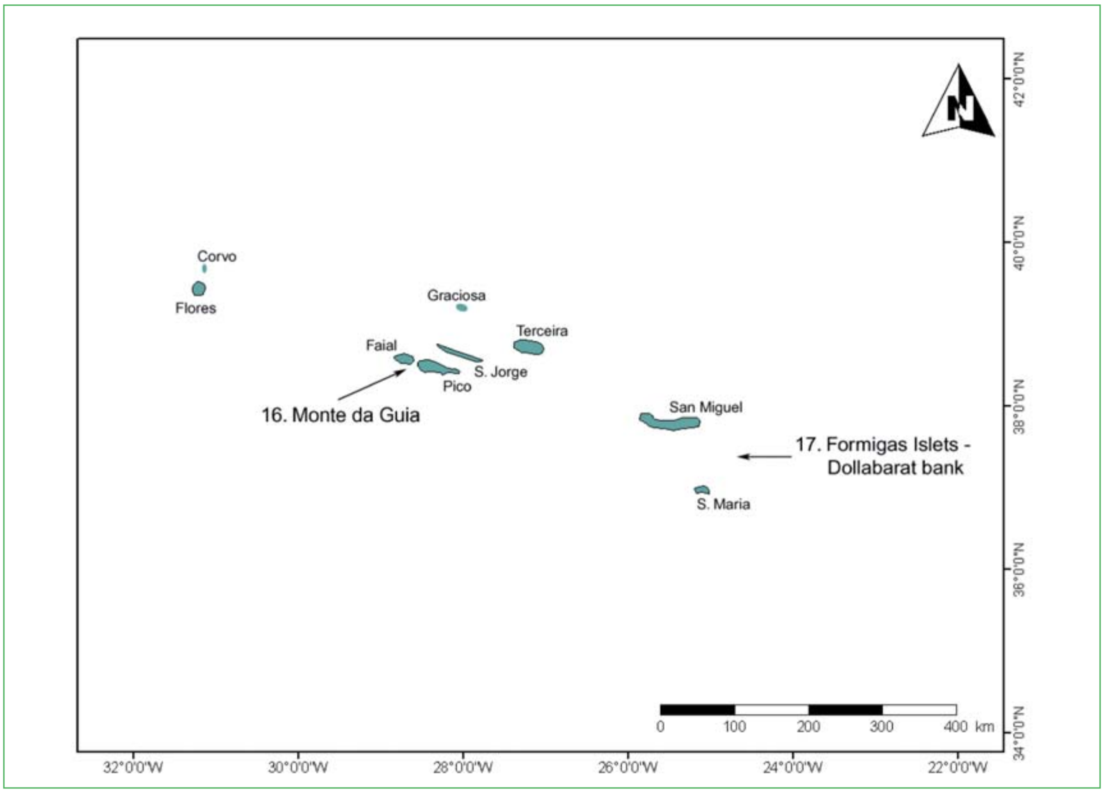


d) Sicily and Malta

e) Canary Islands



f) Azores Islands



3.2 Case studies

1 Cabo de Palos - Islas Hormigas (Spain)

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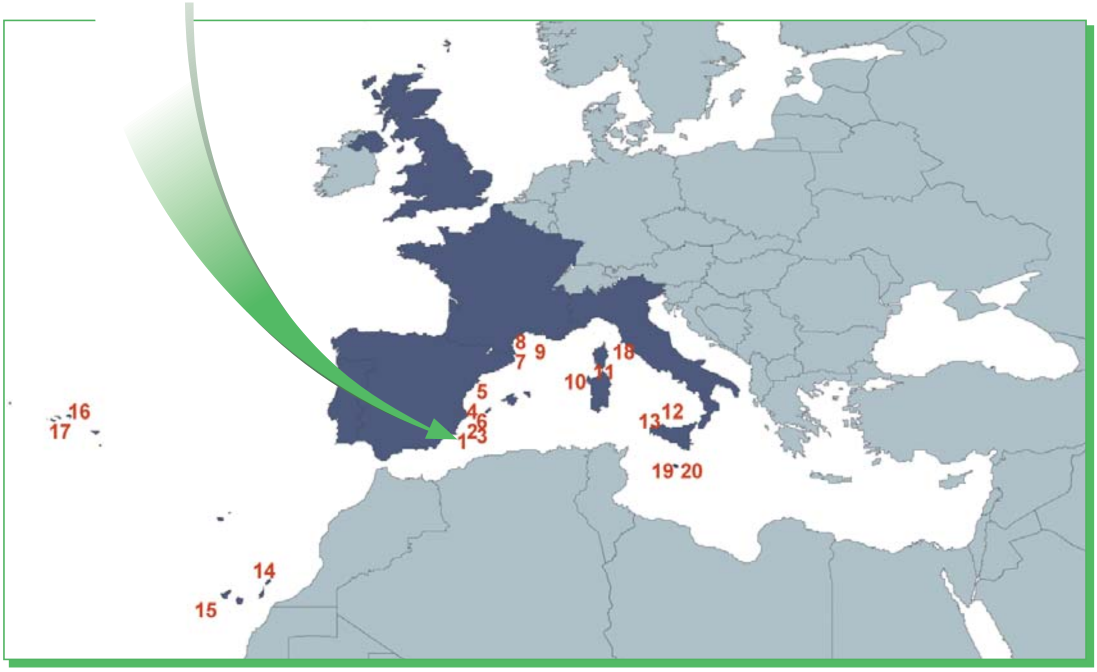

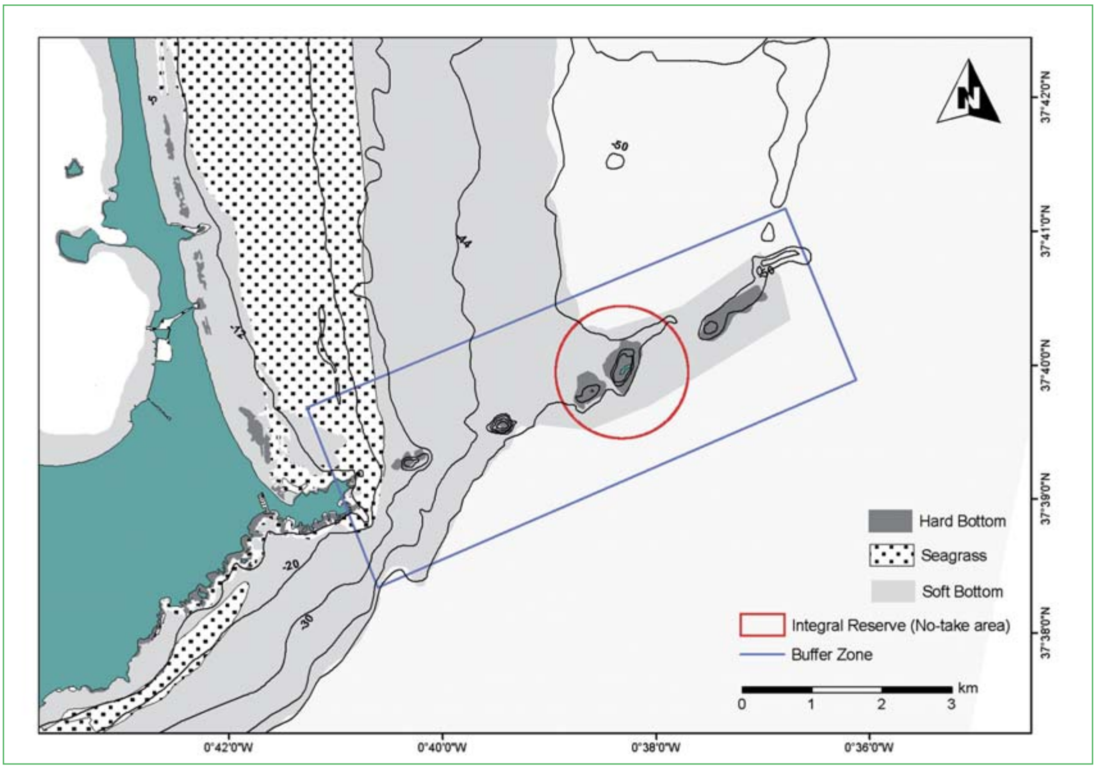

General features

Legal Status	Fishery reserve
International Recognition	Included in 3 Sites of Community Importance (Natura 2000) in the Region of Murcia: ES6200007 (Islands and Islets of Mediterranean Littoral), ES6200029 (Submerged Littoral Fringe at the Region of Murcia) and ES6200048 (Marine Environment); SPA (Special Protection Area) (Birds Directive); SPAMI (Specially protected area of Mediterranean importance) (Barcelona Convention)
Foundation Text	Decree nº 15, 31st March 1995 (Regional Ministry for Agriculture and Water); Order 22nd June 1995, modified by Order 29th April 1999 and by Order 6th June 2001 (Ministry of Agriculture, Fisheries and Food)
Legal References	BORM nº 92, 21st April 1995; BOE nº 161, 7th June 1995; BOE nº 119, 19th May 1999; BORM nº 92, 19th April 2000; BOE nº 146, 19th June 2001; BORM nº 174, 28th July 2001; BOE nº 233, 28th September 2001
Relevant Administration	Ministry of Agriculture, Fisheries and Food; Regional Ministry of Agriculture and Water
Management Body	Representatives of Ministry at Murcia; representatives of Regional Ministry at Cartagena
Consultative Committee	Advisory Committee
Main Marine Species	*Cystoseira* spp., *Posidonia oceanica, Cymodocea nodosa, Octopus vulgaris, Sepia officinalis, Pinna* spp., *Eunicella singularis, Paramuricea clavata, Palinurus elephas, Epinephelus* spp., *Mycteroperca rubra, Sciaena umbra, Mullus surmuletus, Diplodus* spp., *Dentex dentex, Sparus aurata,* Labridae, *Seriola dumerili, Sphyraena* sp., *Scorpaena* spp., *Caretta caretta, Tursiops truncatus*
Marine Area Surface	Total reserve: 1,898 ha Integral reserve: 270 ha
Web page	http://www.mapa.es/rmarinas/index_rm.htm

Regulations

Activities	Integral reserve	Buffer zone
Forbidden	All activities except *	Spear fishing, trawling, seine, angling
Regulated	* Scientific research	Scientific research, artisanal fishing (clear trammel-net, bottom long-line), angling, scuba diving
Allowed		Swimming, boating, anchoring

Other Management Initiatives

Mooring regulated in diving spots; scientific monitoring since 1996

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Cabo de Palos – Islas Hormigas: ecological studies

▪ General

Fish assemblage

Fish assemblage have been extensively studied in the area since 1990, using underwater visual census (UVC) as main sampling technique. The principal objective has been to study the fish-habitat structure relationships at several spatial scales, from 10s to 1000s metres (García-Charton & Pérez-Ruzafa 1998, 2001). Special mention has to be done to the regular coming up of "thermophilic" warm-Atlantic species (e.g. *Serranus atricauda, Pseudocaranx dentex, Parapristipoma octolineatum, Sparisoma cretense, Scorpaena maderensis*) within the Cabo de Palos – Islas Hormigas Marine Reserve (hereafter CPIHMR) and neighbouring areas, probably due to the gradual warming of seawater in south-western Mediterranean. Genetic studies have been undertaken in the area, taking the species *Diplodus sargus* as model (González-Wangüemert *et al.* 2002, 2004).

Benthic communities

First works, prior to the start of protection measures, were devoted to study the biology, ecology and distribution of some benthic taxa, such as molluscs (Templado 1961, 1962; Templado 1980, 1982a, 1982b, 1982c; Templado & Llansó 1981; Templado *et al.* 1983), and echinoderms (López Ibor & Galán 1982; López Ibor *et al.* 1982; Pina & Pérez-Ruzafa 1984; Pérez-Ruzafa & López Ibor 1987). Later, authors undertook the mapping and semi-quantitative characterization of benthic biocœnoses in the area (Ros *et al.* 1984, 1986; Pérez-Ruzafa *et al.* 1991; Calvín *et al.* 1999), which is presently being updated by the Regional Government.

▪ Reserve effect

Fish assemblage

UVC monitoring program show how CPIHMR harbours a very rich and diverse fish assemblage as compared to unprotected areas, showing evidence that management measures have been adequate to protect a number of ecologically as well as commercially important species (Pérez-Ruzafa 1995, 1996, 2001, 2003, 2004; Pérez-Ruzafa *et al.* 2002; García-Charton *et al.* 2004, 2005, 2006, 2007). Fish families responding the best to protection measures, by having higher abundance and/or biomass within the MPA, are serranids (groupers and combers) and sparids (sea-breams) species.

Superimposed to the reserve effect, a "habitat effect" on ichtyofauna is apparent, derived from the fact that this MPA house rocky habitats being more complex (due to the importance of crevices, hangs, vertical walls, etc.) than neighbouring unprotected areas, which are more heterogeneous (by having a higher proportion of *Posidonia* and/or sand embedded in the rocky matrix), all these differences having a great influence on the structure of fish assemblage (García-Charton & Pérez-Ruzafa 1998, 1999, 2001; García-Charton *et al.* 2000, 2004). Hence, some fish species appeared to be more abundant and/or big in size in unprotected areas used as control sites (some labrids, other sparids, striped red mullet, etc.), because they show affinities for these heterogeneous bottoms. This is an additional example on the difficulties posed by habitat structure when trying to measure "reserve effect" in singular sites selected to become a MPA (García-Charton *et al.* 2004).

Comparing *Diplodus sargus* genetic structure within CPIHMR with unprotected sites, and with other MPAs –including other EMPAFISH case studies, such as Cerbère-Banyuls and Tuscany archipelago, as well as control, unprotected sites (González-Wangüemert *et al.* 2002, 2004; Pérez-Ruzafa *et al.* 2006), it is observed that protected areas show significant higher allelic richness than unprotected sites. In parallel, islands showed lower level of heterozygosis and higher heterozygote deficit compared with coastal areas, making clear the importance of considering the connectivity processes when designing an MPA.

Benthic communities

The abundance and size structure of sea urchins (*Paracentrotus lividus* and *Arbacia lixula*) have been compared between partial reserve (around the cape of Palos) and structurally similar sites in the unprotected areas in 2001 and 2002, in relation with habitat structure (Pérez-Ruzafa 2002). Density of edible sea urchins (*P. lividus*) was three times higher within the marine reserve than in unprotected areas. This species showed consistently a bimodal size structure in the marine reserve, while being unimodal outside. In addition, spatial structure was different between both zones, as *P. lividus* formed larger aggregations within the marine reserve, while patches of sea urchins were significantly smaller outside. Variations in habitat structure (rugosity, rocky cover, etc.) explain in part the observed differences. Regarding *A. lixula*, no significant differences were found in density or size. When density of sea urchins is compared between several sites in the partially protected area and the integral, no-use area (see section about diving impact below), edible sea urchin *P. lividus* is more than twice as much abundant in the partial reserve. Increased food availability due to sediment resuspension by divers, variations of habitat complexity, and indirect food-chain effects are proposed as not mutually exclusive hypotheses to explain the observed pattern.

- **Fish movement (including spillover)**

Within the CE project BIOMEX (http://biomex.univ-perp.fr), studies have been undertaken to test the hypothesis that spillover from MPAs to neighbouring areas should have as consequence the observation of gradients of fish biomass across boundaries. In Cabo de Palos, this hypothesis has been tested by using UVC, baited video, and collection of fish eggs and larvae by plankton nets as sampling techniques, following a sampling design including several sites inside the MPA plus other sites outside the MPA (to the North, and to the South). Results of these works are being analysed at present (see section 4 below). In addition, this problem has been approached by modelling the process of fish biomass exportation (Pérez-Ruzafa *et al.* in prep.).

The problem of connectivity has been also approached through genetic studies on *Diplodus sargus*. A significant genetic difference has been detected among fish species distant 10s to 100s km, which is much influenced by the pattern of local currents (González-Wangüemert *et al.* 2002, 2004). It would seem as if Cabo de Palos had the lowest genetic fluxes of all studied areas in SE Spain.

- **Other biological (e.g. density-dependent) effects**

Size, sex and age structure of *Diplodus sargus* populations has been studied in Cabo de Palos, compared with unprotected areas in SE Spain (González-Wangüemert 2004). As a consequence of the decrease in mean size due to fishing pressure, and the proterandric character of this species, a deficit of females was observed in exploited sites, while in the MPA the proportion of female and hermaphrodite specimens was higher.

- **Effects on habitat (including impact of divers)**

CPIHMR receives ca. 18,000 divers per year, this activity concentrating mostly in summer, and principally in four diving spots. Impact of divers on benthos has been studied since 2003 (Pérez-Ruzafa *et al.* 2003, 2004; García-Charton *et al.* 2005, 2006, 2007), by comparing, for each year, the density of a series benthic species selected as indicators (algae, sponges, cnidarians, echinoderms, bryozoans, polychaetes and ascidians) just before and after summer, in both partial (where diving is allowed) and integral reserve areas, using UVC and digital photography techniques (Herrero *et al.* in prep). Specially, the white gorgonian *Eunicella singularis* is being monitored in terms of density, morphometric descriptors and occurrence of necrosis. In addition, field experiments are being undertaken to quantify the individual action of divers to remove benthic organisms and sediments.

Spatio-temporal variability of algal cover was high, hence masking any effect of diving erosion. None of the taxa included in the analyses showed differences in their density or cover that could be clearly attributed to the erosion caused by the activity of recreational divers. Some benthic suspension-feeder species showed higher density in dived sites. Increased food availability due to sediment resuspension by divers, variations of habitat complexity, and indirect food-chain effects are proposed as not mutually exclusive hypotheses to explain the observed pattern. In contrast, experimental simulations of diving impact on photophilous bottoms showed that successive passes by a diver caused the detachment of 4 g m^{-2} AFDW as average amount of algae, as well as fragments of the fragile invertebrate species *Clavelina dellavallei* and *Myriapora truncata*, this loss determining a significant change in their respective cover or density. Vaulted / total density ratio of the white sea-fan *Eunicella singularis* was significantly higher in the dived sites compared to the integral reserve; in addition, there was a slender trend to a higher degree of necrosis in dived sites. These results seem to indicate that current levels of diving intensity in the Cabo de Palos – Islas Hormigas marine reserve are probably within acceptable limits, although further increase in the number of divers could be such as benthic communities could not counteract their erosive effect (Herrero *et al.* in prep).

All these works served as basis for proposing a system for calculating the Carrying Capacity of Diving Activity in the CPIHMR, based on the application of correcting factors (considering social, difficulty, fragility, damage, accessibility, and weather aspects) to the Physical Capacity, to obtain a Real Capacity, which in turn is modulated by a Management Capacity (in function of management actions actually applied *in situ*) to achieve the final Effective Carrying Capacity (García-Charton *et al.* 2005; Herrero *et al.* in prep.).

- **Indirect effects (trophic cascades, changes in assemblage – trophic structure, etc.)**

Studies about changes in fish assemblage structure, as well as on sea urchins (see above) can be considered in the framework of indirect (trophic) effects of protection. Also, a study can be cited which approached the relationship between feeding deterrence by an opistobranch (*Elysia timida*) and the learning capacity by a potential predator (*Thalassoma pavo*), in two sites differing in the predation pressure and the availability of the mollusc (Cabo de Palos and Mazarrón bay) (Giménez Casalduero *et al.* 2002).

2 Tabarca (Spain)

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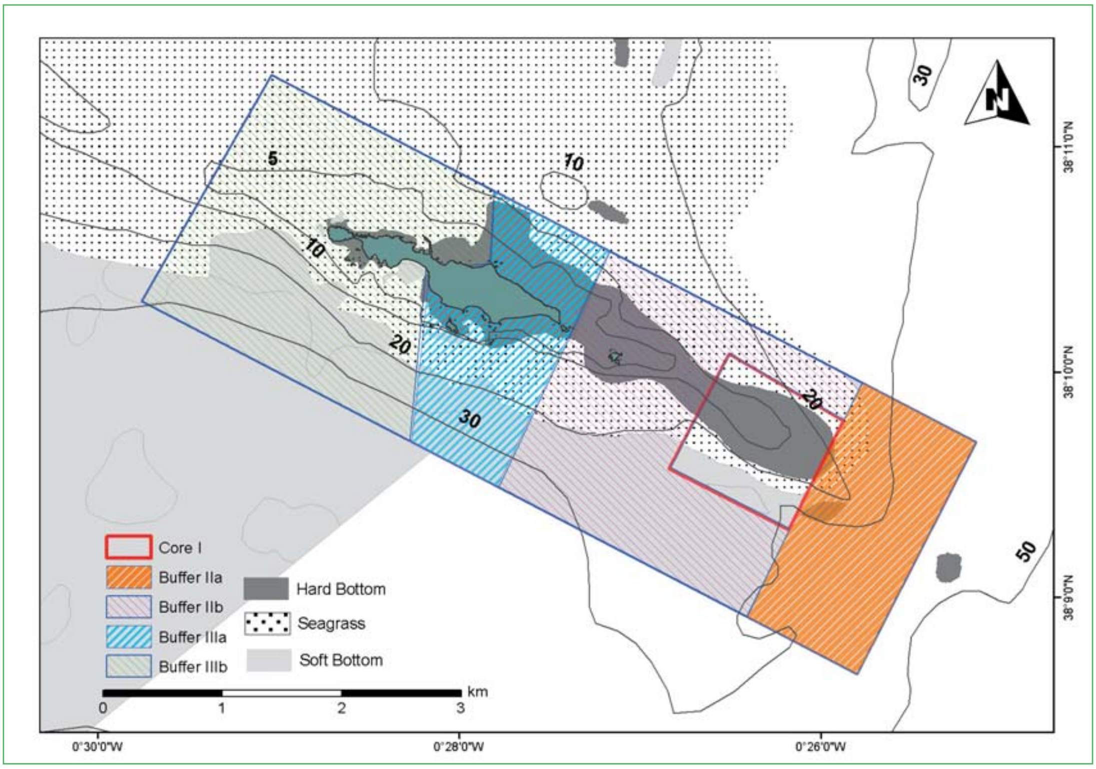

General features

Legal Status	Fishery Reserve
International Recognition	Included in a Site of Community Importance in the Mediterranean (ES5213024 Cabo de Santa Pola-L'Illa de Tabarca)
Foundation Text	Order 4th April 1986 modified by Order 15 th June 1988 and Order 24th July 2000 (Ministry of Agriculture, Fisheries and Food); Order 4th April 1986 modifyed by Order 19th October 2000 (Regional Ministry of Agriculture and Fisheries)
Legal References	BOE nº 112, 10th May 1986; DOGV nº 397, 27th June 1986; BOE nº 163, 8 th July 1988; BOE nº 184, 2nd August 2000; DOGV nº 3868, 31st October 2000
Relevant Administration	Ministry of Agriculture, Fisheries and Food; Regional Ministry of Agriculture and Fisheries
Management Body	Representatives of Ministry and Regional Ministry in Alicante
Consultative Committee	Consultative committee
Main Marine Species	*Epinephelus marginatus, Epinephelus costae, Epinephelus aeneus, Mycteroperca rubra, Scianea umbra, Dentex dentex, Seriola dumerili, Mullus surmuletus, Dendropoma petraeum, Posidonia oceanica, Cymodocea nodosa, Cystoseira* spp.
Marine Area Surface	Total surface: 1,400 ha Core area (I): 100 ha, Buffer zone (II): 630 ha, Restricted zone (III): 670 ha
Web page	http://www.mapa.es/rmarinas/index_rirm.htm

Regulations

Activities	Core I	Buffer IIa	Buffer IIb	Restricted IIIa	Restricted IIIb
Forbidden	Recreational fishing, professional fishing, swimming, anchoring, recreational diving	Recreational fishing, swimming, anchoring	Recreational fishing, swimming, anchoring	Recreational fishing, anchoring	Recreational fishing
Regulated	Scientific research*	Professional fishing (with traditional gears)	Professional fishing (with traditional gears)	Professional fishing (with traditional gears)	Professional fishing (with traditional gears)
Allowed	Boating	Scientific research, recreational diving*, boating	Scientific research, recreational diving*, boating	Scientific research, recreational diving*, swimming, boating	Scientific research, recreational diving*, swimming, anchoring, boating

* Activities permitted under permission

Other Management Initiatives

Monitoring on effects of fisheries in surrounding areas - Monitoring on dynamics of *Posidonia oceanica* meadows - Monitoring on invasive *Caulerpa racemosa* - Surveillance - Mooring areas

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Tabarca: ecological studies

▪ General

Fish assemblage

Fish assemblages have been extensively studied in the Tabarca Island Marine Reserve (TIMR) since 1990, using underwater visual census (UVC) as the main sampling technique. The principal objective has been to study the temporal and spatial variations of fish assemblage at several spatial scales, from 10s to 1000s metres (Valle Pérez 2001, 2005; Valle Pérez *et al.* 2001; Bayle 2002; Forcada 2004). Fish assemblages associated with an artificial reef placed in the TIMR were also studied to evaluate the suitability of these structures to restore marine habitats and species (Bayle *et al*. 1994, 2001; Bayle & Ramos 2003). Larval fish stages were also studied to describe its assemblage structure over an annual cycle (Bordehore 2000; Bordehore *et al.* 2001) and the effect of *Posidonia oceanica* seagrass meadows as habitat on the vertical distribution of ichthyoplankton (Del Pilar Ruso 2004; Del Pilar Ruso & Bayle 2006). Metallic trace elements were studied in otholits of *Diplodus vulgaris* to define their suitability as a markers to assess the spillover from MPAs (Gillanders *et al.* 2001), and the results showed a very low variability among different locations along Alicante coast.

Benthic communities

First works, conducted even prior to the inauguration of protection measures, were devoted to study the biology, ecology and distribution of some benthic taxa and describe the spatial distribution of benthic species (Ramos 1985; Sánchez Jerez *et al*. 1994; Romero & Sánchez Lizaso 1999), especially on *Posidonia oceanica* beds (Romero *et al.* 1998; Mateo 2003). Recently, some studies have been carried out on the distribution and abundance of *Pinna nobilis* (Sánchez Jerez *et al.* 2003), *Dendropoma petraeum* (Bayle *et al.* 2004) and echinoderms (Sánchez Jerez *et al.* 2005).

▪ Reserve effect

Management of MPA

Some data were provided on the successfulness of the management and zoning of the TIMR (Ramos *et al.* 1990a, 1990b, 1990c, 1992a, 1992b). The management plan and zoning of TIMR were suitable to organize the human activities carried out around Tabarca Island, favouring a compatible socio-economic development of the local community. TIMR were included too as a case study in a review on the importance of cultural and socio-economic factors to assess the successfulness of an MPA (Badalamenti *et al.* 2000; Sánchez Lizaso *et al.* 2002) and the fishery sector (Sánchez Lizaso & Giner 2001).

Fish assemblage

Descriptive data were provided some years after protection (Ramos & Bayle 1990, 1992) and about the indicator value of fish assemblage to assess the effects of protection (Bayle & Ramos 1993). UVC monitoring program show how TIMR harbours a very rich and diverse fish assemblage as compared to unprotected areas, indicating that management measures have been adequate to protect a number of ecologically as well as commercially important species (Bayle 2002; Forcada 2004, 2007). Fish families responding the best to protection measures –by having higher abundance and/or biomass within the MPA, are serranid (groupers and combers) and sparid (sea-breams) species. Some fish species were more abundant and/or big in size in protected areas than in control sites. A meta-analytical approach were used to assess the effects of protection of fishes integrating data from different studies (Ojeda-Martínez 2004; Ojeda-Martínez *et al.* 2007), showing the importance of implementing long-term studies to evaluate effectively the “*reserve effect*”.

Benthic communities

The abundance and size structure of sea urchins (*Paracentrotus lividus* and *Arbacia lixula*) have been compared between full reserve and unprotected areas in 2005 (Sánchez Jerez *et al*. 2005). Density of edible sea urchins (*P. lividus*) was six times higher within the marine reserve. Descriptive studies on maërl beds and the associated macrofauna were carried out in TIMR (Bordehore *et al.* 2000a, 2000b, 2003; Barberá *et al.* 2003).

▪ Fish movement (including spillover)

Within the CE project BIOMEX (http://biomex.univ-perp.fr), studies have been undertaken to test the hypothesis that spillover from MPAs to neighbouring areas should have as consequence the observation of gradients of fish biomass across boundaries. In Tabarca, this hypothesis has been tested by using UVC, experimental fishing, sampling commercial fishing data, baited video, and collection of fish eggs and larvae by plankton nets. Several sites inside the MPA plus other sites outside the MPA have been used in this survey. Results of these studies are being analysed at present.

▪ Indirect effects (trophic cascades, changes in assemblage – trophic structure, etc.)

Studies about changes in fish assemblage structure, as well as on sea urchins (see above) can be considered in the framework of indirect (trophic) effects of protection.

3 San Antonio (Spain)

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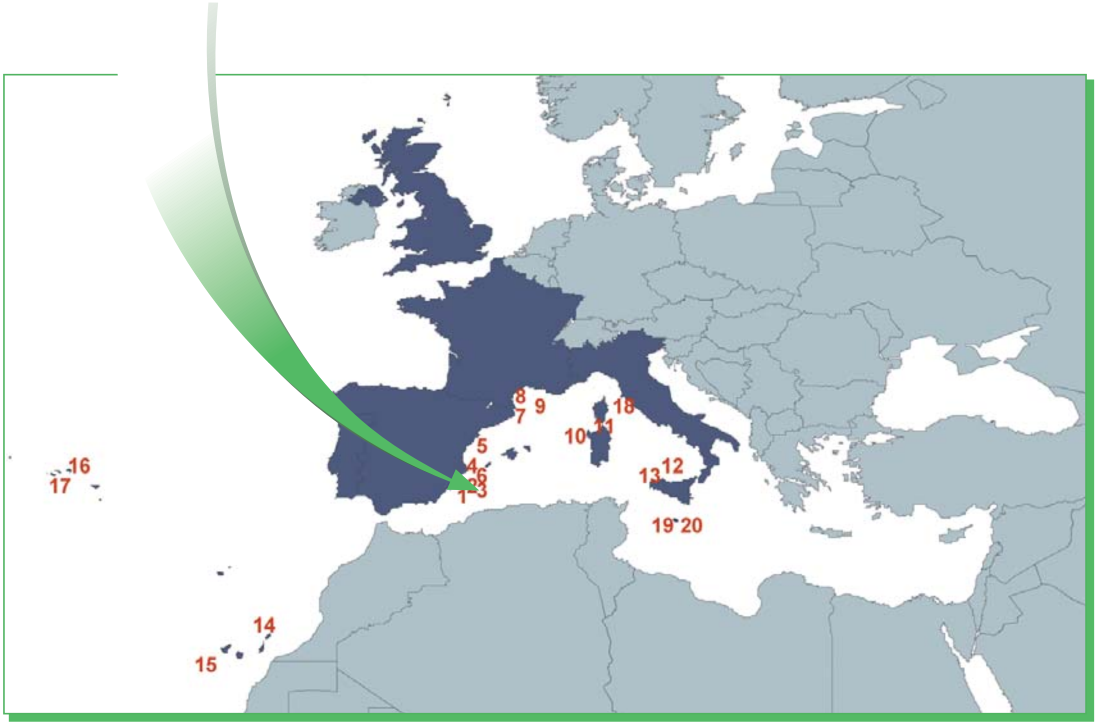

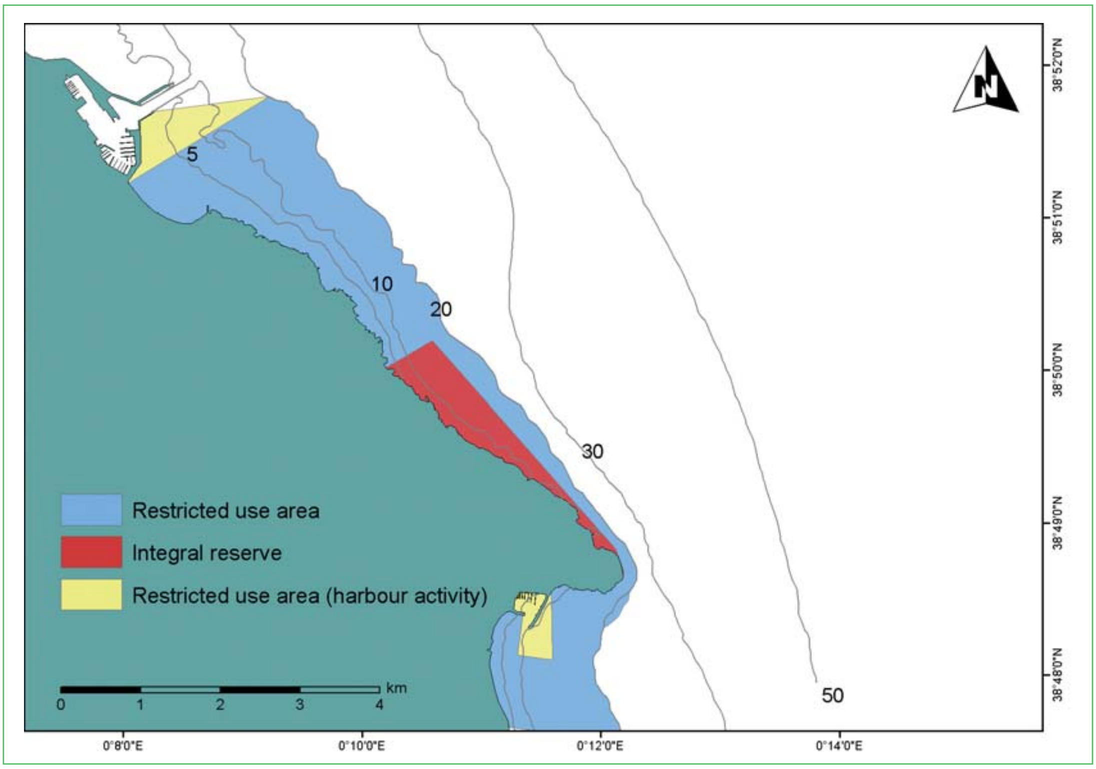

General features

Legal Status	Fishery Reserve
International Recognition	
Foundation Text	Order 9th November 212/1993, Order 8th November 180/2002, Order 10th June 110/ 2005
Legal References	DOGV nº 2145, DOGV nº 4374, DOGV nº 5027
Relevant Administration	Regional Ministry of Agriculture and Fisheries
Management Body	Representatives of Regional Ministry in Alicante
Consultative Committee	Consultative committee
Main Marine Species	*Epinephelus marginatus, Epinephelus costae, Epinephelus aeneus, Mycteroperca rubra, Sciaena umbra, Dentex dentex, Seriola dumerili, Mullus surmuletus, Dendropoma petraeum, Posidonia oceanica, Cymodocea nodosa* and *Cystoseira* spp.
Marine Area Surface	Integral reserve: 115 ha Restricted use area: 837.99 ha
Web page	http://www.mapa.es/rmarinas/index_rirm.htm

Regulations

Activities	Integral reserve	Restricted use area
Forbidden	Angling, spear fishing, anchoring, professional fishing	Spear fishing, anchoring
Regulated	Recreational diving*, scientific research*	Scientific research*, angling
Allowed	Professional fishing (only traditional gears), swimming boating	Professional fishing (only traditional gears), recreational diving, swimming, boating

*Activities permitted under permission

Other Management Initiatives

Surveillance

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San Antonio: ecological studies

▪ General

Fish assemblage

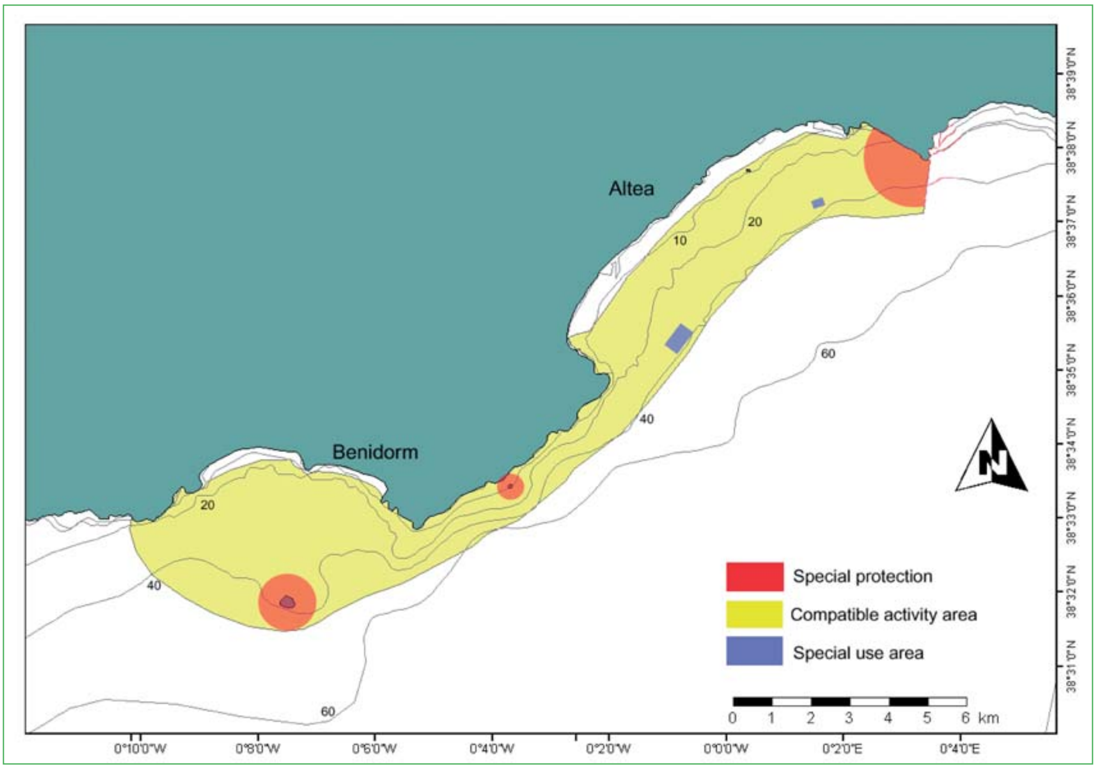
The effect of beach replenishment on artisanal fisheries was studied close to San Antonio Coastal Marine Reserve (Valle Pérez 2005). The results from this study suggest some negative effect of beach replenishment on some species targeted by commercial artisanal fisheries.

Fish assemblages have been studied in the area since 2000, using underwater visual census (UVC) as main sampling technique. The principal objective has been to study the temporal and spatial variations of fish assemblage in this MPA at several spatial scales, from 10s to 1000s metres (Forcada 2004) compared with control fished areas. The results exhibited higher densities and biomass for some target species (e.g. *Epinephelus marginatus*, *Dentex dentex*) inside this protected areas. However, and despite the greater habitat quality in this area, fish assemblage parameters (mean abundance, biomass, and species number) from San Antonio were lower than in Tabarca Island Marine Reserve. These differences were blamed to differences in total size of the marine protected areas. In theory, as the size increases, the variety of habitats is enhanced, resulting in an increase in fish richness, abundance and biomass. Although Tabarca harboured less percentage of rocky cover, its greater size incorporate higher amounts of the different habitats required by the different life stages of fish, and would result in a more diverse assemblage.

On the other hand, the results exhibited a different temporal variability for some target species in the San Antonio Marine Reserve, usually targeted intensively by fishing. Over time, biomass of *Dentex dentex*, *Diplodus vulgaris* and, particularly, *Epinephelus marginatus* tended to decrease in this MPA. The accentuated temporal variability in this MPA can be due to the contrasting movement patterns among species with some individuals remaining in the MPA, whilst others move outside up to some kilometres away. In this sense, the San Antonio Marine Reserve can permit high transfer rates between reserve and exploited areas, and concomitant loss of spawning stock as motile individuals disperse beyond reserve boundaries, increasing their vulnerability to fishing outside the MPA.

4 Serra Gelada - Benidorm islets (Spain)

Contributors: Celia Ojeda-Martínez, Aitor Forcada-Almarcha, Carlos Valle, Carmen Barberá-Cebrián, Pablo Sánchez-Jerez & Just T. Bayle. Unidad de Biología Marina, Departamento de Ciencias del Mar y Biología Aplicada, Universidad de Alicante, Spain.



General features

Legal Status	Natural Park
International Recognition	Site of Community Importance "Serra Gelada i litoral de la Marina Baixa" (ES5213021) Special Protection Area (Birds Directive) Illots de Benidorm (ES 0000121)
Foundation Text	Order of Regional Government 129/2005, 29th July 2005
Legal References	DOGV nº5062
Relevant Administration	Regional Ministry of Environment
Management Body	Representatives of Regional Ministry in Alicante
Consultative Committee	Consultative committee
Main Marine Species	*Epinephelus marginatus, Epinephelus costae, Epinephelus aeneus, Mycteroperca rubra, Sciaena umbra, Dentex dentex, Seriola dumerili, Mullus surmuletus, Dendropoma petraeum, Posidonia oceanica, Cymodocea nodosa, Cystoseira* spp. and *Pinna nobilis*
Marine Area Surface	Total marine surface: 4,920 ha
Web page	

Regulations

Activities	Area of special protection	Compatible activity zone	Area of especial use
Forbidden	Recreational fishing	Recreational fishing (spear fishing)	
Regulated	Recreational diving, scientific research, professional fishing, anchoring	Professional fishing, anchoring	
Allowed	Swimming, boating	Recreational fishing (angling), recreational diving, swimming, boating, scientific research	Only fish farm activities

Other Management Initiatives

Monitoring

Surveillance

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Serra Gelada – Benidorm islets: ecological studies

▪ General

Fish assemblages

Fish assemblages have been extensively studied in the area since 1996, using underwater visual census (UVC) as main sampling technique, to study the temporal and spatial variations of fish assemblage at several spatial scales, from 10s to 1000s metres (Bayle 2002; Forcada 2004; Sánchez-Jerez *et al.* 2007). Metallic trace elements were studied in otholits of *D. vulgaris* to define their suitability as markers to assess the spillover from MPAs (Gillanders *et al.* 2001), and the results showed a very low variability among different locations along Alicante coast.

Benthic assemblages

Some technical studies were carried out on the distribution and abundance of *Pinna nobilis* (Sánchez Jerez *et al.* 2003), *Dendropoma petraeum* (Bayle *et al.* 2004) and echinoderms (Sánchez Jerez *et al*. 2005). Density of edible sea urchins (*P. lividus*) was six times higher within this protected area. Descriptive studies on maërl beds and the associated macrofauna were carried out in Serra Gelada – Islets of Benidorm Natural Park (Barberá *et al.* 1999, 2003; Bordehore *et al.* 2000a, 2000b, 2003). A recent study focused on the effects of diving activity on benthos (Luna *et al.* 2007).

▪ Indirect effects (trophic cascades, changes in assemblage – trophic structure, etc.)

Studies about changes in fish assemblage structure, as well as on sea urchins (see above) can be considered in the framework of indirect (trophic) effects of protection.

5 Columbretes islands (Spain)

Contributors: Ben Stobart & Raquel Goñi.

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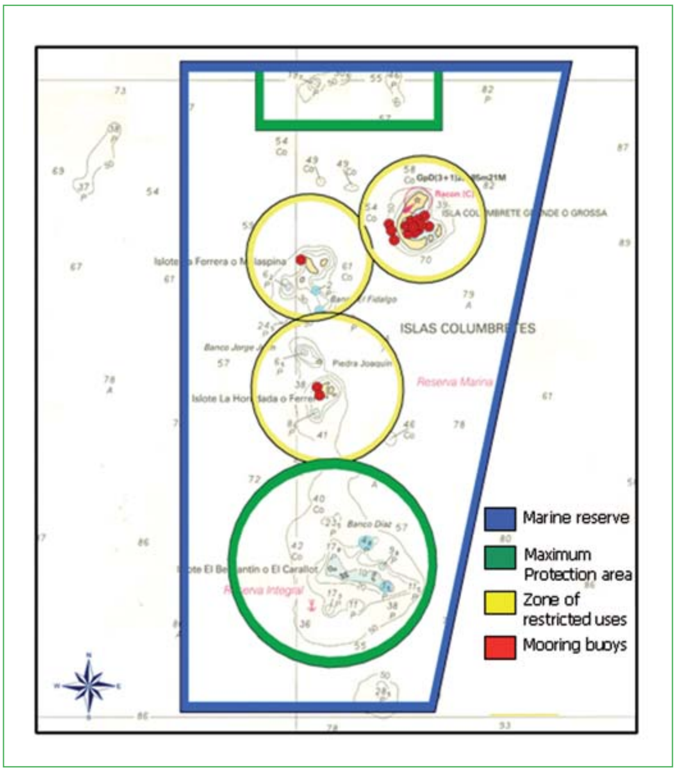

General features

Legal Status	Marine fishery reserve
International Recognition	Barcelona Convention 2001 "Specially Protected Areas of Mediterranean Interest" (SPAMI)
Foundation Text	Ministerial order 19/04/1990
Legal References	B.O.E. nº 97, 23rd April 1990
Relevant Administration	Ministry of Agriculture, Fisheries and Food
Management Body	General Secretariat of Marine Fisheries
Consultative Committee	Consultative Advisory Committee
Main Marine Species	*Palinurus elephas, Epinephelus marginatus, Mycteroperca rubra,* Maërl communities, gorgonians, *Cymodocea nodosa* & noted absence of *Posidonia oceanica*
Marine Area Surface	Core area (no take): 1,883 ha Total area: 4,400 ha
Web page	http://www.mapa.es/rmarinas/index_rm.htm

Regulations

Activities	Integral reserve	Buffer zone
Forbidden	Trawling, spear-fishing, recreational fishing, anchoring	Trawling, spear-fishing, anchoring
Regulated	Scuba-diving	Recreational fishing, scuba-diving
Allowed	Cruising	Cruising

Other Management Initiatives

Mooring areas

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Columbretes islands: ecological studies

▪ General

There is a very good general guide to the flora and fauna of the Columbretes islands edited by Templado & Calvo (2002). This book includes a comprehensive species list for the Columbretes islands and good habitat descriptions. Other general information on the legislation and establishment of the park can be found in Jimenez Pérez (1995) and González-Serrano & Revenga (1998).

Fish assemblage

Few studies of fish assemblages have been undertaken at Columbretes. García-Charton *et al.* conducted UVC surveys in 1996 as part of a large scale MPA survey (García-Charton *et al.* 2004). There is also a National Museum of Natural History report on the effect of recreational fishing on the Columbretes marine reserve (Calvo & Templado 2002). Some information on the fish assemblages found at Columbretes is also available in Martin & Vilar (1990).

Benthic communities

The most comprehensive work on benthic communities at Columbretes is contained in a monograph that includes work on algae, foraminiferans, cnidarians, briozoans, molluscs, ostracods, decapods and ascidians (Matilla *et al.* 1991). This monograph also contains information on the geology and terrestrial flora and fauna of the Columbretes. By far the most extensive study of a benthic species has been that carried out for the past 9 years by the Spanish Institute of Oceanography on the spiny lobster (*Palinurus elephas*). Work completed to this date by the institute includes studies on lobster diet (Goñi *et al.* 2001a), sustainability of the fishery (Goñi *et al.* 2003a), differential catchability of male and female lobsters (Goñi *et al.* 2003b), reproductive biology (Goñi *et al.* 2003d), population dynamics (Goñi *et al.* 2001b), effect of protection (Goñi *et al.* 1999; Goñi & Reñones 2003c), spillover (Goñi *et al.* 2006), and general biology (Goñi *et al.* 2003c).

Studies are also currently being undertaken on the fan shells, *Pinna nobilis* and *Pinna rudis*, and the seagrass *Cymodocea nodosa,* as well as monitoring of *Cladocora caespitosa* colonies since 2003. There is also sporadic monitoring of mucilaginous aggregates and for disease in the spiny oyster *Spondylus gaederopus,* and regular dives to detect invasive species (Diego Kersting pers. comm.).

Reptiles

One study has looked at the distribution of loggerhead turtles (*Caretta caretta*) around the Columbretes islands and found no difference in the abundance of this species between the reserve and adjacent areas (Gómez de Segura *et al.* 2003).

▪ Reserve effect

Fish assemblage

The only study of this nature published to date is Reñones *et al.* (2001) that studied the abundance, size structure and mortality rate of *Scorpaena scrofa* and found that this species is significantly more abundant and larger inside the reserve compared to two control sites outside. Columbretes is also included in a study by García-Charton *et al.* (2004) which examines the effect of marine reserves on fish assemblages in rocky reefs, but no controls are available directly outside the Columbretes marine reserve for this study. Nevertheless, comparison of Columbretes fish assemblage with other protected areas shows that abundance and biomass (total and by species and species groups) and species richness is similar to other MPAs included in this study, which in turn are generally higher than unprotected sites.

The Spanish Institute of Oceanography has also collected data on several other fish species that will be included in future papers on the effect of the reserve (Goñi pers. comm.).

Lobsters (*Palinurus elephas*)

Goñi *et al.* (1999, 2003a, 2003c) studied the reserve effect on lobster populations at Columbretes and found that lobsters are more abundant inside the reserve than in adjacent fished areas, and that the average size of both male and female lobsters is also greater inside the reserve than outside. The size structure of the lobster population in Columbretes has undergone a 'naturalization' process since the studies started in eight years after the creation of the reserve. The modal size and the proportion of large individuals of both males and females in the population have been increasing steadily since 1998 (Goñi *et al.* 2005).

The same team also studied the reproductive biology of *P. elephas* in the reserve and compared size at maturity, fecundity and spawning potential with those of fished populations (Goñi *et al.* 2003d). Fecundity at size was higher in the protected population, and the spawning potential per unit area was 5-18 times higher in the reserve than in fished grounds depending on their level of exploitation.

A comprehensive study of lobster catches involving sampling on-board commercial fishing vessels outside the reserve, and experimental fishing inside, showed a significant non-linear decline in lobster captures per unit of effort (CPUE) with distance from the centre of the reserve (Goñi *et al.* 2006). There was a depression in this decline near the reserve boundary associated with concentration of fishing effort in this area. Lobsters tagged inside the reserve and recaptured outside confirmed that the density gradient was caused by lobsters leaving the reserve. From the study it was concluded that export from the reserve is sufficient to maintain stable catch rates up to 1500 m from the boundary.

6 Anti-trawling zones (SE Spain)

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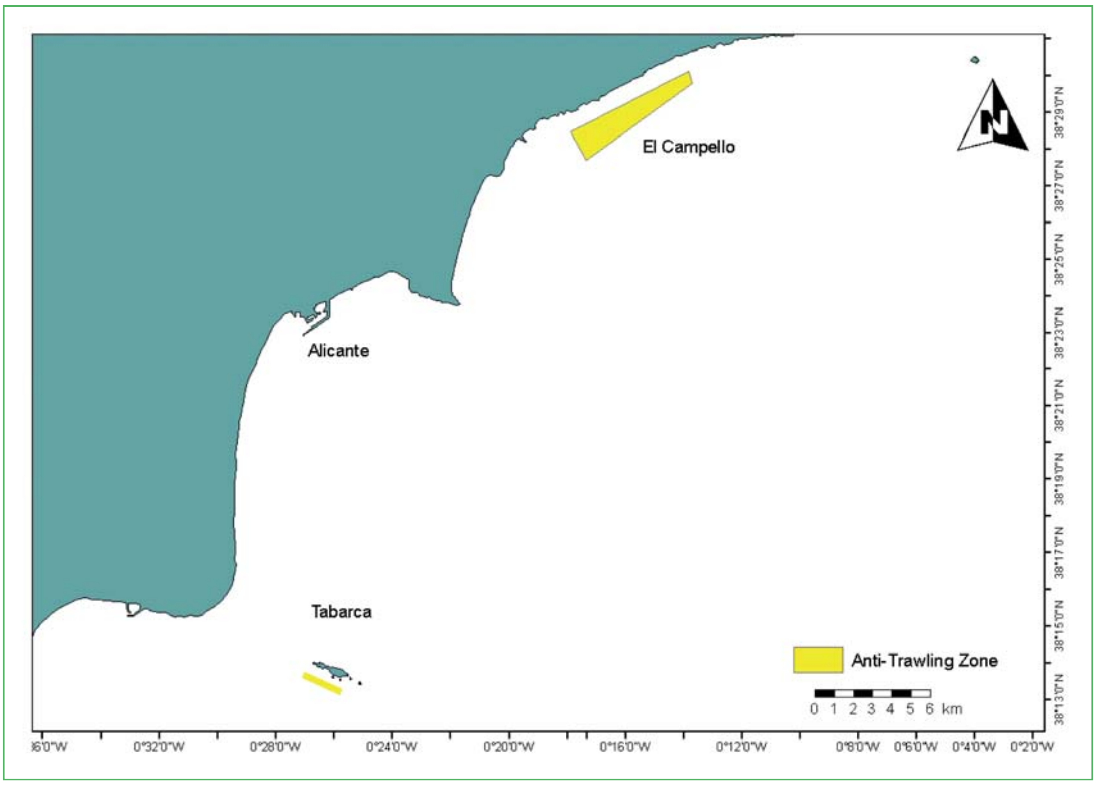

General features

Legal Status	Artificial reefs
International Recognition	
Foundation Text	
Legal References	
Relevant Administration	Regional Ministry of Agriculture and Fisheries
Management Body	Representatives of Regional Ministry in Alicante
Consultative Committee	None
Main Marine Species	*Epinephelus marginatus, Epinephelus costae, Epinephelus aeneus, Mycteroperca rubra, Sciaena umbra, Dentex dentex, Seriola dumerili, Mullus surmuletus, Dendropoma petraeum* and *Posidonia oceanica*
Marine Area Surface	20 – 800 ha
Web page	

Regulations

Activities	Anti-trawling zone
Forbidden	Trawling
Regulated	
Allowed	Professional fishing, recreational fishing, recreational diving, swimming, boating, scientific research

Other Management Initiatives

Scientific monitoring during the first three years

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Anti-trawling zones (SE Spain): ecological studies

▪ General

Fish assemblage

Fish assemblages have been studied in the artificial reef of Tabarca since 1990, using underwater visual census (UVC) as the main sampling technique. The principal objective has been to study the temporal and spatial variations of fish assemblage at several spatial scales, and define the colonization patterns in this kind of structures (Bayle 1994, 2002, 2001, 2003). Spatial distribution of fish assemblage associated with *Posidonia oceanica* beds near artificial reefs were studied widely (Valle Pérez 2000, 2005; Valle Pérez *et al*. 2001), reflecting the role of different ecological factors at each spatial scale.

Benthic communities

Benthic colonization was studied by Aranda & Boisset (1993) and results show evidence of high diversity of sessile species due to the structural heterogeneity of the artificial reef.

Effects on artisanal fisheries

Enhancement of artisanal fisheries around the artificial reef of El Campello were evidenced by Martínez-Hernández (1997), showing a significant increase of catches for *Mullus surmulletus*.

7 Medes islands (Spain)

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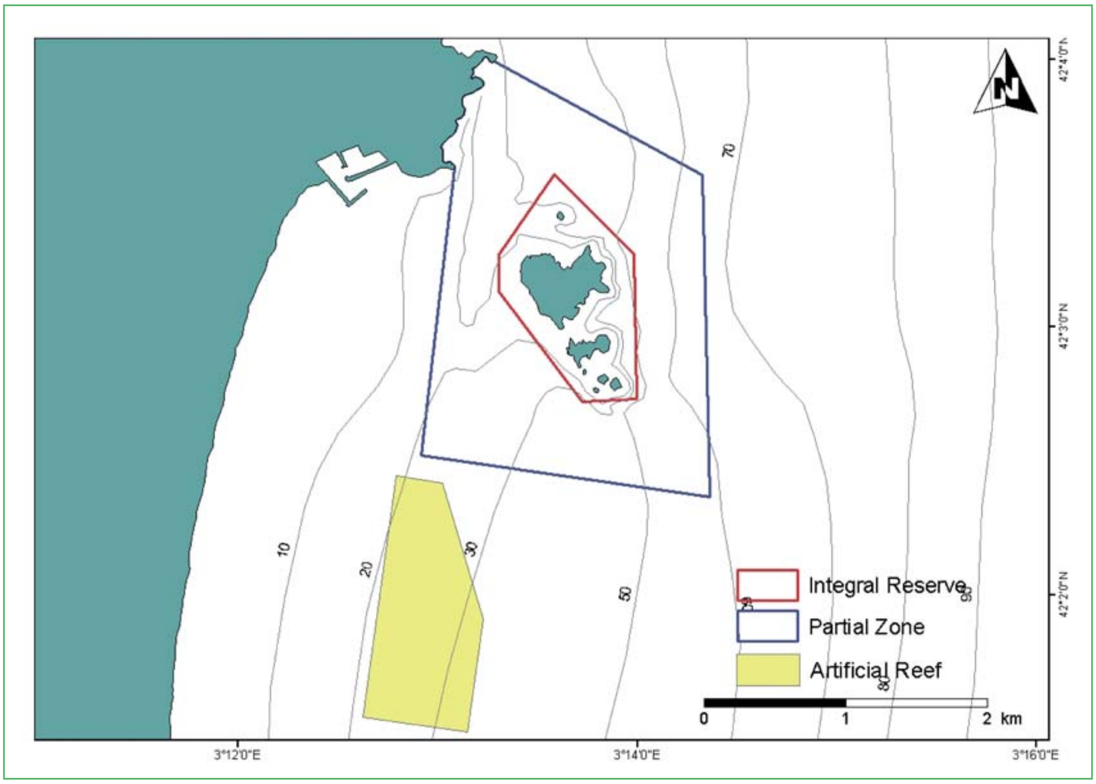

General features

Legal Status	Marine Natural Park
International Recognition	
Foundation Text	Order of 25th November 1983 by the Department of Agriculture and Fisheries (DARP) of the Catalan Autonomous Government
Legal References	DOGC 391, 21-12-83; complemented by law 19/90 of DARP (DOGC 1381, 17-12-90)
Relevant Administration	Department of Environment of the Catalan Autonomous Government
Management Body	Department of Environment of the Catalan Autonomous Government
Consultative Committee	Consell Assessor (Advisory Council) of the Marine Natural Park of Medes Islands
Main Marine Species	Main Species caught in the area of the Marine Reserve and landed in the nearby harbour of L'Estartit: Elasmobranchs – *Scyliorhinus canicula, Torpedo marmorata, Dasyatis pastinaca* Teleosts – *Conger conger, Diplodus* sp., *Lithognathus mormyrus, Lophius piscatorius, Mugil cephalus, Mullus surmuletus, Pagellus* sp., *Phycis phycis, Scophthalmus rhombus, Scorpaena* sp., *Solea vulgaris, Sparus* sp., *Sphyraena sphyraena, Trachurus trachurus*, Triglidae Decapods – *Homarus gammarus, Palinurus elephas* Cephalopods – *Octopus vulgaris, Sepia officinalis*
Marine Area Surface	Integral Reserve: 93 ha Partial Reserve: 418 ha
Web page	

Regulations

Activities	Integral Reserve (IR)	Restricted Use Area (RU)
Forbidden	All extractive activities (commercial fishing, angling, spear fishing)	Spear fishing, trawling
Regulated	Scuba diving, swimming, anchoring, scientific research	Artisanal fishing
Allowed	Boating (navigation)	Scuba diving, recreational fishing, boating, anchoring

Other Management Initiatives

Artisanal fishing in the Partial Reserve is allowed for licensed boats of L'Estartit only

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Medes Islands: ecological studies

▪ General

The underwater habitats of the Medes Islands have been studied since the early 1970's by ecologists from the University of Barcelona (Zabala 1993) and the Spanish National Research Council (CSIC, laboratories in Blanes and Barcelona) in the framework of different research programs and with different objectives. One of the earliest scientific achievements was the compilation of the fauna and flora of the Medes Islands ecosystems, both terrestrial and marine (Ros *et al.* 1984a). These earlier studies were of a descriptive nature, prior to the establishment of the marine reserve and culminated in the monograph "The Natural Systems of the Medes Islands", including a detailed physiographic chart of the sea floor in the Integral Protection Zone (Ros *et al.* 1984a). Unfortunately, these studies did not use quantitative methods that would allow for the definition of a "before" state for the formal analysis of the reserve effect in time. However, the existence of similar biocenoses on the nearby coast (Montgrí) has allowed later studies of control/impact nature that helped determine the role of protection ("reserve effect"). The early scientific studies together with the interest in non-extractive human activities (scuba diving, eco-tourism) led to the creation of the Marine Reserve in 1983, with later amendments (1991). Since 1989 a monitoring research plan by the Autonomous Government of Catalonia has planned to increase the scientific knowledge of the Medes Islands Marine Reserve (MIMR) and has produced numerous publications in scientific peer-reviewed journals as well as the "grey" literature. The focus of this research are benthic organisms such as the gorgonian *Paramuricea clavata*, the red coral *Corallium rubrum*, the sea urchin *Paracentrotus lividus*, the spiny lobster *Palinurus elephas*, and the rocky fish assemblage, especially the dusky grouper *Epinephelus marginatus*.

▪ Reserve effect (including genetic effect)

Fish assemblage

Fish assemblages have been extensively studied in the area since 1989 using underwater visual census (UVC) as main sampling technique (Garcia-Rubies & Zabala 1990). The results show an important increase in the abundance of the grouper *Epinephelus marginatus* compared to nearby unprotected locations and within the MIMR previous to the establishment of the reserve. The entire rocky fish assemblage has been positively impacted by the establishment of the reserve, according to different indicators: increase in species richness, increase in the abundance of medium-sized and large individuals, increase in biomass of almost all fish species, but especially those of commercial interest (Garcia-Rubies & Zabala 1990). Other possible effects of protection on fish asemblages were the (non-significant) increase in fish mean size and increase in recruitment (Garcia-Rubies & Zabala 1990).

UVC monitoring showed that MIMR harbours a very rich and diverse fish assemblage as compared to unprotected areas (Garcia-Rubies & Zabala 1990). This is very clear with species that are the object of spear-fishing, which are practically confined within the protected area, such as *Epinephelus marginatus* or *Sciaena umbra*. Species vulnerable to other types of fishing (recreational, commercial) also were more abundant within the reserve, except *Serranus cabrilla* and *Mullus surmuletus*. The main piscivorous fish species (*E. marginatus*, *Dentex dentex*, *Dicentrarchus labrax*, *Sphyraena sphyraena*, *Pomatomus saltatrix*, *Scorpaena scrofa* and *Seriola dumerili*) are extremely abundant in the protected sites of the MIMR compared to the nearby unprotected coast, where they are caught by commercial and recreational fishers (Macpherson *et al.* 2000). On the contrary, small predatory fish or small individuals of the large piscivorous species are not affected by the "reserve effect" and have similar densities in protected and unprotected areas (Macpherson *et al.* 2000).

Larval fish assemblages have been studied in the MIMR and nearby locations by Sabatés *et al.* (2003) using ichthyoplankton sampling protocols. The larval assemblages in the study area are composed by resident or shore fish species, shelf species and oceanic species, with different temporal patterns of abundance. The larvae of certain species (*Coris julis*, *Boops boops*, *Serranus hepatus*, Blenniidae and Gobiidae) undergo significant dispersal towards the open sea, suggesting that the MIMR and nearby unprotected rocky sites could be a source of propagules for these species. However, the abundance of larvae of resident, or shore, fish species was not significantly different in the protected and unprotected areas.

Benthic assemblage

Studies conducted in the 1980's and early 1990's showed that the algal cover around the Medes Islands was dominated by nitrophilous species and species provided with protection devices, interpreted by Zabala (1993) as a defense mechanism against the proliferation of herbivorous fishes due to the fishing ban. Conversely, after the fishing ban the population of some invertebrates, especially sea urchins, has decreased. The mean diameter of the branches of the red coral *Corallium rubrum* was larger in the reserve than in the adjacent unprotected coast (Zabala 1993). The density of spiny lobster *Palinurus elephas* seem to be lower within the reserved than in adjacent unprotected areas (Zabala 1993).

The abundance and population structure of the sea urchin *Paracentrotus lividus* have been studied in the MIMR by Sala and Zabala (1996) among others. The results show that *P. lividus* populations were 3-4 times denser and predation rates by fish were 5 times lower in unprotected areas than in protected areas. Considering that fish are responsible for the major part of mortality of *P. lividus*, the high intensity of fishing in unprotected areas would explain the patterns observed. Additionally, Sala & Zabala (1996) showed that the population structure of this species is determined by fish predation within the protected area of the MIMR, while recruitment success determines the population structure in unprotected areas.

- **Fish movement (including spillover)**

As in the other MPAs selected as case studies within the CE project BIOMEX (http://biomex.univ-perp.fr), studies have been undertaken to test the hypothesis that spillover from MPAs to neighbouring areas should have as a consequence the observation of gradients of fish biomass across boundaries. In Medes, this hypothesis is going to be tested by using UVC, baited video, and collection of fish eggs and larvae by plankton nets as sampling techniques, following a sampling design including several sites inside the MPA plus other sites outside the MPA (to the North). Results of these studies are being analysed at present.

- **Other biological (e.g. density-dependent) effects**

Natural mortality (*M*) rates were determined for five common species (*Coris julis*, *Diplodus annularis*, *Diplodus sargus*, *Serranus cabrilla* and *Symphodus roissali*) by UVC in the MIMR (Macpherson *et al.* 2000). This study showed low variability of *M* at seasonal and interannual scales. The mortality rates were not affected by a "reserve effect", i.e. they were not significantly different between the protected and unprotected study sites of the MIMR. This finding was explained by the higher abundance of piscivorous predators in the protected areas, which are the main cause of natural mortality in fishes.

Macpherson *et al.* (1997) evidenced a density-dependent effect on mortality from settlement to recruitment to the adult population in three species of sparid fishes, *Diplodus puntazzo*, *D. sargus* and *D. vulgaris*. This density-dependent effect on mortality of settlers explained the low variability in year-class strength for the three species studies. Additionally, this study showed that mortality rates did not differ significantly in protected and unprotected areas of the MIMR, suggesting that marine reserves are not necessarily a sink for post-settlement fishes.

The MIMR has also allowed for interesting studies on the reproduction and territoriality of the dusky grouper *Epinephelus marginatus*, scarce elsewhere in the Mediterranean (Zabala *et al.* 1997a, 1997b). These authors reported the first observations on reproductive behaviour in this species by scuba diving surveys in 1996. This study also showed that *Oblada melanura* preys strongly on recently spawned eggs, suggesting that high densities of this sparid fish may undermine the reproductive success of the dusky grouper in the MIMR.

- **Effects on habitat (including impact of divers)**

MIMR receives ca. 60,000 divers per year, concentrated between April and September. Most divers visit the same diving places where buoys are located and maintained by the Park Service. The diving spots represent ca. 10% of the protected area. Comprehensive scientific studies on the impact of divers are lacking, but observations point to a noticeable erosion of the benthic communities around the preferred diving spots (Zabala 1993). Some landscape-forming invertebrates, such as the gorgonian *Paramuricea clavata*, the red coral *Corallium rubrum*, or fragile bryozoans, and the spiny lobster *Palinurus elephas* that have been intensively studied show the negative effect of excessive frequentation by divers on benthic assemblages (Zabala 1993).

Surveys of diving activity conducted from 1992 to 1995 on a study site where no diving was permitted before showed that diving increased 60-fold at the impact location. A significant decrease in the density of colonies of the bryozoan *Pentapora fascialis* was observed at the impact location one year after the start of the diving disturbance (Garrabou *et al.* 1998).

An undesired side-effect of excessive frequentation by divers is the possible change in behaviour of a paradigmatic species such as *Epinephelus marginatus*, which has become accustomed to hand-feeding by divers and is not shy to humans (Zabala *et al.* 1997a, 1997b).

- **Indirect effects (trophic cascades, changes in assemblage – trophic structure, etc.)**

Studies on the changes in fish assemblages and sea urchins derived from the establishment of the MIMR have shown the decrease of sea urchins parallel with an increase in herbivorous fishes in the MIMR, especially *Diplodus sargus*, *D. vulgaris* and *Coris julis* (Sala & Zabala 1996). Considering that the sea urchin *Paracentrotus lividus* is the major benthic herbivore in the NW Mediterranean, this study showed that the removal of fishing pressure on predatory fish would have a positive effect on herbivorous fishes, algal cover and sessile assemblages, through a cascade effect (Sala & Boudouresque 1997; Pinnegar *et al.* 2000).

8 Cerbère - Banyuls (France)

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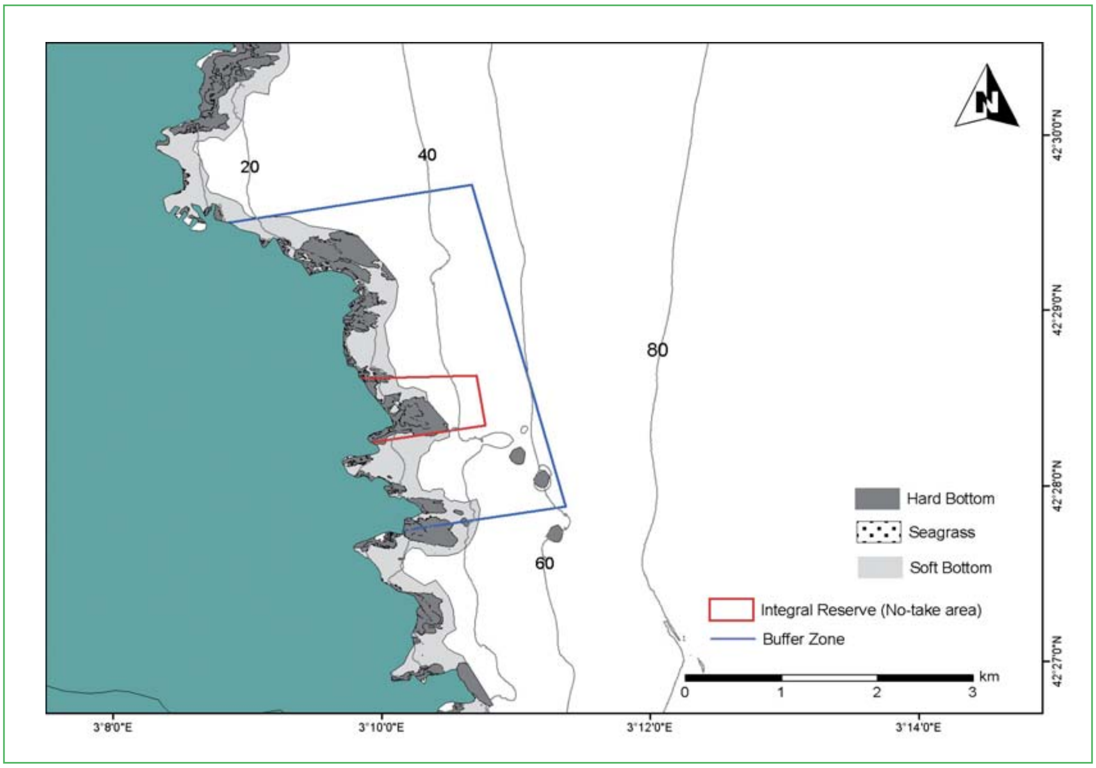

General features

Legal Status	Nature Reserve
International Recognition	NR included within the Natura 2000 site “Posidonie de la côte des Albères” (FR 910 1482)
Foundation Text	Order (26/02/1974) modified by decree n° 90-790 (6/09/1990)
Legal References	JORF (09/09/1990)
Relevant Administration	Ministry of Ecology and Sustainable Development
Management Body	Department of Pyrénées-Orientales
Consultative Committee	Scientific committee and Consultative committee
Main Marine Species	*Epinephelus marginatus, Sciaena umbra, Posidonia oceanica, Dasyatis pastinaca, Eunicella singularis*
Marine Area Surface	Buffer zone: 650 ha Integral reserve size: 65 ha
Web page	

Regulations

Activities	Integral Reserve	Buffer zone
Forbidden	Professional fishing, scuba diving, angling, spear fishing, anchoring	Spear fishing
Regulated	Cruising	Fishing, angling, anchoring, cruising
Allowed	Swimming	Swimming, scuba diving

Other Management Initiatives

Contractual agreements with diving centers

Underwater visits

Mooring areas

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www.cg66.fr/reserve_banyuls.htm

Cerbère – Banyuls: ecological studies

▪ General

Fish assemblage

Fish assemblages are being studied in the area since the first survey by Johann Bell using UVC (Bell 1983). Several studies (Tito de Morais 1980; Seloudre 1984) have been undertaken aiming at ascertaining the fish assemblage structure in relation to protection from fishing, finally leading to a check-list of fish species for the area (Jouvenel 1992, 1996). Some special emphasis has been devoted to the emblematic Mediterranean dusky grouper *Epinephelus marginatus* (Tissot 1998; Louisy *et al.* 2001)

Benthic communities

A complete characterisation of the substratum of the entire MPA was undertaken in 2001 (Ballesta 1997a; Lenfant *et al.* 2001a) with the objective to set a management plan for the MPA. Together with this global view, specific surveys were done in specific locations for *Lithophyllum lichenoides* (Fajon & Lestienne 1991), long-term dynamics of fucales (Thibaut *et al.* 2005), *Posidonia oceanica* beds (Pergent-Martini & Pergent 1989, Ballesta 1997, Claes 2000), red gorgonians (Martinie De Maisonneuve 1996), red coral (L'Œil d'Andromède 2004), *Pina nobilis* (Guille & Medionie 1996; Cazes & Gazeilles 1997), sea urchins (Laspougeas 1994), the ascidian *Microcosmus* sp. (Monniot 1965), and ichtyoplankton assemblage (Crec'hriou 2000).

▪ Reserve effect (including genetic effect)

Fish assemblage

Several surveys have been undertaken with the objective to quantify the impact of the MPA on the fish assemblage in the Cebère/Banyuls MPA. Most of the studies come from UVC projects (Bell 1983; Jouvenel 1992; Cadoret 1993; Licari 1993; Dufour *et al.* 1995; Hertel 1995; García-Charton & Planes 2002). Fish families responding the best to protection measures are serranid (groupers and combers) and sparid (sea-breams) species.

Superimposed to the reserve effect, a “habitat effect” on ichtyofauna is apparent, derived from the existence of rocky habitats being more complex than neighbouring unprotected areas (García-Charton & Planes 2002). Hence, some fish species appeared to be more abundant and/or big in size in unprotected areas used as control sites (some labrids, other sparids, striped red mullet, etc.), because they show affinities for heterogeneous bottoms (i.e. with a major cover by *Posidonia* and/or sand, which are more frequent in unprotected sites).

The population of the MPA did not reveal any genetic differentiation compared to surrounding areas (Lenfant 1998). Comparing *D. sargus* genetic structure within Cerbère/Banyuls with unprotected sites, and with other MPAs –including other EMPAFISH case studies, such as Cabo de Palos and Tuscany archipelago, as well as control, unprotected sites (González-Wangüemert *et al.* 2002, 2004; Pérez-Ruzafa *et al.* 2006), it is observed that protected areas show significant higher allelic richness than unprotected sites. In parallel, islands showed lower level of heterozygosis and higher heterozygote deficit compared with coastal areas, making clear the importance of considering the connectivity processes when designing an MPA.

Benthic assemblage

The abundance and size structure of sea urchins (*Paracentrotus lividus*) have been compared between partial reserve and unprotected areas (Laspougeas 1994; Skaki 1997; Lecchini 1999) in relation with the fishing pressure (Binche 1987a). Density of edible sea urchins (*P. lividus*) was three times higher within the marine reserve together with an average larger size inside the MPA.

Similar approach was also undertaken for *Mytilus galloprovincialis* (Jacquet 1999) considering both the MPA effect together with the location and the accessibility. The result shows a larger size of individuals in the MPA, but the distribution is extremely biased by the accessibility of the mussels.

▪ Fish movement (including spillover)

A preliminary work was targeted into the determination of a biomass gradient through the MPA limits (Garcia-Charton & Planes 2002) considering the variability in the substratum. The result demonstrated a significant gradient in the southern areas and not in the northern, suggesting some export of biomass from the MPA. Within the CE project BIOMEX (http://biomex.univ-perp.fr), studies have been undertaken to test the hypothesis that spillover from MPAs to neighbouring areas should have as consequence the observation of gradients of fish biomass across boundaries. In Cerbère/Banyuls, this hypothesis is going to be tested by using UVC, baited video, collection of fish eggs and larvae by plankton nets, and experimental fishing as sampling techniques, following a sampling design including several sites inside the MPA plus other sites outside the MPA (to the North, and to the South). Results of these studies are being analysed at present (see section 4 below).

Tele-acoustic works are under development presently to investigate movement of grouper and sparids across the MPA boundaries (Lenfant *et al*. in prep.).

▪ Effects on habitat (including impact of divers)

The MPA of Cerbère/Banyuls receives ca. 25,000 divers per year, this activity concentrating mostly in summer, and principally in 2 diving spots. Impact of divers on benthos are under survey by comparing, each year, the density of a series of benthic species selected as indicators (algae, sponges, cnidarians, echinoderms, bryozoans, polychaetes and ascidians) just before and after summer, in both partial (where diving is allowed) and integral reserve areas, using permanent transect approach. Specially, the white gorgonian *Eunicella singularis* is being monitored in terms of density and morphometric descriptors.

Together with the survey of diver a survey of area surrounding the recreational free-diving walk is also monitored from year to year (Métivier 1996; Montagné 2000; Planque 2001). Finally, the activity of recreational fishing, partly permitted in the MPA is also surveyed (Démaret 2002).

▪ Indirect effects

Studies on the changing effects of *Sarpa salpa* on *Posidonia oceanica* beds are presently being conducted (Ferrari, unpublished data). First results are demonstrating that by protecting herbivory fish the MPA result in higher grazing on *Posidonia*, and the seagrass is reacting by developing larger underground structure to be able to produce more roots per individuals. Similar studies are in progress with sea-urchin as well.

9 Côte Bleue (Carry-Le-Rouet & Cap Couronne) (France)

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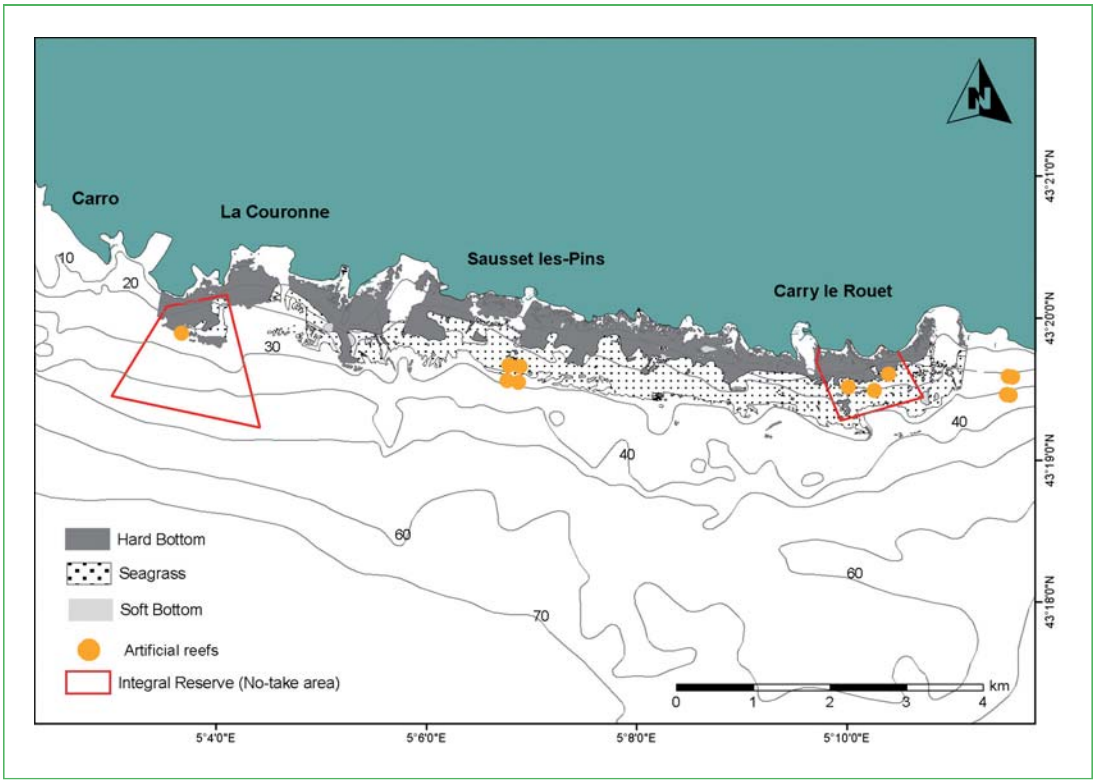

General features

Legal Status	Marine Park
International Recognition	
Foundation Text	Arrêtés spécifiques / Specifics orders (1983/1993/2000) Arrêtés d'extension / Extension orders (15/12/2003; 16/12/2004)
Legal References	JORF (09/09/1990)
Relevant Administration	Maritime Affairs Administration
Management Body	Management Consortium (5 municipalities [Martigues, Sausset-les-Pins, Carry-le-Rouet, Ensuèsla- Redonne, Le Rove], Région Provence-Alpes-Côte d'Azur, Département of Bouches-du-Rhône, and as associated members, fishermen representants)
Consultative Committee	Scientific Committee (2001)
Main Marine Species	*Sciaena umbra, Sparus aurata, Dentex dentex, Diplodus cervinus, Sarpa salpa, Gobius cruentatus, Homarus gamarus, Epinephelus marginatus, Posidonia oceanica, Corallium rubrum, Paramuricea clavata, Pinna nobilis, Litophaga lithophaga*
Marine Area Surface	Intervention area (surveillance and artificial reefs): 9,873 ha Integral reserve : 295 ha
Web page	

Regulations

Activities	Integral reserve
Forbidden	All types of fishing, professional fishing and recreational fishing including spear fishing, scuba diving, anchoring
Allowed	Swimming, snorkeling, cruising, boating

Other Management Initiatives

Underwater visits

Environmental education with local schools

Artificial reefs

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Côte Bleue: ecological studies

▪ General

Fish assemblage

Fish assemblages have been studied in the area around the Parc Marin de la Côte Bleue (PMCB) since 1983, using underwater visual census (UVC) as main sampling technique (see "reserve effect").

Benthic communities

Sedimentary dynamic of the occidental part of the Gulf of Fos was studied by Vernier (1972) and Roux & Vernier (1975) and macrofauna during Aquitanian period by Catzigras (1943). Sartoretto studied growth and bioerosion of coralligenious bottoms in 1996. The mapping of *Posidonia oceanica* meadows was done in 1980 by Cristiani, and in 2001/2002 by IFREMER & GIS-Posidonie (Bonhomme *et al.* 2002). Characterization of benthic biocœnoses in the area of Côte Bleue was done by Bellan *et al.* (2001). Pollution impacts were studied on hard bottom populations (Desrosiers 1977; Hong 1980) and macrobenthos near the effluent discharge of wastewater treatment plant (Ramade-Gerim 1983, 1994, 2000; Pergent-Martini *et al.* 1995).

Posidonia oceanica meadows are regularly monitored by GIS-Posidonie and PMCB (Charbonnel & Bonhomme 1998; Charbonnel *et al.* 2001a, 2003; De Maisonneuve *et al.* 2001; Daniel *et al.* 2002; Charbonnel 2004; Ruitton *et al.* 2006). Regression processes of *Posidonia* meadows are actually studied in the Côte Bleue as well as in other sites of the French Mediterranean coast by Mayot *et al.* (2003). Two surveys were dedicated to the invasive alga *Caulerpa racemosa*, that has started to colonize the Côte Bleue coast (De Maisonneuve *et al.* 2001, 2002).

In 1998/1999 a survey of red coral (*Corallium rubrum*) was started inside the protected areas of Carry and Couronne by Harmelin and the Marine Park team (Garrabou *et al*. 2001; Garrabou & Harmelin 2002). Another survey of red coral began in 2004/2005 in both reserves (Torrents-Cabestany 2003). *Pinna nobilis* was censused by Vicente (2002).

Planktonic assemblages

Circulation of water masses was studied by Castelbon in 1972, and Kim studied microplankton around Carry-le-Rouet in 1980. BIOMEX European program included ichtyoplancton study and currents modelisation from Carry-le-Rouet to Sausset-les-Pins.

▪ Reserve effect

Fish assemblage (UVC detectable species)

Fish assemblages have been studied in 1992 in both reserves, inside and outside, using UVC as the main sampling technique (Harmelin & Bachet 1993). The principal objective was to evidence regeneration of communities and habitats, the second one was to demonstrate the possibilities of managing fishing resources, by benefiting artisanal fishing métiers. The first studies started in 1983-1985-1986 with Ody and Bregliano using visual census, to look at reserve effect on species composition, densities and biomasses of fishes (Bregliano 1985; Ody 1987). The fish fauna of artificial reefs has been compared to the one of rocky bottoms. From 1989 to 1994 other surveys have been performed in the Côte Bleue by Harmelin and Bachet, and a special survey has been dedicated to target species of reserve effect (1995, 1999, 2001) (Harmelin 1995, 1999; Daniel *et al.* 1999). Fish indices have been developped by Harmelin with the PMCB team in 1999 and 2001/2002. The impact of protection has been evaluated inside the reserve of Carry and Couronne by a presence/absence test with target species (Daniel *et al.* 2002).

UVC monitoring program conducted in Couronne since 1995 (before implementation of the reserve) showed how specific composition of fish fauna was restored. Noble species came back since 2001 (Jouvenel *et al.* 2002). The fish fauna is surveyed every 3 years (1998/2001/2004) by visual censuses and experimental fishing (Jouvenel *et al.* 1995, 1998, 2002). Abundances of different species increase since 1995 inside the protected area. Since 2001, densities are more equilibrated between protected and unprotected zones, as a likely indication of spillover across the boundaries. The biomass increases inside the MPA and is amplified when artificial reefs effect is added to reserve effect, despite decreasing biomass of prey species that is probably linked to predators increasing as *Dicentrarchus labrax*. The demographic structure is more balanced inside the reserve, and since 2004 natural mortality is the main structuring factor in fishes assemblages.

Fish assemblage (commercial species)

The use of standardised experimental fishing is complementary to UVC, and provides data concerning the nocturnal fish fauna and precise measures of length and weights of caught fishes inside and outside the reserve of Couronne. Moreover, simulations of professional and/or recreational fishing inside and outside the reserves allow evaluations of yields around the protected area.

Standardised experimental fishing program has shown an increase of mean species richness per unit effort between 1995 and 2004 (4.4 to 7.4 species/E.U.). Captures and individual mean weights were constantly increasing since 1995 inside the marine reserve (92 to 246 individuals; 110.7 to 216.4 g/individual). Yields were increasing in the protected area as compared to boundaries (1,077 to 4,570 g/E.U.) with more *Mullus surmuletus* and *Phycis phycis*. Simulations of recreational line fishing showed also an amplification of biomass increase on natural grounds inside the reserve.

When reserve effect was combined with artificial reefs effect, biomass was rapidly increased, reaching 671 g/m^3 of artificial reef. Since 2004, installation of *D. labrax* and *Conger conger* seemed to regulate the abundance of other species around the reef. Fish families more sensible to protection measures – having higher abundance and/or biomass within the MPA, are serranids (groupers and combers) and sparids (sea-breams) species. Groupers (*Epinephelus marginatus)*, *Dentex dentex* and *Dicentrarchus labrax*, which are targets of artisanal and recreative fishing (spearfishing) are now well represented inside the reserves.

Benthic assemblage (commercial species)

The abundance and size structure of sea urchins (*Paracentrotus lividus* and *Arbacia lixula*) have been surveyed from 1985 to 1987 (by L. Le Diréach and F. Bachet) in relation to habitat structure. Stock assessment of urchins and transplantation experiments were conducted by San Martin (1995). There is a survey especially dedicated to *Paracentrotus lividus* in different sites of the Côte Bleue since 1994 (2 surveys per year) (Bachet *et al.* 2001, 2002, 2003).

▪ Artificial reefs (including colonization)

About ten immersions of artificial reefs have been realised since 1983 (2,500 m^3 of production reefs and 2,200 m^3 of protection reefs against trawling). First surveys on artificial reefs were conducted by Ody and Bregliano from 1983 to 1985 and 1987 using fish UVC and experimental fishing (Bregliano *et al.* 1985; Ody 1987). Charbonnel and Francour (1994) conducted another survey on the Côte Bleue artificial reefs in 1993. Special attention was dedicated to colonization of experimental artificial reefs in 1995/1997, and long term evolution was studied in 2000 by Charbonnel on 5 sites of the PMCB (Charbonnel *et al.* 2000, 2001b, 2001c).

▪ Reserve effect and spillover

Within the European project BIOMEX, studies have been undertaken in 2003/2004 to test the hypothesis that spillover from MPAs to neighbouring areas should have as consequence the observation of gradients of fish biomass across boundaries. In Carry-le-Rouet, as in the other 6 Mediterranean reserves choosen for comparison, this hypothesis has been tested by using UVC, baited video, and collection of fish eggs and larvae by plankton nets as sampling techniques, following the same sampling design including several sites inside and outside Eastern and Western from the MPA (Le Diréach 2003).

▪ Other experimentations and scientific applications

Experiments using transplants of edible urchins (*Paracentrotus lividus*) were conducted in 1990 inside the PMCB perimeter. Surveys of the sea urchins were conducted inside the reserve of Carry in 1991/1992. Groupers (*E. marginatus*) caught by fishermen were tagged and released occasionnally inside the Carry reserve (Bachet & Jouvenel 1999).

Temperature is continuously recorded inside the reserves at 10, 17 and 23 m depth since 1998 (De Maisonneuve *et al.* 2001, 2002; Daniel *et al.* 2003).

The PMCB has coorganised three international symposia about marine ecology dedicated to *Paracentrotus lividus* (Boudouresque *et al.* 1987), marine species to be protected in Mediterranean (Boudouresque *et al.* 1989), and biological and physical indicators of quality of marine environment (Boudouresque *et al.* 1993).

▪ Human impact and frequentation

In order to evaluate frequentation and quantify fishing pressure applied to both reserves, the PMCB started in 2003 a frequentation census of several fishing activities: artisanal professional fishing, spearfishing, linefishing from the coast and from boats and harvesting with a concentric zonation (Charbonnel 2003; Daniel & Pacchiardi 2003). Questions on management issues such as buoys, frequentation, and moorings are regularly reported by the MPA managers (Daniel & Maisonneuve 2002; Bachet *et al.* 2003). First informations about economic impacts of PMCB were reported in Bachet (1992).

10 Sinis - Maldiventre (Italy)

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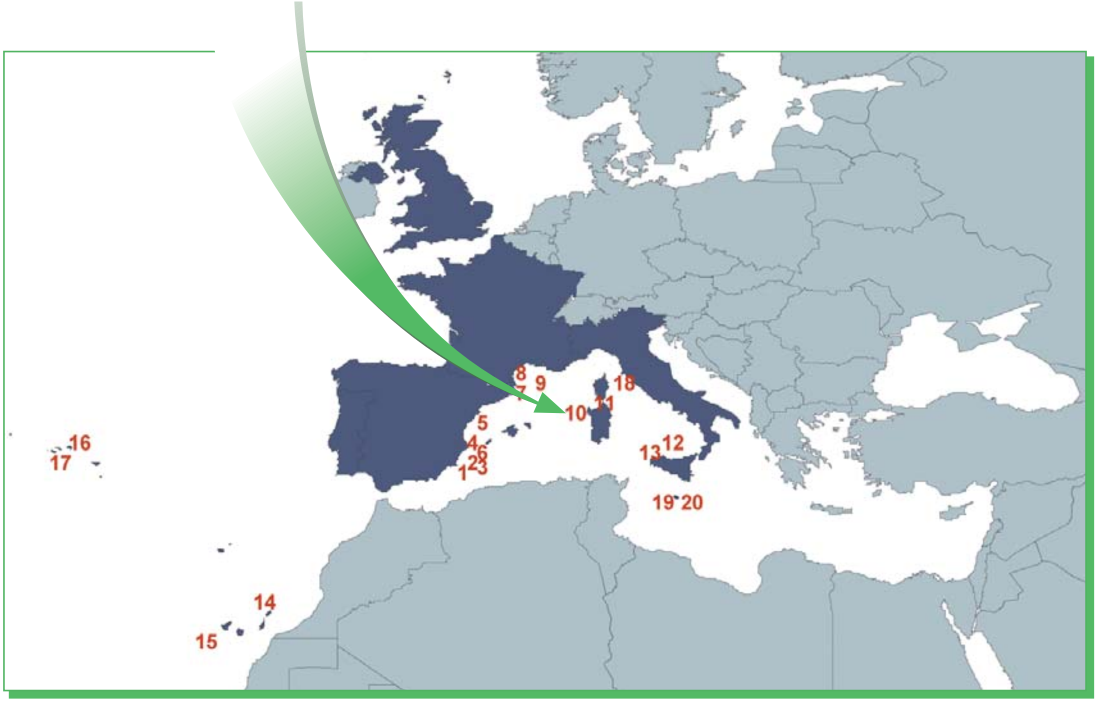

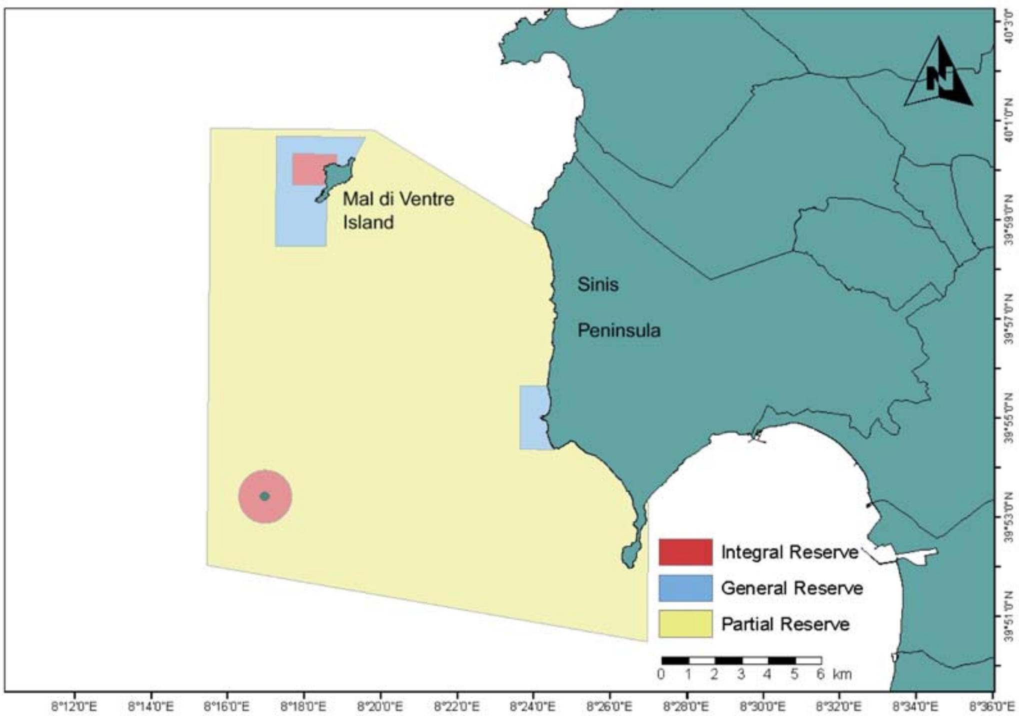

General features

Legal Status	Marine Protected Area
International Recognition	SIC, ZPS, EU directive 92/43; EU directive 73/409; MPA included within the Natura 2000 sites “Isola di Maldiventre ” (ITB 030039) and “Catalano” (ITB 030080)
Foundation Text	Decree 12.12.1997, integrally substituted by decree 06.09.1999, modified by decree 17.07.2003
Legal References	GURI n°45 (24/02/1998), GURI n°255 (29/10/1999) and GURI n°262 (11/11/2003)
Relevant Administration	Ministry of Environment and Protection of the Territory
Management Body	Council of Cabras
Consultative Committee	Reserve committee
Main Marine Species	*Posidonia oceanica, Paracentrotus lividus, Epinephelus marginatus, Sciaena umbra, Dentex dentex, Palinurus elephas, Phalacrocorax aristotelis, Larus ridibundus*
Marine Area Surface	Integral reserve (zone A): 529 ha General reserve (zone B): 1,031 ha Partial reserve (zone C): 24,113 ha
Web page	http://www.areamarinasinis.it

Regulations

Activities	Integral Reserve (zone A)	General Reserve (zone B)	Partial Reserve (zone C)
Forbidden	Fishing, scuba diving, boating, swimming, angling	Spear fishing	Spear fishing
Restricted	Scientific survey	Scientific survey, boat anchoring, fishing, scuba diving, angling, boating	Scientific survey, fishing, scuba diving, angling
Allowed		Swimming	Swimming, boating, anchoring

Other Management Initiatives

Mooring areas - Underwater visits - Environmental education - Scientific research

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Sinis – Mal di Ventre: Ecological studies

▪ General

Fish assemblages

Fish assemblages have been studied in the area just in recent years, after the establishment of the MPA, using underwater visual census (UVC) as the main sampling technique. A preliminary study was devoted to comparing the fish assemblages of the Sinis MPA with those of two other MPAs around the island of Sardinia (Murenu *et al*. 2004). A comparison between the MPA and reference areas was carried out in order to study potential differences in fish abundance and distribution, due to the different regulatory measures. Special attention was devoted to the sea-urchin consumers (i.e. *Diplodus sargus*, *D. vulgaris*, *Thalassoma pavo* and *Coris julis*) in order to evaluate cascade effects (Guala *et al*. 2006).

Benthic communities

Prior to the protection measures, work was devoted to describe the main biocoenosis in order to provide a scenario for the zonation of the future MPA (AA.VV. 1990). Preliminary mapping of main biocoenosis were provided by means of Side Scan Sonar and direct surveys (Chessa *et al*. 1990; Tursi *et al*. 1992); the environmental heterogeneity was evaluated by using 4 environmental descriptors: (i) morphology of landscape; (ii) lithotypes (structural elements of landscape); (iii) benthic assemblages; (iv) physical parameters (mesological characteristics) (Cocito & Bianchi 1992).

More recently, a preliminary study was carried out to compare the invertebrate assemblages associated to *Cystoseira* spp., comparing the Sinis MPA and other two MPAs around the island of Sardinia (Addis *et al*. 2004). Mapping and primary production of *Posidonia oceanica* meadows were carried out to assess the status of health of the ecosystem and to identify mooring sites for leisure boats (Cancemi *et al*. 2000; Baroli *et al*. 2001, 2003). The optimal habitat for the edible sea urchin *Paracentrotus lividus* was characterized in terms of environmental factors (i.e. substrate, wave exposition, abiotic variables, macroalgal % cover, *P. oceanica* density, leaf area index and epiphyte biomass); its abundance, size structure and distribution were assessed in 2004 and 2007 to identify management measures for the fishing activity of *P. lividus* along the MPA coasts (estimation of stock, fishing effort and captures) (Baroli *et al*. 2006, 2007; Diago 2007). The abundance, size structure and spatial distribution of *Pinna nobilis* were assessed in the southern part of the MPA in order to suggest management measures for the conservation of this species (Coppa *et al*. 2007, in prep.; Wrachien 2007).

▪ Reserve effect

Fish assemblage

UVC monitoring carried out in 2005 does not show significant differences in the richness and diversity of fish assemblage between the MPA and unprotected areas (Guala *et al.* 2006); management measures do not seem to be adequate, so far, to enhance the abundance of fish species. Differences in fish abundance were found at site scale, mostly related to the habitat structure rather than the degree of protection (in agreement with García-Charton *et al*. 2004). In particular, the number of species was found higher on rocky substrate compared to *Posidonia oceanica* beds and sandy bottom. Also, the insularity seems to play a more important rule for fish assemblage structure, with higher abundance in insular than in continental localities, independently from protection measures.

Benthic community

The abundance and size structure of *Paracentrotus lividus* have been evaluated within the MPA (integral and partial localities) and unprotected areas in 2005 (Guala *et al*. 2006). Total density was higher on rocky substrate than on *P. oceanica* meadow, a part from large individuals (diameter > 5 mm) which showed comparable values. Considering only the rocky substrate, significant higher density, due to the higher number of young individuals, was found in the unprotected localities. These results maybe attributable to differences in habitat structure: within the MPA the substrate is characterized by a lower complexity (*sensu* García-Charton & Pérez-Ruzafa 2001), because of basaltic and granite rocks, while sandstone substrate (with a higher number of crevices and hiding-places for young urchins) is dominant in the unprotected areas.

Macroalgal assemblages and *P. oceanica* meadow density have been studied within MPA (integral and partial localities) and unprotected areas in 2005 (Guala *et al*. 2006). Differences were mostly attributable to geographic factors (i.e. insularity, exposition, substrate) rather than to protection measures.

- **Effects on habitat (including impact of divers)**

A preliminary study on the state of submarine resources within the MPA was carried out to evaluate the influence of tourists' visitation on the structure of fish and benthic assemblages. A description of diving sites and relative benthic communities (target species) was done, also providing a qualitative evaluation (environmental and touristic value), in order to assess the risk of diving activity (sensivity of sites, impact indicators, carring capacity) (Massaro 2004).

- **Indirect effects**

Studies on the changes in fish assemblage structure, as well as on sea urchins and macroalgal assemblages (see above) are in progress to evaluate the possible indirect (trophic) effects of protection.

11 Bouches de Bonifacio (France / Italy)

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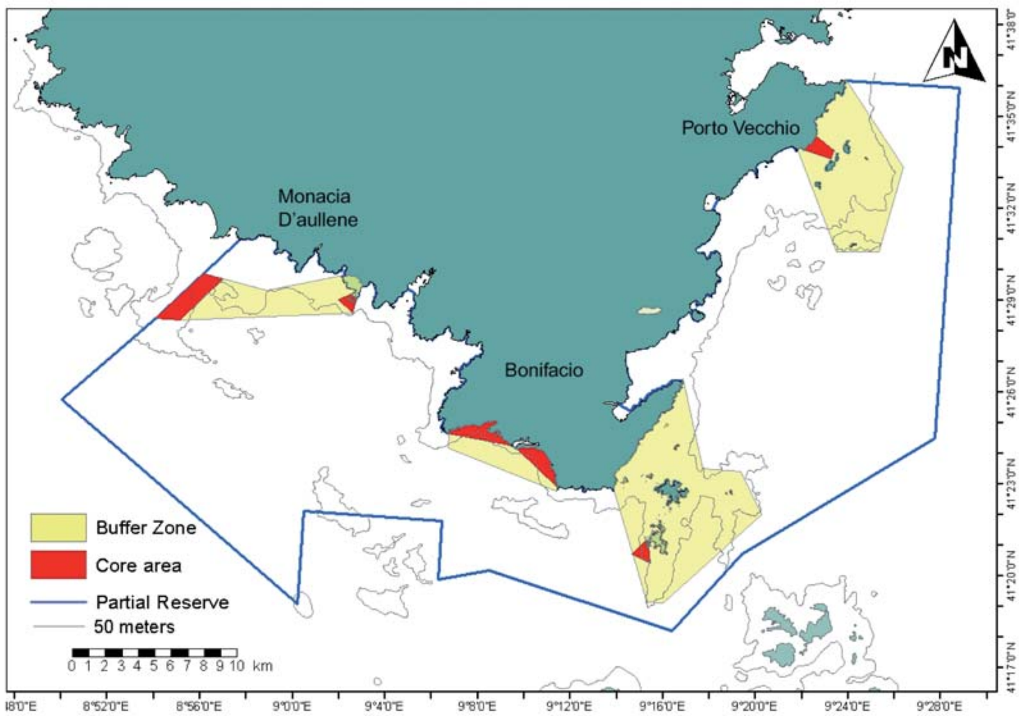

General features

Legal Status	Nature Reserve
International Recognition	French-Italian agreement protocol for the creation of an international marine park in the Bonifacio Straits
Foundation Text	Decree (23/09/1999)
Legal References	JORF n° 222, September 24th, 1999
Relevant Administration	Ministry of Ecology and Sustainable Development
Management Body	Corsican Environment Office
Consultative Committee	Scientific committee and Management committee
Main Marine Species	*Posidonia oceanica, Caretta caretta, Tursiops truncatus, Pinna nobilis, Patella ferruginea, Epinephelus marginatus, Sciaena umbra, Scyllarides latus, Centrostephanus longispinus, Corallium rubrum*
Marine Area Surface	Core area: 1,200 ha Buffer zone: 12,000 ha Partial reserve: 65,700 ha
Web page	http://www.parcmarininternational.com

Regulations

Activities	Integral Reserve	Buffer zone	Partial Reserve
Forbidden	Fishing, scuba diving	Spear fishing, Small net mesh size (<62mm), recreational coast angling, recreational longline	Small net mesh size (<62mm)
Restricted	Scientific survey	Scientific survey, fishing, scuba diving	Spear fishing, scientific survey, fishing, scuba diving, angling
Allowed	Boating, anchoring, swimming	Swimming, boating, anchoring, artisanal fishery	Swimming, boating, anchoring, artisanal fishery

Other Management Initiatives

Contractual agreements with diving centers
Underwater visits
Mooring areas

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Bouches de Bonifacio: ecological studies

▪ General

Fish assemblage

Fish assemblages have been extensively studied in this area since 1986, using underwater visual census (UVC) as main sampling technique. The principal objective has been to develop an inventory (Camus *et al.* 1987; Joyeux *et al.* 1988; Bouchereau *et al.* 1989; Tomasini *et al.* 1991). Some ecological studies including monthly variations, bathymetrics and biotops migrations (0-30 m) at Lavezzi Islands were carried out for 16 species fish (serranids, labrids and sparids) in 1992 in the rocky shores and *Posidonia oceanica* beds (Culioli 1996).

Benthic communities

The first inventories on the benthic fauna and algae have been carried out around Lavezzi islands (Frick *et al.* 1985; Chraibi & Ledoyer 1987; Verlaque 1991) and extended to the whole area of the Strait of Bonifacio (Sartoretto & Pergent-Martini 1995). The inventory and the cartography of the mediolittoral and superior infralittoral species have been carried out since 1994 and are regularly operated by the Bonifacio MPA management (Blacher *et al.* 1994; Javel *et al.* 2005).

▪ Reserve effect

Fish assemblage

UVC monitoring program started in southern Corsica in 1995 at the large scale for protected area (partial, integral before 1982) and unprotected areas for the rocky shore and *P. oceanica* seabeds in summer and winter (Culioli 1995). After the statistical studies on dispersion and sample size densities and biomass estimates (Mouillot *et al.* 1999; Mouillot & Culioli 2002), this monitoring were extended in 2002 to the northern of Sardinia with the support of the project of the international marine park (Culioli *et al.* 2003). After the creation of the Natural Reserve of Bonifacio Straits (1999), 15 stations for the Corsican part (in 2000, 2002 and 2005), and 12 stations for the Sardinian part (in 2002 and 2005) were monitored in order to compare the abundance and the biomass in the different regulations and managements situations.

The biomass index appears to be on average about 6 times higher inside the MPA than outside (i.e. in the areas that are either unprotected or with little surveillance). The biomass has increased two-three fold in two years, and four fold in 10 years, and six fold in 20 years (for *Sciaena umbra*, the increase has been 6, 17 and 38 times, respectively). In 2005, in the area of Cerbicale, biomass has increased three times since the ban on underwater spear fishing in 1999, reaching the level observed inside the MPA, and therefore proving the effectiveness of the MPA rules and their application (Culioli, unpublished data). In addition, unlike what happens in the areas outside the MPA, these values of biomass remain stable in the protected areas.

Benthic community

The abundance and size structure of *Patella ferruginea* have been compared between partial reserve and unprotected areas in the southern Corsica (Meier 2003). A positive trend in the populations of *P. ferruginea* has been noted in the areas of the MPA, particularly inside the protected area where a no-take zone was established. The role of hydrodynamics on the distribution of *P. ferruginea* has been confirmed by the fact that the highest number of individuals are found in the areas facing west. It is also interesting to note that a positive effect of the MPA was found in the sea urchin *Paracentrotus lividus*, for which a 25% difference was observed when comparing zones inside and outside the protected areas. Series of observations started in 2002 show a stabilization of the population level in the areas exploited by sea urchin fishermen (Culioli, unpublished data).

▪ Other biological (e.g. density-dependent) effects

Ethological studies on groupers (*Epinephelus* spp.) have allowed studying the demography and the territoriality of large males in the sites from Pellu to Lavezzi (Culioli & Quignard 1998). Inventories of dusky groupers (*E. marginatus*) populations have been carried out in the whole of the Bonifacio MPA (GEM 2001, 2003). The effects of certain environmental variables, such as lunar cycle and meteorological changes, have been demonstrated thanks to the fisheries studies on the MPA (Orsoni 2000).

▪ Effects on habitat (including impact of divers)

Impact of divers on *Paramuricea clavata* colonies was shown in the Pellu diving spot (Pichot 1998), a site that is highly frequented by divers. The *Posidonia oceanica* habitat has been studied in its inferior limits and in carrying out the cartography (Meinesz & Verlaque 1989). Since 1998, various studies have demonstrated a decrease in the size of the *P. oceanica* meadows in the bays of Santa Manza and Figari, in the most interior side of the bays (Ferrat *et al.* 2002). These meadows are characterised by reduced vitality, little growth and general detachment of rhizomes. The reduction in the *Posidonia* meadows can be explained by an increase in the sediment load and its enrichment by phosphates (Cancemi *et al.* 2003). The causes of this phenomenon have not be ascertained. A comparison with the Bay of Figari was carried out in order to test the possibility that reduction in *Posidonia* meadows is due to the organic input from aquaculture plants.

12 Ustica island (Italy)

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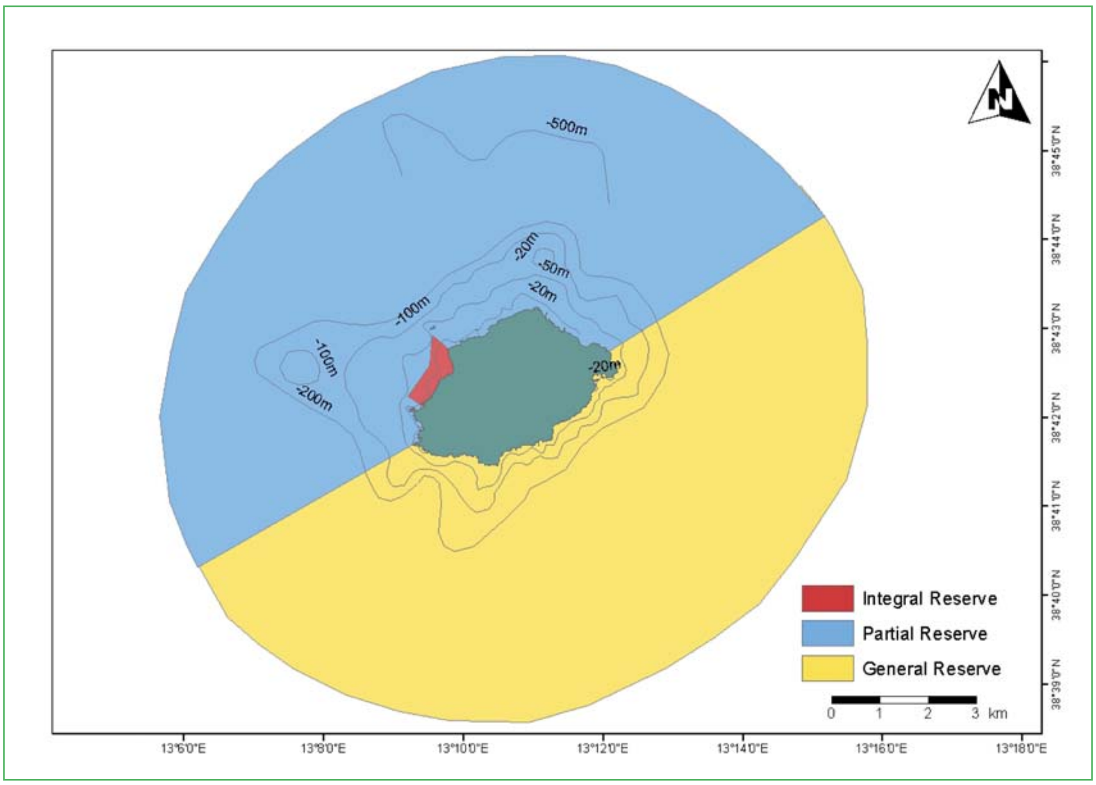

General features

Legal Status	Marine Natural Protected Area
International Recognition	
Foundation Text	Decree, November 12 th , 1986
Legal References	GURI n° 71 (26/03 /1987)
Relevant Administration	Ministry of the Environment and Protection of the Territory
Management Body	Palermo Harbour Authority (provisional management body)
Consultative Committee	
Main Marine Species	*Epinephelus marginatus, Sciaena umbra, Caretta caretta, Pinna nobilis, Erosaria spurca, Luria lurida, Paracentrotus lividus, Centrostephanus longispinus, Posidonia oceanica, Astroides calycularis*
Marine Area Surface	Total area: 15,961 ha Integral reserve: 60 ha Partial reserve: 7,901 ha General reserve: 8,000 ha
Web page	

Regulations

Activities	Integral reserve	Partial reserve	General reserve
Forbidden	All activities (including access)	Trawling, spear fishing, sea urchin harvesting	Trawling, spear fishing
Regulated		Professional fishing (small scale fishery) is limited to local boats	Professional fishing (small scale fishery) is limited to local boats
Allowed	scientific research, swimming permitted in two small beaches	Scuba diving, swimming, sport fishing, mooring	Scuba diving, swimming, sport fishing (including sea urchin harvesting), mooring

Other Management Initiatives

Mooring areas

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Ustica Island: ecological studies

▪ General

Fish assemblage

Some circumstantial information on the fish fauna of the Ustica island prior to protection is available in De Cristofaro (1970). In this report a total of 75 fish species were listed.

Fish assemblage structure has been studied only after the effective enforcement of the reserve. Structure and composition of coastal fish assemblages were investigated by underwater visual census (UVC) and experimental trammel nets (Arculeo *et al.* 1994, 1996; Vacchi *et al.* 1998; La Mesa & Vacchi 1999; Palmeri 2004). Most studies focused on the nekto-benthic fish fauna associated to the photophilic rocky infralittoral (Vacchi *et al.* 1998; La Mesa & Vacchi 1999), although patchy information on other habitats (e.g. barrens and seagrass meadows) are also available along the island coasts (Arculeo *et al.* 1994, 1996; Palmeri 2004). Overall 102 species were recorded, representing the 19.2% of the whole Mediterranean Basin (Riggio & Milazzo 2004). Among these 20 cryptobenthic species belonging to Blenniidae, Gobiidae, Tripterygiidae, Scorpaenidae and Gobiesocidae were recorded. Species composition, diversity and relative density of these cryptic species were also investigated in relation to habitat macro- and micro- characteristics (La Mesa *et al.* 2006), and a similar approach was used to assess microhabitat requirements of juvenile dusky grouper (*Epinephelus marginatus*) (La Mesa *et al.* 2002). Habitat selection and habitat use of two coastal species (*Thalassoma pavo* and *Chromis chromis*) was also investigated (Badalamenti 2004).

Findings worth mentioning for biogeographical and ecological reasons are the constant and increasing presence of some subtropical fish species mainly of Atlantic origin – such as *Sphyraena viridensis*, *Sparisoma cretense*, *Scorpaena maderensis*, *Thorogobius ephippiatus*, *Gobius vittatus* and *Caranx crysos* (Vacchi *et al.* 1999) – although such information can be generally extended to the whole Southwestern Mediterranean region.

Benthic communities

Riggio & Milazzo (2004) reviewed the major results of the scientific research carried out in the Ustica Island coastal waters (within 50 m depth) during the latest 30 years. The list of taxa censused showed that local species richness exceeds the values expected on account of the coastal perimeter and bottom area of the island. Benthic biodiversity described was on average 24.8% of the total Mediterranean Sea. This is definitely an underestimation since not all the habitats have been investigated in the Ustica waters.

Phytobenthos (rodophytes, chlorophytes, pheophytes and phanerogams) with 450 species represents 33% of the Mediterranean marine flora (Giaccone 1967, 1968, 1983; Giaccone *et al.* 1985; Buia *et al.* 1999; Furnari *et al.* 2003a, 2003b; Milazzo *et al.* 2004; Graziano *et al.* 2005) - with a great influence of Atlantic origin – while invertebrates (poriferans, cnidarians, bryozoans, annelids, crustaceans, molluscs, echinoderms and tunicates) represent 15.8% of the total invertebrate fauna (De Cristofaro 1970; Chemello 1986; Riggio 1996; Corriero *et al.* 1997a, 1997b, 1999; Castriota *et al.* 1998; Scalera Liaci *et al.* 1998; Badalamenti *et al.* 1999; Bavestrello *et al.* 1999; Buia *et al.* 1999; Chemello *et al.* 1999; Gusso-Chimenz *et al.* 1999; Piraino *et al.* 1999; Tursi & Mastrototaro 1999; Milazzo *et al.* 2000; Nasta *et al.* 2000; Pipitone 2003; Cianciolo *et al.* 2005; Graziano *et al.* 2005).

▪ Reserve effect

Fish assemblage

Before protection, fish assemblage monitoring programs were not constantly carried out in the Ustica Island. Five years after protection, eight fish species belonging to Labrids (*Labrus viridis* and *Labrus merula*), Sparids (*Spondyliosoma cantharus, Oblada melanura* and *Sarpa salpa*) and Serranids (*Epinephelus marginatus*, *Serranus scriba* and *Serranus cabrilla*) were showing higher abundances and sizes within the integral reserve than control zones (La Mesa & Vacchi 1999). Within the Afrodite national program (Greco *et al.* 2004) fish assemblages were further monitored with the main aim of increasing knowledge on protection effectiveness.

Fish fauna seemed to be influenced more by 'habitat' effects of depth than by 'reserve' effects. The upper assemblages showed composition and structure totally different from the deeper ones, whereas any difference statistically significant (both in density and in number of taxa) was obtained between protected and fished areas during three years. It is likely that the initial differences detected between protected and unprotected areas (La Mesa & Vacchi 1999) to be successively minimised (Palmeri 2004).

Outside the integral reserve fishing pressure is very low (only 7 small scale fishing boats can operate within the MPA), and this has been the case since 2000 when spearfishing was definetively banned in the general reserve. Our study demonstrated that the level of exploitation might be a key factor for a positive response to MPA restrictions, especially when the fishing disturbance outside the integral reserve is low. This could have intriguing socio-economical consequences, when aiming at increasing interest of local stakeholders (e.g. fishermen) in MPA goals.

Benthic community

Before the barrens state dominated shallow waters, in the Ustica Island, within the integral zone, it was noted that during the spring, abundance and species richness of polychaetes and gastropods (at 1–15 m depth) were significantly higher than control zones. However, during the autumn, when the algal coverage is greatly reduced, polychaetes were not higher within the integral zone than outside, and within shallow waters (1–5 m), there were no significant differences in the abundance of gastropods (Badalamenti *et al.* 1999; Chemello *et al.* 1999). After barrens outcome, the molluscan assemblage seemed to be affected, exhibiting low values of specific richness and total abundance in sites where these encrusting coralline algae dominated (Cianciolo *et al.* 2005), particularly within the integral reserve.

The population structure of two species of sea urchins (*Paracentrotus lividus* and *Arbacia lixula*) has been monitoring within the MPA perimeter (integral zone vs. general and partial reserve) unfortunately only since 2004. The project is still in progress and data are only preliminary available.

▪ Effects on habitat (impact of recreational activities)

When looking at impact of recreational activities within MPAs, little scientific knowledge seems to support MPA management decision-making process. Some studies carried out in the Ustica Island MPA attempted to evaluate the effects of human recreational activities on different marine communities, indicating potential management solutions to limit their damage. Ustica Island receives ca. 35,000 tourists per summer (Badalamenti *et al.* 2000).

Research was carried out in the field, by quantifying the real impact of tourists and by simulation experiments, on four main recreational activities: scuba-diving in the infralittoral habitats, the boat anchoring on the *Posidonia oceanica* meadows, the human trampling on the shallow algal communities and the feeding by MPA visitors on the coastal fishes.

At Ustica, an estimation of 10,000 divers per year is plausible. Direct observations were used to describe interactions between divers, substrate and marine organisms in eight common habitats of the Mediterranean subtidal (Milazzo *et al.* submitted). Data on habitats' availability, divers' permanence in each habitat and immediate damages (or conditioning) on marine species were collected. Analyses showed that standardized preference of habitat of divers was highest for horizontal photophilic community, marine caves and sciaphilic walls. Contacts were voluntary on the 30% of occasions. Immediate damages were mainly recorded on the slow-growing benthic species *Leptosammia pruvoti*, *Astroides calycularis* and *Myriapora truncata* belonging to marine caves and sciaphilic walls. Contacts in other habitats, although numerous, did not produce any evident damage on the immediate. Behavioural responses (i.e. unnatural aggregations) of several fish species occurred frequently (58%) when divers had contacts with the substrate.

Simulation experiments on the boat anchoring activity revealed that the damage was strongly dependent on the anchor typology adopted and that weighing was the critical stage during the anchoring process. Generally the use of the Hall type anchor seemed to be preferable to minimise the impact on the *Posidonia* meadow in comparison with the Danforth and Folding grapnel anchor types.

Erect macroalgae are very sensitive to human trampling and even relatively low intensities of this human disturbance may be non-sustainable for this shallow assemblage (Milazzo *et al.* 2002). However, after disturbance ceased, the macroalgal recovery seemed to be very rapid: the higher the impact on the system the more rapid the recovery rate (Milazzo *et al.*, 2004). In the short-term, the removal of macroalgal fronds (i.e. canopy reduction) caused evident changes in invertebrate and crypto-benthic fish densities although these indirect effects were species-specific (Milazzo *et al.* 2004).

Fish feeding influenced the fish assemblages within the Ustica MPA, and significant spatio-temporal changes occurred (Milazzo *et al.* 2005). In particular, the saddled bream *Oblada melanura* noticeably increased its density in the impacted location as a result of fish feeding, although its average total length was unaffected. Moreover behavioural changes occurred, with twelve fish species, in the presence of tourists, abandoning their natural habitat and exhibiting a human positive behaviour (Milazzo *et al.* 2006). The non-natural aggregations of fishes around snorkelers, which evolve as a result of fish feeding by the public, have negative effects on local populations of fishes that make up their prey (Milazzo *et al.* 2006).

- **Indirect effects**

Some circumstantial evidence for fish-mediated trophic cascade effects in the Ustica Island MPA is given by different studies. There has been indirect concern of changing rocky bottom community state since the early 1980s. Dominance by canopy-forming brown algae as *Cystoseira* spp. and *Dyctiota* spp. was consistent in shallow rocky areas through 1980s (Giaccone *et al.* 1985). In 1991 the effective institution of the MPA restricted the human exploitation of marine organisms (including sea urchin harvesting) all around the island. Some years later (i.e. from 1994-1997), canopy forming brown algae in shallow waters were still dominant at large scales (10^2-10^3 m) (La Mesa & Vacchi 1999; Milazzo *et al.* 2000), but unstable in patches of coralline barrens at smaller spatial scale (10^0-10^1 m) mainly boulders. Almost during that period, sea urchin populations of *Paracentrotus lividus* dramatically increased, although evidence of this is only qualitative. In 2001, a homogeneous coralline barren habitat took place all around the island coast from about 1.5 to 7-8 m depth (Cianciolo *et al.* 2005). The occurrence of the barren habitat seemed not to be related to fishing restrictions (La Mesa & Vacchi 1999; Palmeri 2004).

In the island of Ustica, the barrens state appeared several years later the institution of the MPA and it seems started in the integral zone, where human access is forbidden. Several reasons may explain the presence of extensive coralline barrens along the shallow waters of the Ustica MPA, among them the scarce presence both inside than outside the MPA of high density of *Diplodus* spp. (Palmeri 2004), considered the most important sea urchin predators. Probably also the prohibition of sea urchin harvesting by humans has played an important role.

13 Gulf of Castellammare / Trawl Ban Area (Italy)

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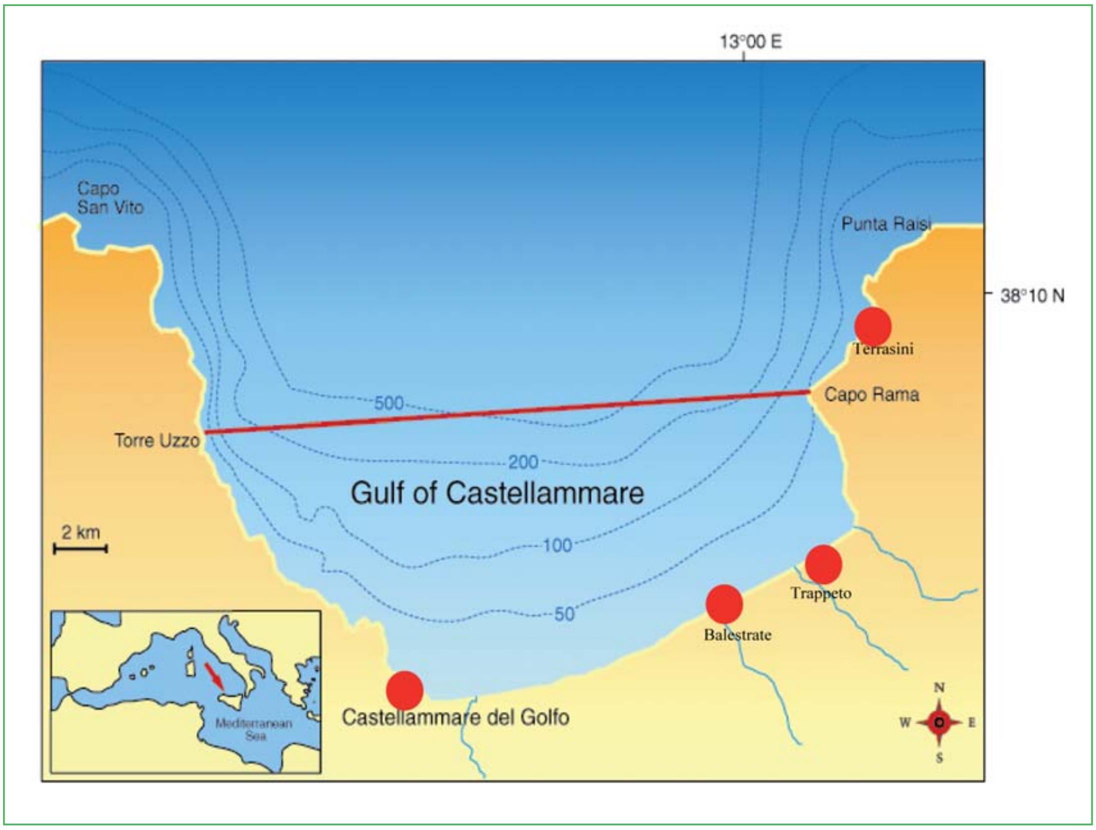

General features

Legal Status	Fishery reserve (trawl ban area)
International Recognition	None
Foundation Text	Regional act of Sicily no. 25/1990
Legal References	GURS no. 38, 11th August 1990
Relevant Administration	Sicilian autonomous regional government
Management Body	Regional Department of Fisheries
Consultative Committee	Regional Consultative committee for fisheries
Main Marine Species	*Alloteuthis media, Argentina sphyraena, Arnoglossus laterna, Lepidotrigla cavillone, Lophius budegassa, Merluccius merluccius, Mullus barbatus, Pagellus erythrinus, Parapenaeus longirostris, Spicara flexuosa, Trachurus* spp.
Marine Area Surface	No trawl area: 20,000 ha
Web page	

Regulations

Activities	Trawl Ban Area
Forbidden	Trawl fishing
Regulated	None
Allowed	All other activities

Other Management Initiatives

Artificial reefs (under the management of the local Consorzio di ripopolamento ittico)

Contacts

Regional Department of Fisheries, Palermo

http://www.regione.sicilia.it/cooperazione/pesca

Gulf of Castellammare: ecological studies

▪ General

Habitat, environment and naturalistic studies

Arena & Bombace (1970) were the first researchers who investigated the benthic and fish assemblages of the Gulf's shelf and upper slope. Their study is still a source of precious information on the benthic communities of the trawlable bottoms in the area. Later on, faunistic studies were carried out on invertebrates (Orlando & Palazzi 1985; Chemello & D'Anna 1986; D'Anna 1986; Pipitone *et al.* 1990; Sparla *et al.* 1992; Lo Brutto & Sparla 1993; Bello *et al.* 1994; Giacobbe *et al.* 1994; Estevez Ojea *et al.* 1996) as well as on fish (Mazzola 1988; Mazzola *et al.* 1990; Pipitone *et al.* 1997a; Vega-Fernández *et al.* 2003). Coastal pollution and filter feeder communities related to anthropogenic wastes were also studied in the central side of the Gulf (D'Anna *et al.* 1985, 1990; Calvo & Genchi 1989; Riggio *et al.* 1992, 1994). A few studies were carried out on the rocky bottom assemblages of the Zingaro Reserve (Riggio *et al.* 1985; Sparla & Riggio 1990; Badalamenti *et al.* 1992a, 1992b; Suriano *et al.* 1992), which is a partially protected area located along the west side of the Gulf.

Several studies were conducted to investigate the oceanographic features of the area, but very few data have been published (Genovese 1996).

Aquaculture

In the 1990's the Gulf's coastal zone has been used for pilot studies in the open sea culture of fish and bivalves (Mazzola 1993, Sorvillo *et al.* 1993, 1994; Mazzola *et al.* 1996; Vega-Fernández *et al.* 2003); offshore cages are now used for the culture of bass and bream and for the stabulation of bluefin tuna. The co-occurrence of artificial reefs, offshore cages and trawl ban make the Gulf a particularly complex area under the aspect of fisheries and coastal management (Pipitone *et al.* 2004).

Feeding ecology of fishes

Several studies have been carried out on fish species at the fishery reserve of Castellammare (Badalamenti *et al.* 1993b; Pepe *et al.* 1996, 1998; Lipari *et al.* 1998). The diet of *Dipodus annularis*, *Lithognathus mormyrus* and *Mullus barbatus* have been investigated in the Artificial Reef Area and in Control Areas while for *Diplodus sargus* and *D. vulgaris* data only exists for the Artificial Reef Area. Furthermore, the daily food intake of *M. barbatus* and *D. annularis* has been estimated. Results show that only *D. vulgaris* has a strong trophic link with the artificial substrates and that the other species depend more on the surrounding soft substrates and on the *Cymodocea nodosa* seagrass meadow nearby for food.

M. barbatus has a circadian feeding rhythm, with peaks of stomach fullness after dawn and before dusk. Food consumption varies from approximately 2 and 6 percent of the body weight and depends on seasons. *D. annularis* has only one peak during the middle of the day and does not feed at night. Food consumption is about 3% of the body weight. Data are also available on the diet and on the daily food consumption for the juveniles *of Seriola dumerili* hovering underneath FADs (Badalamenti *et al.* 1995, 1998).

▪ The fishery reserve

Effect on fish biomass

The first study on the effect of the year-round trawl ban imposed on the Gulf of Castellammare was carried out in 1994 (Pipitone *et al.* 1996, 1997b, 2000). To assess the effect of the ban on the abundance of demersal resources, CPUEs from experimental trawl surveys carried out before the ban (spring 1987 and 1989) and four years after it was in place (spring 1994) were compared. Sampling design was based on three depth strata (10-50 m, 51-100 m, 101-200 m); twenty-one and thirty hauls were made before and after the ban, respectively. Eleven target species (nine finfish and two cephalopods) as well as the total catch were used for comparisons. The total catch underwent an 8-fold increase in biomass after the four-year ban, and all the considered species underwent an increase, ranging from 1.2-fold for musky octopus (*Eledone moschata*) to 497-fold for gurnard (*Lepidotrigla cavillone*). The only decrease was for horned octopus (*Eledone cirrhosa*).

Further studies showed that the demersal biomass remained at very high levels in the following years, in both inshore sandy areas and offshore muddy areas (D'Anna *et al.* 2001; Pipitone *et al.* 2001, 2004). A model of distribution was set up using cellular automata for the red mullet (Badalamenti *et al.* 2002b).

Trophodynamic changes

The consequences for food-web structure of protecting marine communities from trawling have been explored in the Gulf (Badalamenti *et al.* 2000b, 2002d). Using stable isotopes of carbon and nitrogen, our objectives were to see if mean trophic level and omnivory had increased after the ban in three of the most common fishery-target species, namely, the anglerfish *Lophius budegassa*, Mediterranean hake *Merluccius merluccius*, and red mullet *Mullus barbatus*. We compared size data from before and after the fishery closure, but we also compared recently derived data from outside and inside the closed area. In all three species ð13C and ð15N were found to differ markedly depending on fish size. ð13C was found to decrease in *L. budegassa* and *M. merluccius* but increase in *M. barbatus* with increasing fish length. ð15N increased in all three species, and this was thought to reflect feeding at increasingly higher trophic levels during the animals' lives. Mean length, and therefore ð15N derived trophic level, increased after the trawl ban only in the anglerfish *L. budegassa*. Based on ð13C and ð15N data, none of the species became more or less omnivorous after the ban. After 9 years of no trawling, increases in numerical abundance were not accompanied by substantial size-related trophodynamic shifts in any of the three species of fish studied.

The trophodynamics of three Mediterranean fishes robust to trawling disturbance was also investigated (Badalamenti *et al.* in press). Trawling has a significant effect on the structure of marine communities, yet the ubiquity of trawling impacts makes the testing of spatial variation in such effects difficult. This study examines trawling impacts on fish trophodynamics by comparing trophodynamics in the Gulfs of Castellammare and Termini Imerese (northern Sicily) the first of which has had a large no-trawl area since 1990. Nitrogen and carbon stable isotope data were used to assess trophic levels and source of production supporting 3 demersal fish species (Mediterranean hake, red mullet and anglerfish). The exclusion of trawling has no ecologically significant effect on fish trophic level at size and no systematic effect on the sources of production supporting any species at the size sampled, thus discounting a large bottom-up influence on fish trophodynamics. Smaller scale variations (east/central/west sectors or depth strata) in ð13C isotopic signatures suggest fish utilised a complex of productions sources that cannot be resolved with the information available. Elevated ð15N in sectors with major fishing ports suggest utilisation of fisheries discards by the Mediterranean hake. Although stable isotopes do not have the spatial or temporal resolution to identify detailed shifts in diet composition their integrative nature highlight that the trophic role these species play is robust to fishing impacts at scales over which the fishery operates despite significant increases in the abundance of these species and of associated community composition.

· Artificial reefs

Comparison to adjacent natural rocky areas

Benthic communities - The mollusc assemblages of three concrete artificial reefs (ARs) located in different parts of the Gulf of Castellammare were compared with those of two natural reefs (NR) nearby (Badalamenti *et al.* 2002a). In spring 1995 a total of 28 samples of 400 cm2 were scraped off the reefs at depths of 16-18m: twenty were collected in three artificial reef areas (8 in AM-AR, 4 in TR-AR and 8 in TE-AR) and eight were collected from two natural reefs (4 in ZN-NR and 4 in TR-NR). ZN-NR and TE-AR were located in clear water, while TR-NR, TR-AR and AM-AR were found in highly turbid water. In total 116 species and 1084 specimens of Mollusc were found. The most well structured assemblage was that from ZN-NR, which showed the highest values of diversity, species richness and evenness, while the highest mean number of specimens and the highest dominance values were found at TR-AR. The lowest values of diversity and species richness were found at TR-AR and AM-AR respectively and the lowest number of specimens at TR-NR. A comparison of the five localities showed significant differences in the average number of species and in the diversity values, while the differences in the number of specimens were not significant. Factorial correspondence analysis showed a model which was strongly polarised along the first axis by ZN (with high diversity) and by the AR sites (with low diversity). The most distinctive feature was the dominance of specimens of *Bittium* spp. at the AR locations. Many years after the deployment of the artificial reefs in the Gulf of Castellammare their mollusc assemblage remains an entity which is distinct from that of the natural reefs nearby. However, the potential of the assemblage in terms of density of individuals and therefore, presumably, of biomass and production is comparable to that of natural reefs.

Other studies on the benthic colonization and biomass assessment are available in Badalamenti *et al.* (1985, 1988, 1992c, 1993a), Riggio *et al.* (1985, 1990, 2000), Badalamenti & Riggio (1986) and Tumbiolo *et al.* (1995, 1997).

Effects on adjacent soft bottom communities

The deployment of artificial reefs can alter pristine soft bottom communities and can produce alterations in sediment-size distribution, silting rate, sediment organic content and benthic structure. The real effects of reef deployment on the adjacent substratum are still questionable and the few studies carried out on this subject report controversial results. The study was aimed at verifying the influence of the reef, 10 years after its deployment, on both sediment texture and the infaunal community of the adjacent area (Badalamenti *et al.* 1999, 2002c).

Organic matter content varied from 6 mg AFDW/gDW in the outermost stratum to 87 mg AFDW/gDW in the innermost stratum and percentage of silt from 36% to about 1% respectively. Grain size distribution and organic content were found to be significantly different between the four quadrants. Within each quadrant, significant differences were observed in only two, with the differences explained by the innermost stratum (0.5m). No significant differences were detected in the individual density or biomass density of the infaunal community within and between the two quadrants. Average values ranged from 167 to 264 individuals m^{-2} and from 0.4 to 4.8 g m^{-2}. Cluster analysis showed all the strata grouped together. The indices of community structure did not differ between the two quadrants, but revealed significant differences within each quadrant between the first stratum (0.5) and the more external ones.

The Alcamo Marina artificial reef was found to only partially affect the adjacent soft bottom. The most important factor seems to be the bottom current, which sweeps sediment from two sides of the pyramid and accumulates it on the other side. Such an effect was observed only up to 0.5 m from the reef edge and mainly regarded the sediment parameter (grain-size distribution and organic matter content), the benthic community being affected to a lesser extent. The fact that neither biomass density nor individual density were found to be altered could be explained by the extremely low biomass of both the benthic and fish assemblages of the Alcamo Marina artificial reef, as has been reported in previous studies.

▪ Fish assemblage and catches

Nekton assemblage structure and catches of an artificial reefs area were compared with those of surrounding natural habitats (D'Anna *et al.* 1992, 1993, 1994; Badalamenti & D'Anna 1995). Surveys were carried out in 1990-93 at three different sites: the artificial reef area (ARA), a natural rocky area (NRA) and a control area on a sandy bottom (CA). A trammel net was used to obtain samples at each site, and a qualitative visual assessment of the fish assemblage of ARA was also carried out.

Quantitative analysis showed that ARA had significantly more species and a greater number of specimens than CA but no significant difference in catches was recorded, while a general similarity in the nekton assemblage was found comparing ARA and NRA. Overall, ARA displays features intermediate between the two natural sites tested, and the variability of its assemblage could be attributed to the availability of shelter and to the benthic settlement on the concrete boulders.

However, the selectivity of the gear used did not allow us to make a correct estimation of the abundance and biomass of all fish species associated to the artificial structure. As an aid to reach this goal, appropriate visual census surveys (D'Anna *et al.* 1999a) were carried out in 1994 in the artificial reef off Alcamo Marina (ARA) as well as in natural rocky areas (WRB, ERB), in a *Posidonia oceanica* meadow (POA) and in sandy bottom areas (SB) (D'Anna *et al.* 1995). The fish assemblage at each area was censused using the strip transect, the stationary visual census and the spatial census techniques. The estimated abundance and size of fish species were recorded on suitable boards. Fish abundance, community structure indices (*d*', *H*' and *J*') and a multivariate analysis of data were computed. Fish biomass was also estimated from the length-frequency distributions of fishes using length-weight relationships. Sparids characterized the fish assemblage in ARA while labrids were the most representative species in WRB and ERB. ARA displayed values of diversity indices, abundance and biomass significantly higher than those registered in SB and close to those obtained in POA and especially WRB and ERB. From our results it stems that the fish biomass and abundance in ARA are lower than those estimated in other artificial reefs in the Mediterranean Sea. These studies were an attempt to understand the role played by artificial reefs in influencing the composition of nekton assemblages in oligotrophic waters, such as those in the Southern Tyrrhenian Sea.

A review of the efficiency and role of the Castellammare artificial reefs is reported by Badalamenti *et al.* (2000a) and D'Anna *et al.* (2000).

▪ Traditional and experimental FADs

An experimental bottom FAD, stretching 50 m^2 and composed of 36 buoyant polypropylene ropes frayed on the top, was deployed on a sandy area at a depth of 14m in the Gulf of Castellammare (NW Sicily) (D'Anna *et al.* 1997). The FAD was constructed at the aim to attract fish and to diversify the soft bottom fish assemblage. In order to study the fish colonisation of the FAD we carried out 38 visual census counts over the July 1994 to September 1995 period. Fish belonging to 22 taxa, including mainly sparids and labrids, were recorded during the survey. The most frequent and abundant species were *Spicara maena*, *Serranus scriba Chromis chromis*, *Symphodus tinca*, *S. cinereus*, *Boops boops*, and *Seriola dumerili*. Patterns of colonisation distinguished three main phases: Phase A (15 - 95 days after the FAD deployment) was characterised by a fluctuation of the species richness values, high dominance and low diversity. The main pioneer species were: *Spicara maena, Balistes carolinensis, Seriola dumerili* and *Lithognathus mormyrus*. Phase B (96 - 294 days) showed a decrease of abundance and increase of diversity and evenness values. Phase C (295 - 414 days) diplayed an increase of number of species and abundance, mainly due to the recruitment of some juveniles of pelagic and nekto-benthic species. Statistical analysis detected quantitative differences between the fish assemblages of the upper and lower side of the FAD. Cluster analysis, performed on quantitative matrix of abundance excluding species with a frequency of occurrence <10%, groups species mainly recorded above the FAD (I), those frequently observed among the frayed top (II) of the ropes and those associated to the base of the FAD.

Floating fish aggregating devices (FADs) have been used to attract fish in NW Sicily since antiquity. Recently, a number of changes have been made to the type of material employed to construct FADs, with the aim of increasing their effectiveness. In the Gulf of Castellammare (D'Anna *et al.* 1999b), catches made at 8 experimental floating FADs (polypropylene ropes frayed at the ends) were compared with those obtained at 8 traditional FADs. A total of 672 samples were collected during summer and autumn in 1995 and 1996 at the 16 FADs using a surrounding net. Visual observations of fishes associated with the FADs were also conducted to obtain qualitative information about the spatial distribution of species.

A total of 1632 specimens weighting 144 kg and belonging to 8 species were caught during the survey. *Seriola dumerili, Caranx crysos, C. rhonchus* and *Coryphaena hippurus* were the most frequent and abundant species accounting for 96% of the total catch. Average fish abundance and weight, characterised by high variance, were significantly higher at the sites with experimental FADs than at the sites with traditional FADs. *S. dumerili* was the only species with higher catches around the experimental FADs. Some spatial and temporal variations in fish abundance and size were also detected. Younger individuals of *S. dumerili* were observed to show high affinity for the experimental FAD tufts. This studies highlights the role and the efficiency of bottom and floating FAD not only in attracting fish, but also in hosting and supporting a characteristic fish assemblage.

The role of floating FADs in the distribution and shoreward migrations of juvenile of the greater amberjack *Seriola dumerili* has also been studied in the Gulf of Castellammare (Sinopoli *et al.* 2006). In this study, we hypothesised that FADs located along a distance gradient from the shore might lead the greater amberjack inshore. In such case, mean abundance of *S. dumerili* should decrease over time in offshore FADs and increase in inshore FADs. To test the hypothesis three FAD systems were positioned in the Gulf of Castellammare (Sicily, Italy), between July and September 2001, at increasing distances from the coast. During the study period, five visual censuses were carried out within FADs fields. During the first sampling period, no significant difference in abundance and size of juvenile *S.*

dumerili were found between the three FAD systems. All the other sampling periods reported higher abundances and sizes in the offshore FADs than in the two inshore FADs. The findings suggest that FAD systems might be exerting two different effects on YOY *S. dumerili* distribution: (a) offshore FADs tend to retain associated fish for longer periods of time, (b) coastal FADs favour the transition of YOY *S. dumerili* from the pelagic to the benthic domain.

A preliminary Cellular Automata model was also developed to visualise and predict the behaviour of juveniles of the greater amberjack *Seriola dumerili* during the first year of life in the presence of fish aggregating devices (FADs) (Piscitelli *et al.* 2000, 2001). The model was utilised for simulations, concerning the area of the Castellammare Gulf, NW Sicily. First simulations have given encouraging results; they account for the main characteristics of the phenomenon and agree with the observations. The results show that the model could be applied for the optimization of FADs distribution and the evaluation of their environmental impact.

- **Marine ranching**

A pilot experiment of marine ranching using hatchery-reared juveniles of white seabream, *Diplodus sargus*, was made in the Gulf of Castellammare (NW Sicily) (D'Anna *et al.* 2004). The research aimed at evaluating (i) if artificial reefs are suitable for the settlement of reared young seabreams, (ii) what are the main causes of mortality and (iii) the growth rate of released fishes in the open sea. A total of 6930 tagged cultured juvenile white seabreams (305 days old) were released in an artificial reefs (AR) area. Underwater visual census, sightings and recaptures were used as a source of data for estimating abundance and size of released fishes. The survey lasted 15 months and was carried out in artificial (AR, breakwaters and harbours) and natural (river mouths, rocky bottoms and *Posidonia oceanica* meadows) coastal habitats of the Gulf. A few days after the release, more than 90% of the tagged seabreams left AR and moved mainly towards harbours and breakwaters, which resulted to be particularly suitable for their settlement and growth. The recapture was 8.2% of the released stock. During the first days after releasing, the main ascertained sources of mortality were professional fishing (6.7%) and predation by conger eel, *Conger conger* (1.1%). A behavioural deficit of the reared seabreams in the use of refugia and food was observed in the initial period following the release. The results obtained provide some management suggestion for the feasibility of marine ranching initiatives involving hatchery-reared fishes.

14 La Graciosa e Islotes del Norte de Lanzarote (Canary Islands, Spain)

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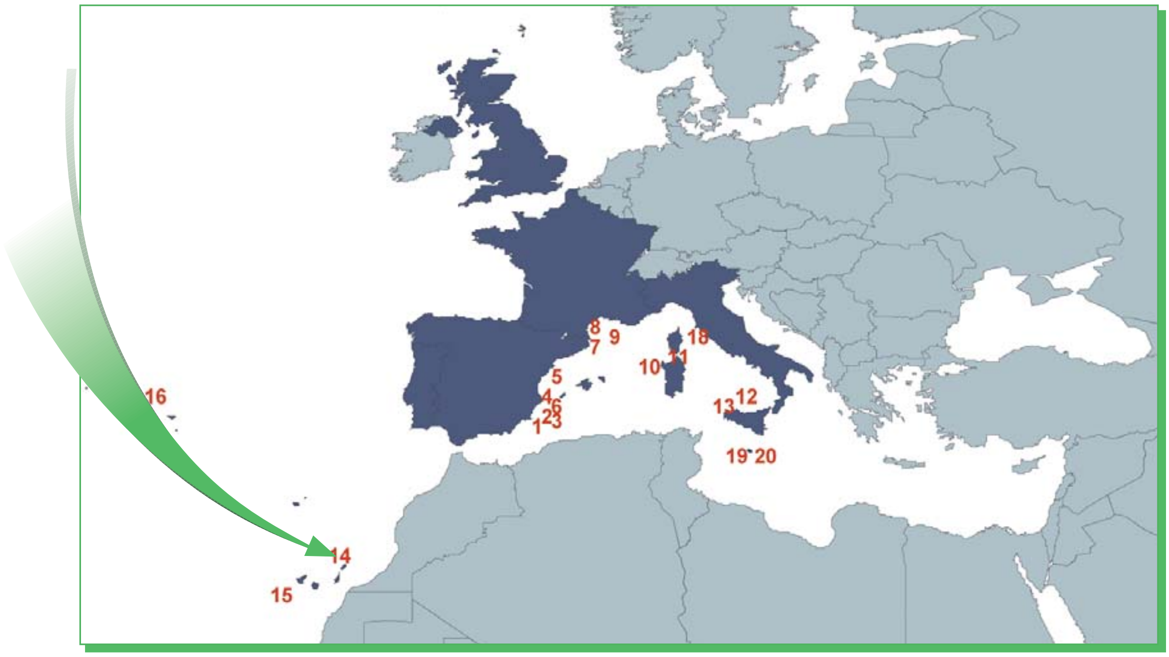

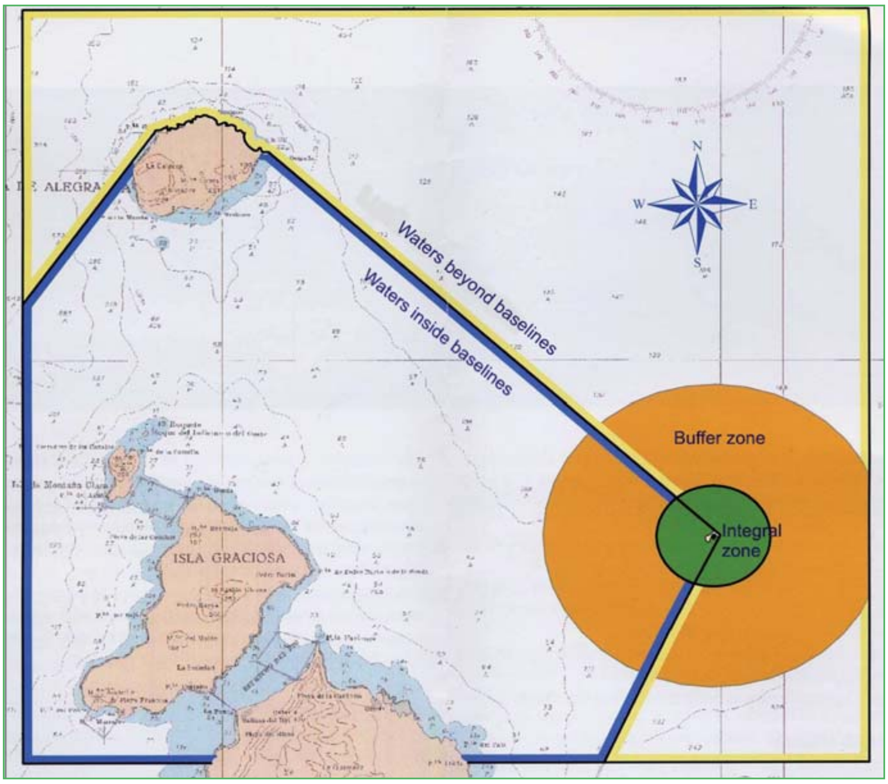

General features

Legal Status	Fishery reserve
International Recognition	Sea grass included within the Natura 2000 site “Sebadales de La Graciosa” (ES010020)
Foundation Text	Ministerial Order (19/05/1995) and Decree 62/1995 (24/03/1995)
Legal References	BOE nº 131 (02/06/1995) and BOC nº 51 (26/04/1995)
Relevant Administration	Ministry of Agriculture, Fishing and Food (waters beyond baselines) and regional Government of the Canary Islands (waters inside baselines)
Management Body	“Comisión Conjunta de Gestión y Seguimiento”
Consultative Committee	Scientific committee and Consultative committee
Main Marine Species	*Sparisoma cretense, Epinephelus marginatus, Mycteroperca fusca, Pagrus pagrus, Diplodus* spp., *Cymodocea nodosa, Patella* spp., *Gerardia macaronesica, Paramuricea grayi, Leptogorgia* spp.
Marine Area Surface	Core area (Integral zone): 1,225 ha Buffer zone: 8,480 ha Rest of the reserve: 60,995 ha
Web page	http://www.mapa.es/rmarinas/index_rm.htm

Regulations

Activities	Core area (Integral zone)	Buffer zone	Rest of the reserve
Forbidden	All activities except scientific research	Recreational fishing, scuba diving, swimming, snorkelling, anchoring	Spear fishing
Regulated	Scientific research	Scientific research	Recreational trolling, angling from the shore, scientific research, scuba diving, anchoring
Allowed		Professional fishing with hook and line and with certain traditional nets for the capture of *Sarpa salpa* and migratory species, boating	Professional fishing with hook and line and with certain traditional nets for the capture of *Sarpa salpa* and migratory species, boating, swimming, snorkeling

Other Management Initiatives

Visitors centre - Contractual agreements with research centres

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La Graciosa e Islotes del Norte de Lanzarote: ecological studies

▪ General

Fish assemblage

Fish assemblages of an island of the area (Alegranza) have been studied since the nineties in subtidal, using underwater visual census (UVC) as main sampling technique (Falcón *et al.* 1993, 1996), as well as intertidal zone (Mata *et al.* 1993). Later, Brito *et al.* (1997) studied the inshore fish community in all the reserve before and during the first years of the implementation of the MPA, and after that, several monitoring studies were performed with irregular periodicity (Brito *et al.* 1998, 2001c, 2006). Recently, other studies partially conducted in the MPA have been published (Tuya *et al.* 2004, 2006). Moreover, some works have called attention to the recent coming-up of tropical fish fauna within the "La Graciosa e Islotes del Norte de Lanzarote" marine reserve (GINLMR) (Brito *et al.* 2001b, 2005b; *Falcón et al.* 2002).

Benthic communities

The mapping and characterization of benthic biocoenosis of Lanzarote, including the marine reserve of La Graciosa, was carried out during 2000 and 2001 by the national government.

Some qualitative or semi-quantitative works devoted to the study of the distribution of some benthic taxa, such as algae (Reyes *et al.* 2000) and molluscs (Ortea *et al.* 2002; Rodríguez *et al.* 2002) can be found in the literature, as well as some quantitative ecological studies partially conducted in the GINLMR (Tuya *et al.* 2004; Barberá *et al.* 2005; Navarro *et al.* 2005; Tuya & Haroun, 2006). Also, within some of the projects financed by the regional government in order to study the reserve effect since the implementation of the MPA (Brito *et al.* 1997, 1998, 2001a, 2001d, 2005a, 2006), density and size structure of the main commercial invertebrates, such as limpets (*Patella* spp.) and marine snails (*Osilinus* spp.), have been studied. Finally, some ecological studies of the long-spined sea urchin *Diadema antillarum* have been recently initiated, but just a few preliminary results have been published for the moment (Hernández *et al.* 2005a, 2005b).

▪ Reserve effect

Fish assemblage

UVC monitoring studies carried out in GINLMR show that no important changes have occurred at the community level (i.e. number of species, abundance, diversity, evenness), despite some changes in species composition and relative abundance. Nevertheless, reserve effect has occurred at the population level, indicating that the protection measures have contributed to the increase and/or the maintenance of the populations of a number of commercially important species (Brito *et al.* 1997, 1998, 2001c, 2006). In these studies, special attention has been devoted to the study of two species very important for the local fishery (*Sparisoma cretense* and *Serranus atricauda*). Both species have higher abundance and/or biomass in the GINLMR as compared to unprotected areas, and after the creation of the reserve than before. Within the MPA, the higher values have been found in the integral reserve. The surveillance in the MPA is very low and the situation could be better (Brito *et al.* 2006).

Since the GINLMR was located in the side with the coldest waters of the archipelago,in the mid of the nineties, and because of the gradual warming of seawater, some tropical species have appeared in this area (Brito *et al.* 2001b, 2005b; Falcón *et al.* 2002), most of them sporadically (e.g. *Caranx crysos, Aluterus scriptus, Aulostomus strigosus, Seriola carpenteri*, *Chilomycterus atringa, Ryncodon typus*), but one of them (*Gnatholepis thompsoni*), and probably *Canthidermis sufflamen* too, have stable populations within the MPA (Falcón *et al.* 2002). Superimposed to, or together with, the reserve effect, a temperature effect seems obvious, which could favour successful recruitment of some species, such as *Sparisoma cretense* (Brito *et al.* 2006).

Benthic community

Since the implementation of the protection measures, some commercially important invertebrates, such as limpets (*Patella* spp.) and marine snails (*Osilinus* spp.), have showed consistently higher values of abundance, biomass and mean size within the integral reserve and in Montaña Clara (integral zone of the Natural Park), were their capture is also forbidden, than in the rest of the reserve and unprotected zones (Brito *et al.* 1997, 1998, 2001a, 2001d, 2006). Nevertheless, during the last years, a decrease of those values has been observed within the integral zones, probably related to the increase of the poaching due to the lack of surveillance (Brito *et al.* 2006)

The long-spined sea urchin *Diadema antillarum* has very high abundances within the MPA, and urchin barrens are widely distributed through the reserve (Brito *et al.* 2001d, 2006; Hernández *et al.* 2005a, 2005b). The implementation of the protection measures have not been efficient to decrease its abundance and to restore the macroalgal beds; quite the opposite, the density and size of the urchin barrens have increased in the last years, probably due to the relatively high sea water temperature, which favours extraordinary recruitment of this species (Brito *et al.* 2006). Consequently, macroalgal cover has decreased. Experimental studies show that the predation level on *D. antillarum* in GINLMR is higher than in unprotected zones, but no so high to be enough to control the urchin (Brito *et al.* 2006).

- **Fish movement (including spillover)**

The integral reserve is more than 14 km away from the closest zones of Lanzarote and La Graciosa, and depths between are more than 100 m. So it is very difficult to test the hypothesis that spillover from the integral reserve increases fish biomass in the neighbouring areas using only UVC methods. No other sampling techniques have been used for the moment.

- **Effects on habitat (including impact of divers)**

Diving in GINLMR is undeveloped. An unknown, but little, number of divers per year come to the MPA. No monitoring programs to evaluate the impact of divers in benthos have been conducted.

- **Indirect effects (trophic cascades, changes in assemblage – trophic structure, etc.)**

Studies about changes in fish assemblage structure, as well as on sea urchins (see above) can be considered in the framework of indirect (trophic) effects of protection.

15 La Restinga - Mar de las Calmas (Canary Islands, Spain)

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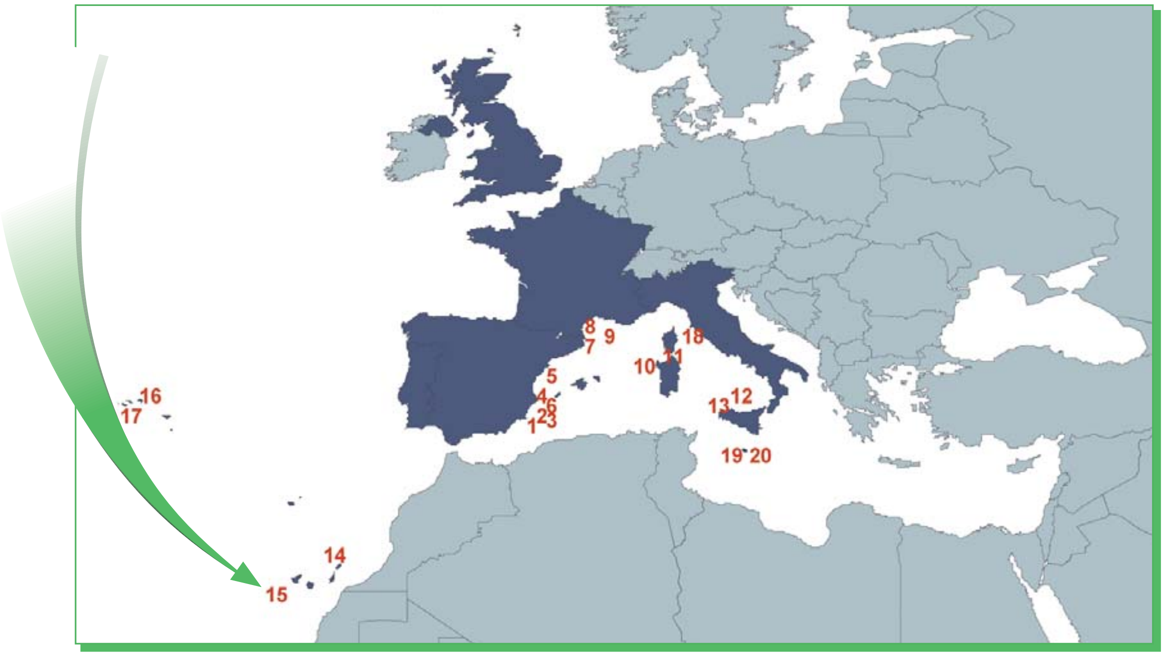

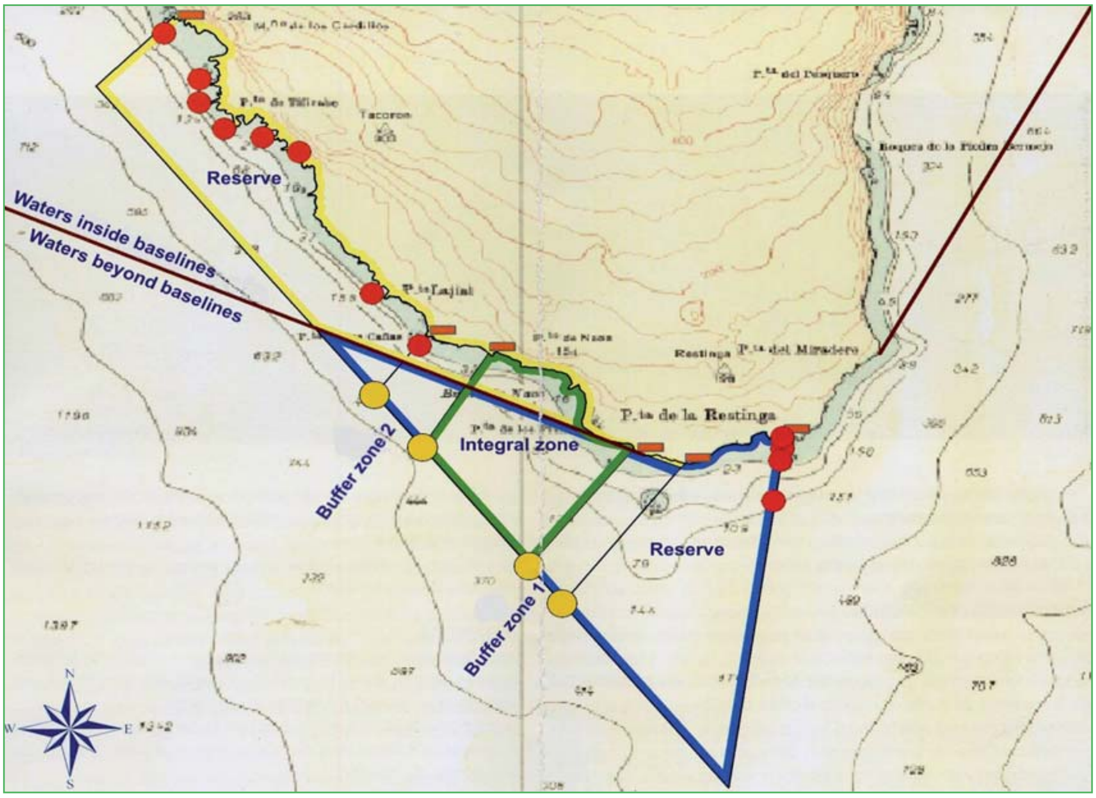

General features

Legal Status	Fishery reserve
International Recognition	Included within the Natura 2000 site "Mar de Las Calmas" (ES7020057)
Foundation Text	Ministerial Order (24/01/1996) and Decree 30/1996 (16/02/1996)
Legal References	BOE nº 30 (03/02/1996) and BOC nº 31 (11/03/1996)
Relevant Administration	Ministry of Agriculture, Fishing and Food (waters beyond baselines) and regional Government of the Canary Islands (waters inside baselines)
Management Body	"Comisión Conjunta de Gestión y Seguimiento"
Consultative Committee	Scientific Committee and Consultative Committee
Main Marine Species	*Sparisoma cretense, Mycteroperca fusca, Muraena augusti, Chilomycterus atringa, Aluterus scriptus, Panulirus echinatus, Patella* spp.*, Pajaudina atlantica, Antipathes wollastoni*
Marine Area Surface	Core area (Integral zone): 180 ha Buffer zone: 90 ha Rest of the reserve: 480 ha
Web page	http://www.mapa.es/rmarinas/index_rm.htm

Regulations

Activities	Core area (Integral zone)	Buffer zone	Rest of the reserve
Forbidden	All activities except scientific research, professional tuna fisheries and boating	Recreational fishing from boat, spear fishing, angling from the shore	Recreational fishing from boat, spear fishing, angling from the shore
Regulated	Scientific research	Scuba diving, scientific research, anchoring	Scuba diving, scientific research, anchoring
Allowed	Professional tuna fisheries, boating	Professional fishing with hook and line, professional tuna fisheries, boating, swimming	Professional fishing with traditional fishing gears, angling from the shore, swimming, boating, snorkelling

Other Management Initiatives

Visitors centre - Signposting of diving points - Monitoring of underwater activities

Contractual agreements with research centres - Mooring areas

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La Restinga – Mar de las Calmas: ecological studies

▪ General

Fish assemblage

The first quantitative studies of the inshore fish community in the area were conducted in 1989 and 1994 by the American foundation "Earthwatch" in collaboration with the University of La Laguna. They used underwater visual census (UVC) data to describe the basic structural parameters (species richness, abundance, diversity, etc.) (Bortone *et al.* 1991). Subsequently, Bortone *et al.* (1992) compared the number, size and biomass of parrotfish (*Sparisoma cretense*) between the islands of El Hierro and Fuerteventura. After the creation of the MPA in 1996, several monitoring studies were performed with irregular periodicity (Brito *et al.* 1998, 2001e, 2005a). Recently, other studies partially conducted in the MPA have been published (Tuya *et al.* 2004, 2006). In addition, some studies have highlighted the increase of the tropical fish fauna in the Canary archipelago (Brito *et al.* 1995, 2001a, 2005b), probably related to the changes of the environmental conditions. In view of the fact that the "La Restinga – Mar de las Calmas" marine reserve (RMCMR) is located in the side with the warmest waters of the archipelago, most of these tropical species have appeared in this area, many of them sporadically, but some of them (*Gnatholepis thompsoni, Canthidermis sufflamen*, *Caranx crysos* and, probably, *Mulloides martinicus*) have stable populations at the moment.

Benthic communities

A preliminary mapping of the benthic bionomy was made by Barquín *et al.* (1997). A more complete mapping and characterization of benthic biocoenosis of El Hierro, including the marine reserve, is presently being updated. Also, within some of the projects financed by the regional government in order to study the reserve effect since the implementation of the MPA (Brito *et al.* 1998, 2001b, 2005a), density and size structure of the main commercial invertebrates, such as limpets (*Patella* spp.) and marine snails (*Osilinus atratus*), have been studied. Some ecological studies of the long-spined sea urchin *Diadema antillarum* have been recently initiated, but just a few preliminary results have been published for the moment (Hernández *et al.* 2005a, 2005b). Finally, some studies have been partially conducted in the RMCMR (Tuya *et al.* 2004; Navarro *et al.* 2005; Tuya & Haroun 2006).

▪ Reserve effect

Fish assemblage

The monitoring studies conducted using UVC methods indicate that RMCMR contributes to the increase and/or the maintenance of the populations of a number of commercially important species, such us *Sparisoma cretense*, *Diplodus* spp*., Mycteroperca fusca, Serranus atricauda* and so on (Brito *et al.* 1998, 2001e, 2005a). With few exceptions, these species have higher abundance and/or biomass in the RMCMR as compared to unprotected areas, or after the creation of the reserve than before. Within the MPA, as expected, the higher values have been found in the integral reserve. Similar tendency occurs for the structural parameters such as richness and species diversity.

As said above, an increase of the number of tropical species has been observed in this area. It seems obvious this is related to the gradual warming of seawater (Brito *et al.* 1995, 2001b, 2005b), but it is reasonable to think that also it could be partially facilitated by the protection measures. This hypothesis needs further testing.

Benthic assemblage

Since the implementation of the protection measures, the limpets (*Patella* spp.), which are commercially very important, have showed consistently higher values of the abundance, biomass and mean size within the integral reserve and the restricted use zone, where their capture is also forbidden, than in the traditional use zone and unprotected zones (Brito *et al.* 1998, 2001e, 2005a). Only a few unprotected sites show similar values than those found within the integral reserve; these are high wave exposed and/or little accessible sites. At present, the abundance of the limpets seems to be stabilized in the integral zone, probably due to the competition with algae and other invertebrates by the substrate and to the predation of fishes and lobster (Brito *et al.* 2005a), but this have not been demonstrated. A Similar tendency has been found for the marine snail *Osilinus atratus*, having higher abundance, biomass and mean size in the protected zones.

Regarding the long-spined sea urchin *Diadema antillarum*, past studies show lower densities of it together with higher algal cover in the integral reserve than in the other zones of the MPA, and also compared to unprotected areas (Brito *et al.* 2005a; Hernández *et al.* 2005a, 2005b). Moreover, experimental studies show a relatively high predation level on the sea urchin in RMCMR compared with other zones of the Canary archipelago, probably due to the greater abundances of specific predators that occur in this area. Anyway, these are just preliminary results and, probably, many biotic and abiotic factors are involved together with the reserve effect (Brito *et al.* 2005a).

Fish movement (including spillover)

UVC monitoring program show that most of commercially important species (*Sparisoma cretense, Diplodus sargus, Myteroperca fusca, Epinephelus marginatus, Serranus atricauda,* etc.) have a gradient of abundance and/or biomass within the MPA, from the integral zone and the closest zones to the distant ones (Brito *et al.* 1998, 2001e, 2005a). It is also known that catches of *Sparisoma cretense* are abundant since the implementation of the protection measures (Brito *et al.* 1998). These could be considered as evidence that spillover from the integral reserve increases fish biomass in the neighbouring areas. Nevertheless, no studies specifically designed to test this hypothesis have been conducted.

Effects on habitat (including impact of divers)

The area of RMCMR is an internationally known diving destination, due to its excellent diving conditions as well as exceptional visibility and good conservation of its depths. Nowadays, more than ten diving centres operate in the area, and the number of divers per year has continuously increased since the creation of the MPA, reaching more than 11,000 at present. Impact of divers in benthos as well as in fish behaviour, which is presently being studied by the national government, is suspected, but nothing is known yet.

Indirect effects (trophic cascades, changes in assemblage – trophic structure, etc.)

Studies about changes in fish assemblage structure, as well as on sea urchins (see above) can be considered in the framework of indirect (trophic) effects of protection.

16 Monte da Guia - Faial (Azores Islands, Portugal)

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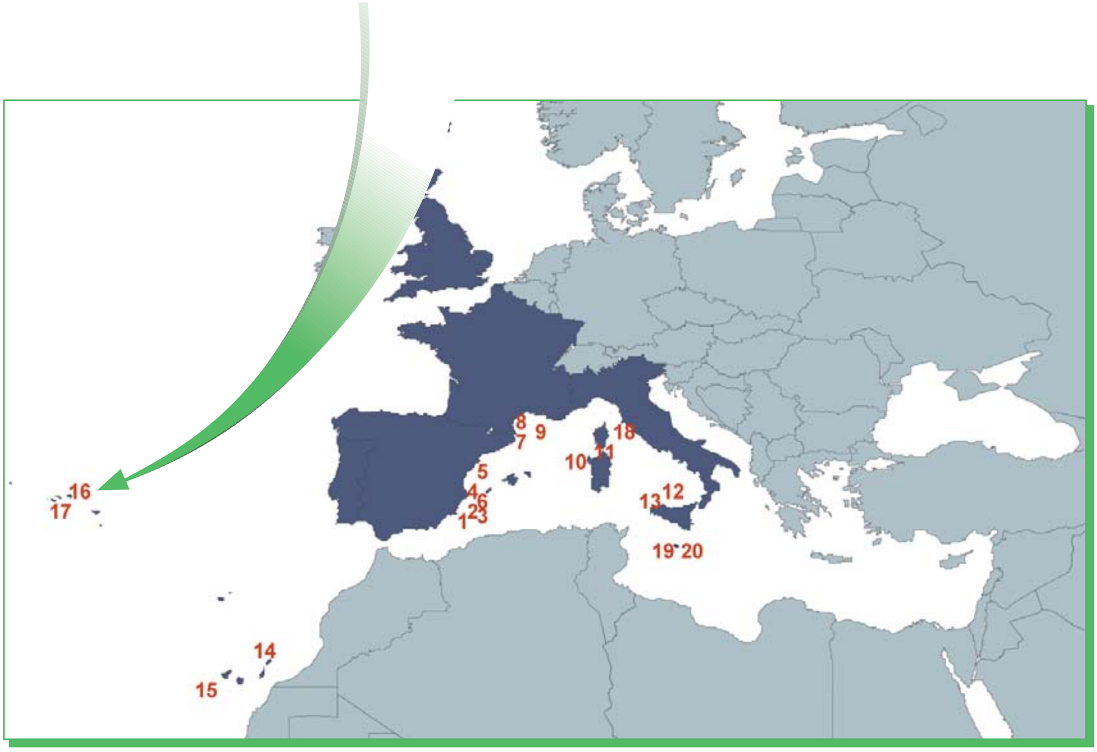

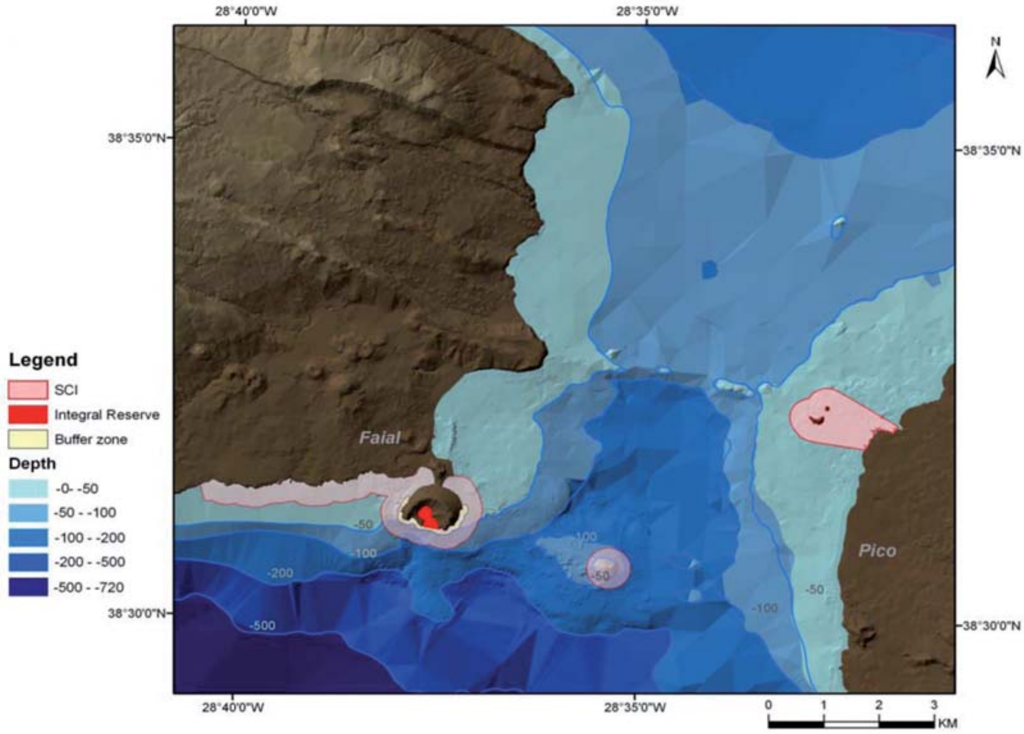

General features

Legal Status	Regional Reserve
International Recognition	Natura 2000 SCI
Foundation Text	
Legal References	
Relevant Administration	Regional Government
Management Body	Environmental Agency
Consultative Committee	Scientific committee and Consultative committee
Main Marine Species	*Codium elisabethae, Antipathes* spp., *Parazoanthus* spp., *Schylarides latus, Patella aspera, Megabalanus azorica, Epinephelus marginatus, Sparisoma cretense*
Marine Area Surface	443 ha, 10 ha no-take
Web page	

Regulations

Activities	Integral Reserve (IR)	Buffer zone	SCI
Forbidden	Fishing, boating, swimming, scuba diving, spear fishing, angling, anchoring	Fishing, spear fishing, angling, all collection of live species	
Restricted	Scientific survey	Scientific survey	Fishing, scientific survey, spear fishing
Allowed		Boating, swimming, scuba diving, anchoring	Scuba diving, swimming, angling, boating, anchoring

Other Management Initiatives

Natura 2000 (management under revision)

Proposed «Channel Marine Park» including a no-take box of 300 ha around Monte da Guia (down to 500 meter depth) and 2 larger fisheries enhancement buffer zones

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Monte da Guia-Faial: ecological studies

▪ General

Fish assemblage

Fish assemblages have been studied in the area since the 1980's, after efforts from a variety of naturalists, but it was in 1989, with an international effort lead by the University of the Azores, the 'Azores Expedition', that the systematic description of the assemblages was undertaken. This boosted numerous studies on the rocky and sandy intertidal community in and around the area (Nash *et al.* 1994a, 1994b; Santos *et al.* 1994; Santos & Nash 1995; Nash & Santos 1998) and underwater visual census (UVC) surveys of the subtidal assemblage (Patzner & Santos 1993). A UVC monitoring program has been in place since 1997, covering most of the habitats in the whole Faial-Pico Channel area, including the Marine Reserve (Afonso 2002; Morato *et al.* 2004). Other related works are the official landings database and some descriptive and assessment studies of local fisheries. The biology (Santos *et al.* 1995; 1998; Nash & Santos 1998; Morato *et al.* 2000, 2001, 2003a, 2003b; Figueiredo *et al.* 2005) and behavioural ecology (e.g. Santos 1995; Oliveira *et al.* 2002; Carvalho *et al.* 2003; Ros *et al.* 2004; Afonso *et al.* 2005) of key shore reef fishes are two other fields that have seen major increase since that date, and some work on coastal fish larvae has also been carried out (Sobrinho-Gonçalves & Isidro 1999). Phylogenetic studies have also been undertaken in the area on several reef fishes (Carvalho *et al.* 2000; Guillemaud *et al.* 2000a, 2000b; Aurelle *et al.* 2003). More recently, the pre-settlement dispersal and post-recruit movements and patterns of habitat use of several key species are also being studied (Fontes *et al.* 2005).

Benthic communities

The "Azores '89 Expedition" also started the descriptive knowledge of the benthic communities around the area (e.g. Moss *et al.* 1992; Tittley & Neto 1994), although some previous work had been done on commercial species (Martins 1985). Ever since, a large effort has been in place to map and characterise the seafloor and associated biotopes, including the use of UVC, ROV, drop-down video and multibeam sonars (e.g. Tempera *et al.* 2001c). A monitoring program on invasive algae and invertebrate species is also in place given the location of the MPA near Horta marina - a reported entrance point for non-native species.

Seabirds

Although the coasts of Monte da Guia are not an Important Bird Area or a Special Protection Area, they do contain seabird features. A small colony of common tern (*Sterna hirundo*) breeds annually on the SW cliffs of Monte da Guia. The numbers of this colony varied between a maximum of 163 and a minimum of 30 breeding pairs. The terrestrial part of the reserve is also used as a nesting site by a small number of Cory's shearwaters (*Calonectris diomedea borealis*). Caldeirinhas coast is used all year round by a small group of non-breeding grey herons (*Ardea cinerea*), mostly as a resting place.

The sheltered bays around the site provide resting and feeding areas for groups of waders and some other waterbirds that winter in Faial. Rarities from far-off regions are also regularly recorded in the area.

Marine mammals

Descriptive and some quantitative work on cetacean assemblages in this area started in 1998 (e.g. Tempera *et al.* 2001b, 2001c). As a result of that work, focus was put in the ecology of bottlenose dolphins (*Tursiops truncatus*) within and outside the area. Work has been developed in the study of the population structure, residency, distribution and habitat preferences of bottlenose dolphins in the area (Silva *et al.* 2005, 2006; Seabra *et al.* 2006). Although the main focus is in the bottlenose dolphin, distribution and habitat preferences are also being evaluated for other cetacean species occurring in the area.

▪ Reserve effect

Fish assemblage

The UVC monitoring program has shown that the diversity within the Monte da Guia reserve is higher than in any other habitat group in the island (Afonso 2002; Tempera *et al.* 2002b). Some species also seem to have responded to the effects of protection, namely an increase in abundance and size of parrotfish and groupers in the last 5 years, although other species that are legally or illegally exploited within the reserve do not seem to show the same patterns. The two shallow bays fringing the reserve are amongst the best examples of the role of this kind of habitat as nursery areas for a variety of marine fishes (e.g. Santos *et al.* 1994, 2005). Additionally, the offshore reefs within the future Channel Marine Park harbour a specific assemblage, where benthic and pelagic species coexist in large numbers (Afonso 2002). Furthermore, recent movement studies are also showing that these act as summer spawning aggregating sites for several pelagic predators, such as yellowmouth barracuda, white trevally, and amberjacks (Afonso *et al.* 2006).

The sum of these habitats and the rich assemblages within it turn the Marine Park into a pivotal structure in the conservation efforts of the region to protect representative species and habitats and manage coastal resources (Tempera *et al.* 2001c; Santos *et al.* 2005).

Benthic assemblage

Sub-littoral assemblages of Monte da Guia were recently surveyed using a physiognomic approach in the scope of projects Maré, Marov and Maya. This information has been instrumental for producing an inventory of benthic assemblages characterizing the rocky bottoms of the MPA and shall provide a reference for future monitoring. The same information is relevant for assessing habitat preferences of the coastal fishes tracked by telemetry in the site.

As a harvest refuge for limpets, Monte da Guia has been used as a benchmark in assessing the impacts of collection in exploited sites.

Larval export and spillover of exploited species

Several projects are addressing the questions of whether exploited species can be retained with the present and future reserve boundaries, hence benefiting of an effective protection, and if this can lead to a net spillover of part of such fish to adjacent fishing grounds. Results show that the scale of movement of adult fishes depend on the species, from small scale, highly resident species, such as the parrotfish, to highly mobile, seasonally aggregating species, such as the white trevally. Other species appear to show an intermediate degree of movement and an optimal spillover potential, such as the red porgy.

The problem of connectivity is been also being addressed through studies of recruitment dynamics in model species. The island of Faial and neighbouring seamounts are being surveyed for newsettlers of several wrasse species and their otholits scanned in search for different chemical signatures. These protocols should help clarify if local reserves, including Monte da Guia, can act as source areas and at what spatial scale (within island, between islands) (Fontes *et al.* 2006).

17 Formigas islets - Dollabarat bank (Azores Islands, Portugal)

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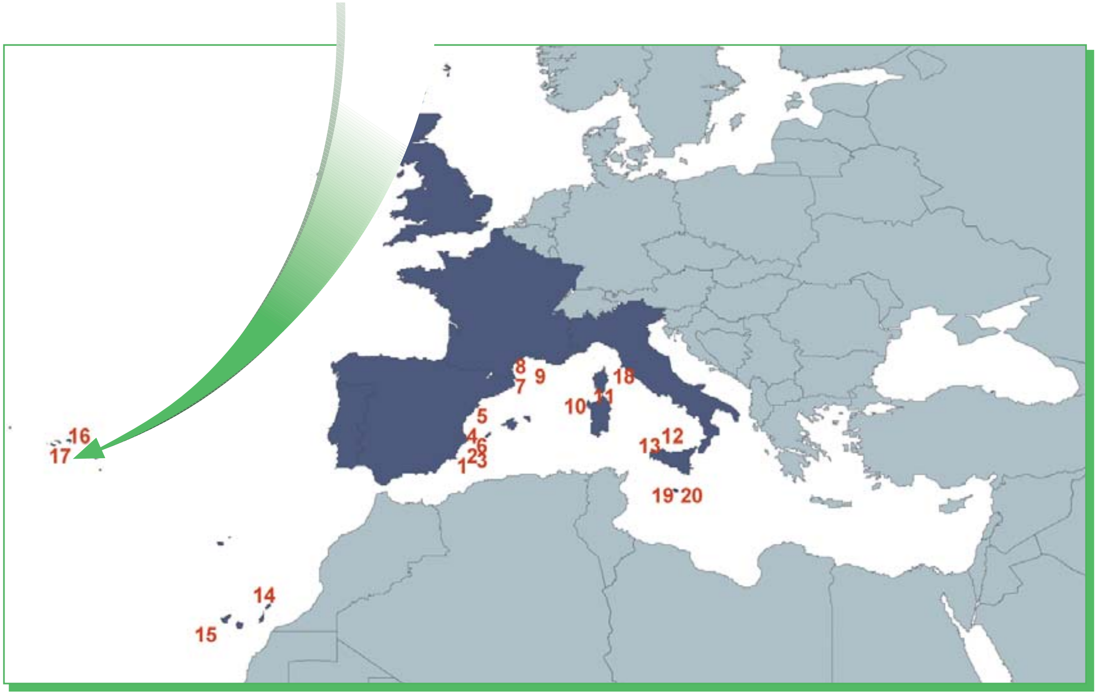

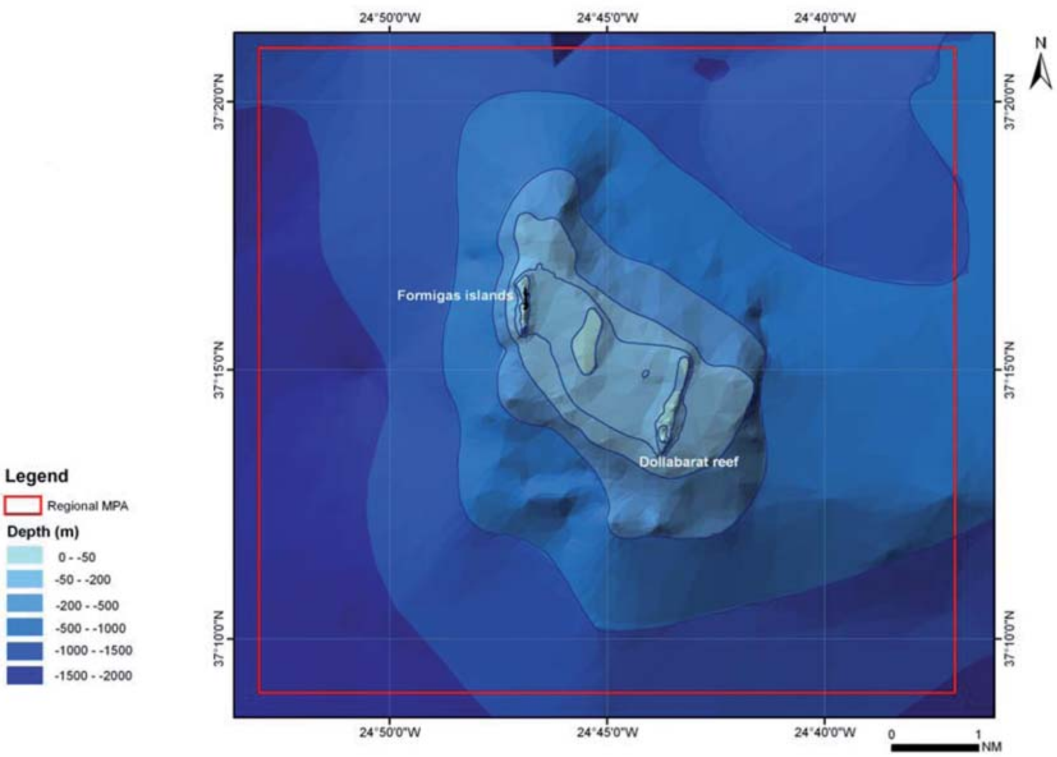

General features

Legal Status	Azores Regional Nature Reserve
International Recognition	Natura 2000 SCI and OSPAR site
Foundation Text	DLR 11/88/A
Legal References	DLR 8/90/A; Res. 30/98; Decl. 12/98, DLR18/2002/A; DLR 26/2003/A
Relevant Administration	Regional Government of the Azores
Management Body	Regional Secretariat for the Environment and the Sea
Consultative Committee	Scientific committee and Consultative committee
Main Marine Species	*Cystoseira* sp., *Laminaria ochroleuca*, *Zonaria tournefortii*, *Antipathes wollastoni, Gerardia macaronesica*, *Corynactis viridis*, *Grapsus grapsus*, *Neopycnodonte cochlear*, *Mycteroperca fusca*, *Bodianus scrofa*, *Kyphosus* sp. (including xanthic morphs), *Seriola* spp., *Mobula tarapacana*, *Phycis phycis, Zeus faber*, *Pagellus bogaraveo*, *Polyprion americanus*, *Caretta caretta*, *Tursiops truncatus*
Marine Area Surface	52,527 ha
Web page	

Regulations

Activities	General reserve
Forbidden	Spear fishing, catch and collection of organisms except*
Regulated	*Tuna fishing, scientific research, archaeological extraction, geological extraction
Allowed	Boating, diving, anchoring

Other Management Initiatives

EU Natura 2000 Site of Conservation Importance;

Permanent no-take area for limpets under the legislation regulating the collection of this resource;

OSPAR Site;

Normal Focal site on the European large-scale, long-term Marine Biodiversity Research Network (project BIOMARE)

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Formigas islets – Dollabarat bank: ecological studies

▪ General

The fish, invertebrate and algal assemblages associated with the environments of the Formigas Bank have been studied since the late 1890s' after some expeditions to the site (e.g. Milne-Edwards & Bouvier 1899; Piccone 1899). Modern exploration, including observation by SCUBA divers and scientific collection of organisms in shallow-water habitats, started in the 1970's (Ardré *et al.* 1973; Gofas 1989; Arruda *et al.* 1992; Brum *et al.* 1995; Ávila & Azevedo 1997). The sampling has become more regular since 1998 when the underwater visual census (UVC) survey program was set up (Tempera *et al.* 2001a; Afonso 2002). More recently a study was started to characterise the patterns of pre-settlement dispersal and recruitment of several reef species (Fontes *et al.* 2006). Deepwater fish fauna, the major component of the bank, that spreads down to more than 1800 m deep, has been studied by means of independent fishing cruises since the early 1990s (Menezes *et al.* 1998, 2000). Some effort has been in place to survey the bottoms and associated biotopes in sublittoral and circalittoral depths, using SCUBA diving, UVC, ROV and drop-down video (e.g. Tempera *et al.* 2001a, 2001d). These studies of the bank summit have been exposing remarkable biotopes including dense *Cystoseira* beds, overhangs dominated by black corals, kelp forests down to unreported depths and sediments pockets with intense bioturbation. Data on multispecies interactions (including cetaceans, seabirds, seaturtles and fish) and on tuna catches, the only extractive activity authorized since the 2003 revision of the reserve protection measures is available from the POPA observers program.

▪ Reserve effect

The UVC monitoring program has shown that the shallow water assemblage of the bank is highly specific and found nowhere else in the region (Afonso 2002; Afonso *et al.* 2006). This stems from a unique mixture of demersal species typical of coastal habitats, and oceanic species, either seasonal visitors or residents, which seems to be highly dependent on increased local upwelling. Changes in this balance might be related to the recent decrease of the shallow *Cystoseira* coverage observed in Dollabarat. This dramatic alteration is reflected on algal-associated species, such as labrids, and may confound the effects of protection. Increases in biomass and abundance were not detected in commercially important species since 1998. However, this is considered to reflect the short time past since the introduction of the stricter regulations, which prohibited all exploitation except of tuna. It is expected that the continuing of the monitoring program will allow such distinction in the future, although stricter enforcement of the regulation is required to guarantee the meeting of the reserve objectives.

▪ Population connectivity

The issue of connectivity between populations of the reserve and those residing in other banks and islands is being addressed through studies of recruitment dynamics in model species. The bank and neighbouring islands are being surveyed for newsettlers of several wrasse species and their otholits scanned in search for different chemical signatures. These protocols should help clarify if the Formigas bank reserve acts as source or sink area, or of it is dependent on self-recruitment to sustain its fragile populations.

18 Tuscany archipelago (Italy)

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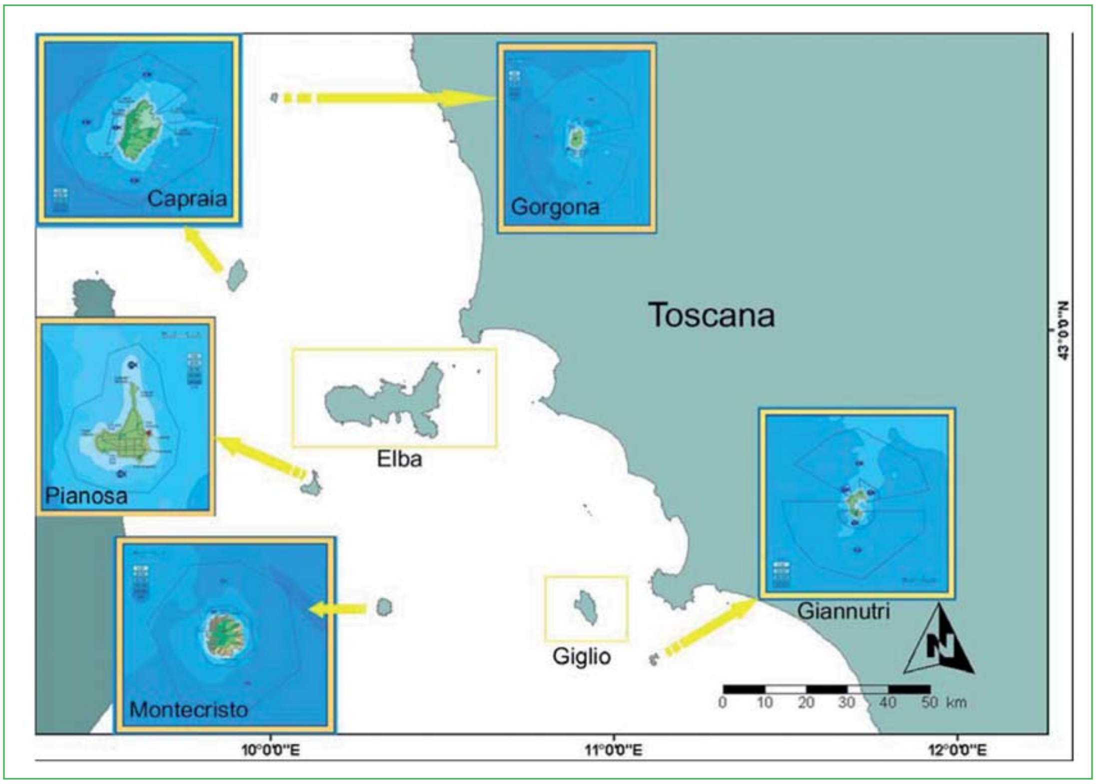

General features

Legal Status	National Park
International Recognition	
Foundation Text	L. 394/91; D.P.R. 22/07/1996; DM Ambiente 19/12/1997
Legal References	GURI
Relevant Administration	Ente Parco Nazionale Arcipelago Toscano, Ministero dell'Ambiente e della Tutela del Territorio, Ministero delle Politiche Agricole e Forestali
Management Body	Capitaneria di Porto – Guardia Costiera (Ministero delle Infrastrutture e dei Trasporti)
Consultative Committee	
Main Marine Species	Main species by group landed in the local fish markets Elasmobranchs: *Mustelus mustelus, Raja* spp. Teleosts: *Merluccius merluccius, Dentex dentex, Trachurus* spp., *Scomber scombrus, Scorpaena* spp., *Engraulis encrasicolus, Sardina pilchardus, Solea* spp. Crustaceans: *Parapenaeus longirostris, Nephrops norvegicus, Squilla mantis, Aristeomorpha foliacea, Palinurus elephas* Cephalopods: *Octopus vulgaris, Loligo vulgaris, Illex coindetti, Sepia officinalis, Eledone moschata, Eledone cirrhosa*
Marine Area Surface	Total size: 56,766 ha Integral reserve size: 6,147.4 ha
Web page	

Regulations

Activities	Integral Reserve (IR)	Restricted use area (RU)	Free access
Forbidden	fishing, spearfishing, angling, diving, swimming, boating, anchoring	spearfishing	
Regulated	scientific research	fishing, angling	
Allowed		swimming, diving, scientific research, boating, anchoring	all activities

Other Management Initiatives

Recreational and commercial fishing activities in the free access area are regulated by general Italian maritime laws

Contacts

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Tuscany archipelago: ecological studies

▪ General

Benthic communities

The ecology of benthic assemblages was investigated in the area since the late 1990s. Patterns of variability of mid-shore and low-shore algal and invertebrate assemblages on Tuscany Archipelago rocky shores were investigated at several scales in space and time. It was documented large variability of organisms across the vertical gradient of the shore and horizontal variability mainly at small (10s of cm) and large (100s to 1000s of m) spatial scale (Benedetti-Cecchi 2001). As part of these studies, assemblages of rocky shores on islands were compared to those of the mainland in order to examine if insular assemblages could be considered unique because they are exposed to particular patterns of colonization/extinction depending on distance from other sources of colonists and on size of islands, or if islands provide different habitats, regardless of potential effects of size and isolation. Structure of assemblages, mean abundance of common taxa and magnitude of spatial and temporal variance in abundance at mid-shore and low-shore habitats differed between islands and the mainland, indicating that islands in the Tuscany Archipelago contributed to diversity and complexity of rocky shore assemblages over and above any possible effect of size and isolation (Benedetti-Cecchi *et al.* 2003a). Patterns in distribution and demography were analysed in detail for the barnacle *Chthamalus stellatus*, indicating large temporal and spatial variability at different scales, probably driven by pre-emption of the substratum and mortality of juveniles (Benedetti-Cecchi *et al.* 2000a).

Data from experiments of exclusion of limpets documented the importance of grazing by limpets in maintaining differences between mid-shore and low-shore algal assemblages, with patterns generally independent of the inclination of the substratum, but largely variable in space and time (Benedetti-Cecchi *et al.* 2000a, 2001b). Empirical data were also related to predictions obtained from simulations, indicating that the understanding of effects of consumer documented could be implemented by including in food-web models changes in variance of trophic interactions (Benedetti-Cecchi 2000).

The occurrence of canopy-forming algae in the genus *Cystoseira* in the area of Tuscany Archipelago appeared related to anthropogenic disturbance, as indicated by their dominance on relatively pristine shores and their virtual absence in urban areas, where, in contrast, they were replaced by turf-forming algae (Benedetti-Cecchi *et al.* 2001b). The experimental removal of *Cystoseira* resulted in the development of algal and invertebrate assemblages similar to those found where this alga was naturally absent, with patterns consistent in space and time, underlining the importance of these algae as habitat-forming organisms (Benedetti-Cecchi *et al.* 2001b; Bulleri *et al.* 2002).

Subtidal assemblages on the rocky cliffs of Giannutri Island were studied using a photographic method within the bathymetric range 25-35m over three spatial scales (ranging from 10s to 1000s of m). Such assemblages were clearly heterogeneous, particularly at the smallest scale investigated (Ferdeghini *et al.* 2000).

Subtidal phytobenthic assemblages were compared among islands in the Tuscany Archipelago, continental coasts and offshore banks, showing no differences between the three habitats, while spatial variability within each habitat was large at small scale and in relation to the inclination of the substratum (Piazzi *et al.* 2004b). A floristic list was specifically compiled for macroalgal assemblages of Gorgona Island, separated for rocky bottom, *Posidonia oceanica* meadows and rhodoliths (Piazzi *et al.* 2004a).

P. oceanica beds around Elba Island were mapped in 2000 using a combination of direct and indirect methods, including sampling of macroalgal epiphytes (Piazzi *et al.* 2000). Macroalgal assemblages associated with *P. oceanica* rhizomes were studied in detail in several locations in the western Mediterranean, also in relation to the invasion by the introduced algae *Acrothamnion preissii* and *Womersleyella setacea* (Piazzi *et al.* 2002).

Factors affecting the invasion performance of the introduced alga *Caulerpa taxifolia* were experimentally investigated in a bay on the south coast of Elba Island over the period 1997-1999. Short-term experiments on the effects of nutrient addition in sediments and competitive interactions between *C. taxifolia* and the seagrass *Cymodocea nodosa* indicated that colonization by *C. taxifolia* could explain the observed regression of *C. nodosa* beds and that *C. taxifolia* was favoured by high loads of nutrients in the sediment, while *C. nodosa* was not (Ceccherelli & Cinelli 1997). In fact, while *C. taxifolia* did not indicate nutrient limitation, *C. nodosa* was characterized by limiting nutrients either in the below ground and above ground tissues (Ceccherelli & Cinelli 1999a). Measures of size and density of blades of *C. taxifolia* in different habitats suggested a positive affects of seagrasses on this alga, despite large variability found at small spatial and temporal scales (Ceccherelli & Cinelli 1998). The positive influence of *P. oceanica* on *C. taxifolia* was investigated experimentally and appeared greater at the deepest edge of the seagrass bed, where shoot density was lower (Ceccherelli & Cinelli 1999b). A multifactorial experiment involving the dispersion of drifting fragments of *C. taxifolia* along the margin of a bed of *P. oceanica* indicated that the probability of their establishment was variable seasonally and at small spatial and temporal scales (Ceccherelli & Cinelli 1999c).

At the end of 2003, thirteen years after its first record, the colonization of the green alga *Caulerpa racemosa* var. *cylindracea* was evaluated at several locations in the Mediterranean, including the Tuscany Archipelago (Piazzi *et al.* 2005).

The geographical distribution of the tropical alga *Acrothamnion preissi* was also reported, including a detailed study carried out around Gorgona Island (Piazzi *et al.* 1996).

▪ Reserve effects

Benthic communities

The effectiveness of marine protected areas for affecting assemblages of algae and invertebrates between 0 and 0.5 m above the mean low water level of rocky coasts of the islands of Capraia and Giannutri was investigated through a multifactorial sampling design (Benedetti-Cecchi *et al.* 2003b). Differences in structure of assemblages, in mean abundance of common taxa and in univariate and multivariate measures of spatial variation were evaluated on three replicate shores for each condition of protected and reference areas on the west side of each island and three unprotected shores on the eastern side. Assemblages were sampled independently four times on each island over a period of two years. At each time of sampling two sites were selected randomly at each of the two heights on each shore. Most patterns resulted inconsistent with the predicted effect of management through MPAs. This suggested that designation of MPAs in the Tuscany Archipelago should proceed through management of multiple shore and types of habitat, to guarantee protection to a representative sample of assemblages and to the processes responsible for maintenance of spatial patchiness at different scales.

Fish assemblage

The relative roles of human impacts and hydrographical conditions on fish assemblages of shallow (3-10 m depth) rocky reefs were examined by comparing no-take reserves with fishing areas occurring in gradients of exposure of the coastline to dominant winds and waves around the islands of Giannutri and Capraia (Micheli *et al.* 2005). Fish assemblages were sampled using underwater visual census techniques. The composition of fish assemblages differed significantly between sites within no-take reserves and fished reference sites. Four target (*Oblada melanura, Diplodus sargus, Diplodus vulgaris, Spicara flexuosa*) and one non-target species (*Chromis chromis*) at Giannutri and two target (*O. melanura, D. sargus*) and two non-target species (*Thalassoma pavo, C. chromis*) at Capraia showed larger abundance and larger size in no-take reserves than in fished areas. These findings indicated a direct influence of protection from fishing on fish assemblages. It was also hypothesized that fishing could influence assemblages indirectly by reducing predation on sea urchins, thus intensifying herbivory and causing “barrens” of encrusting coralline algae. Results of this part of the study are summarized in the following paragraph.

▪ Indirect effects (trophic cascades, changes in assemblage)

Sea urchin densities, the extent of coralline barrens and the structure of algal and invertebrate benthic assemblages showed clear variation associated with exposure of the coastline to dominant wind and waves, but weak effects of protection from human use (Micheli *et al.* 2005). Densities of the black sea urchin *Arbacia lixula* were greater along the windward than along the leeward sides of the islands, and were positively correlated with the extent of coralline barrens. Opposite pattern of abundance was observed for the purple sea urchin *Paracentrotus lividus*, which showed indirect responses to protection at Giannutri. These findings indicated that indirect effects of fishing and recovery of assemblages within MPAs in the Tuscany Archipelago through cascading trophic interactions varied depending on local physical conditions and on the characteristics of locally dominant species.

19 Malta 25-NM Fisheries Management Zone (Malta)

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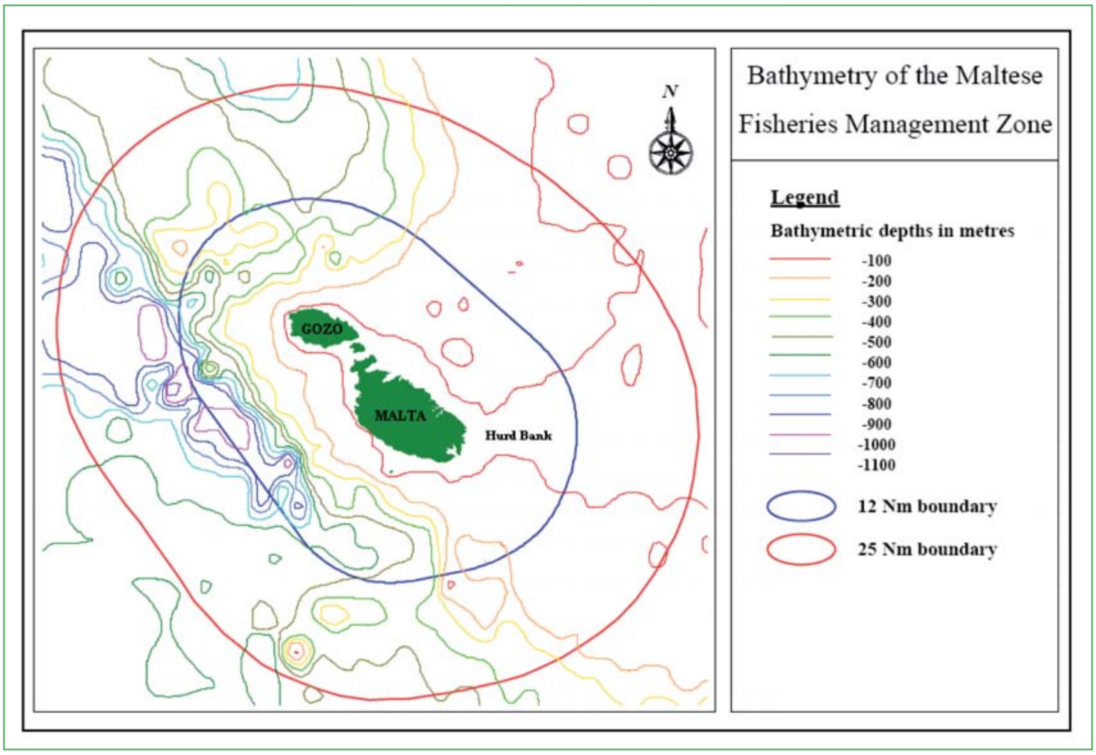

General features

Legal Status	Fisheries Management Zone
International Recognition	Originally established in 1971 as a 25-NM Exclusive Fishing Zone under the United Nations Convention on the Law of the Sea and then established as a FMZ by EU Council Regulation in 2004
Foundation Text	As Exclusive Fishing Zone: Malta Government Act XXXII of 1971
Legal References	Official Journal of the European Union I.150/32; 30.04.2004
Relevant Administration	Ministry for Rural Affairs and Environment (MRAE)
Management Body	Fisheries Conservation and Control Division (FCCD) of MRAE
Consultative Committee	Fisheries Board
Main Marine Species	Main Species by Group Landed in the Official Fish Market: Elasmobranchs - *Squalus acanthias, Raja* spp., *Centrophorus granulosus, Prionace glauca, Lamna nasus* Teleosts - *Thunnus thynnus, Coryphaena hippurus, Xiphias gladius, Epinephelus costae, Boops boops, Mullus barbatus, Naucrates ductor, Euthynnus alletteratus, Pagrus pagrus* Decapods - *Parapenaeus longirostris, Plesionika* spp., *Aristeomorpha foliacea* Cephalopods - *Octopus vulgaris, Loligo vulgaris, Illex coindetti, Sepia officinalis*
Marine Area Surface	3 Nautical mile limit 12 Nautical mile limit: 145,500 ha (approx.) 25 Nautical mile limit: 1,198,000 ha (approx.)
Web page	

Regulations

Activities	3-NM limit	12-NM limit	25-NM limit
Forbidden	Trawling		
Regulated	Angling, fishing	Angling, fishing, trawling	Angling, fishing, trawling
Allowed	Swimming, diving, boating, archoring, spear fishing	Swimming, diving, boating, archoring, spear fishing	Swimming, diving, boating, archoring, spear fishing

Other Management Initiatives

Fishing with vessels longer than 12 m is not permitted in the 25-NM zone, except for lampara fishing (using a light source to attract fish) and fishing for dolphinfish, tuna, swordfish and other migratory species

Only trawlers smaller than 24 m can fish and where the depth is less than 200 m the engine capacity must not exceed 185 kW

There can be no further registration of trawlers that can fish in the zone

Only fishers who currently hold a licence can fish

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Malta 25-NM Fisheries Management Zone: ecological studies

▪ Demersal Fish assemblage

Studies on the demersal assemblages in the Fisheries Management Zone (FMZ) have only started recently. Data are being collated through Maltese participation in the Mediterranean International Trawl Survey (MEDITS, since 2000), in the GRUND (GRUppo Nazionale Demersali) trawl survey, and in the FAO programme MedSudMed. In general, all the Mediterranean European Union states are participating in the MEDITS programme, which is designed to contribute to the characterization of bottom fisheries resources in the Mediterranean in terms of population distribution (relative abundance indices) as well as demographic structure of the populations based on total length (TL), weight, sex, maturity stage and gonad weight.

From analysis of data from the first MEDITS research cruise carried out in the Maltese FMZ (MEDITS 2000), the Zone was found to be a distinct spatial unit for demersal fish species. Fish abundance data obtained from trawl surveys within the FMZ were compared with those from Sicilian waters; in general, the abundance at depths between 50 m and 500 m was double within the FMZ. There is also evidence that adult populations of shallow (less than 200 m depth) shelf resources within the Zone are isolated from those of adjacent areas, and that the Maltese shelf constitutes the main offshore area where spawning takes place for a significant proportion of the Zone's demersal resources and for other deep water species (Anon. 2000, 2001; Camilleri 2003).

Using data from subsequent MEDITS surveys (MEDITS 2001, 2002, 2003; Anon. 2002, 2003, 2004), fishing-induced changes in composition, diversity and size spectra of demersal fish communities in the Strait of Sicily, in areas exposed to different levels of fishing pressure (Gristina *et al.* 2000, 2003, 2004; Fiorentino *et al.* 2003, 2004). According to Gristina *et al.* (2003), the Shannon diversity index (*H'*) and the taxonomic distinctness index (Α) do not seem to be the best measures to use to investigate the impact of fishing on the demersal fish communities; in fact, significantly lower diversity values were not at all clearly linked to trawl disturbance. On the contrary, the structure of the demersal assemblages and the analysis of size spectra proved to be more sensitive for detecting changes in the demersal communities. Gristina *et al.* (2004) developed a multispecies index defined as the ratio of bottom-dwelling fish to overall-fish biomasses (BOI index). According to these authors, the BOI index used in association with biomass indices seemed to distinguish between areas with different levels of trawling pressure.

▪ Benthic communities

Prior to 2003, information on the benthos and benthic assemblages and on their ecology within the FMZ was limited to relatively shallow waters, 50–80 m (Biomaërl team 1998, 1999; Borg *et al.* 1998a, 1998b; Schembri 1998; Lanfranco *et al.* 1999; Dimech *et al.* 2004). In an effort to address this lack of basic information, the Malta Centre for Fisheries Sciences (MCFS) together with the Marine Ecology Research Group (MERG) of the Department of Biology of the University of Malta initiated several studies on the benthic habitats and biotic assemblages of actual and potential fishing grounds within the Maltese FMZ in the ambit of the MEDITS, GRUND and MedSudMed programmes. Research activities which originated from the MEDITS 2003, 2004, 2005 and GRUND 2003, 2004 research cruises included studies on:

– The benthic assemblages and sediment characteristics of the deep-water fishing grounds within the FMZ (Dimech & Schembri 2003, 2004, 2005; Page 2003);
– The relationships between demersal commercial species, benthic assemblages and sediment characteristics in the FMZ (Dimech *et al.* 2005a, 2005b);
– The abundance of anthropogenic litter in Maltese waters and its use as a substratum by epibenthos (Pace 2006);
– Selected decapod species of commercial importance (*Aristeomorpha foliacea, Parapenaeus longirostris, Nephrops norvegicus*) and on dominant echinoderm species (*Cidaris cidaris, Stylocidaris affinis*) inside and outside the FMZ (Balzan 2006).

The last-named study showed that for all the decapods, smaller-sized individuals were recorded from within the Malta FMZ than outside, while only P. *longirostris* was found to be significantly more abundant within the FMZ than outside (Balzan 2006).

20 Rdum Majjiesa / Ras Ir-Raheb (Malta)

Contributors: Joseph A. Borg[1], Mark Dimech[2], I. Philip Smith[3] & Patrick J. Schembri[1].

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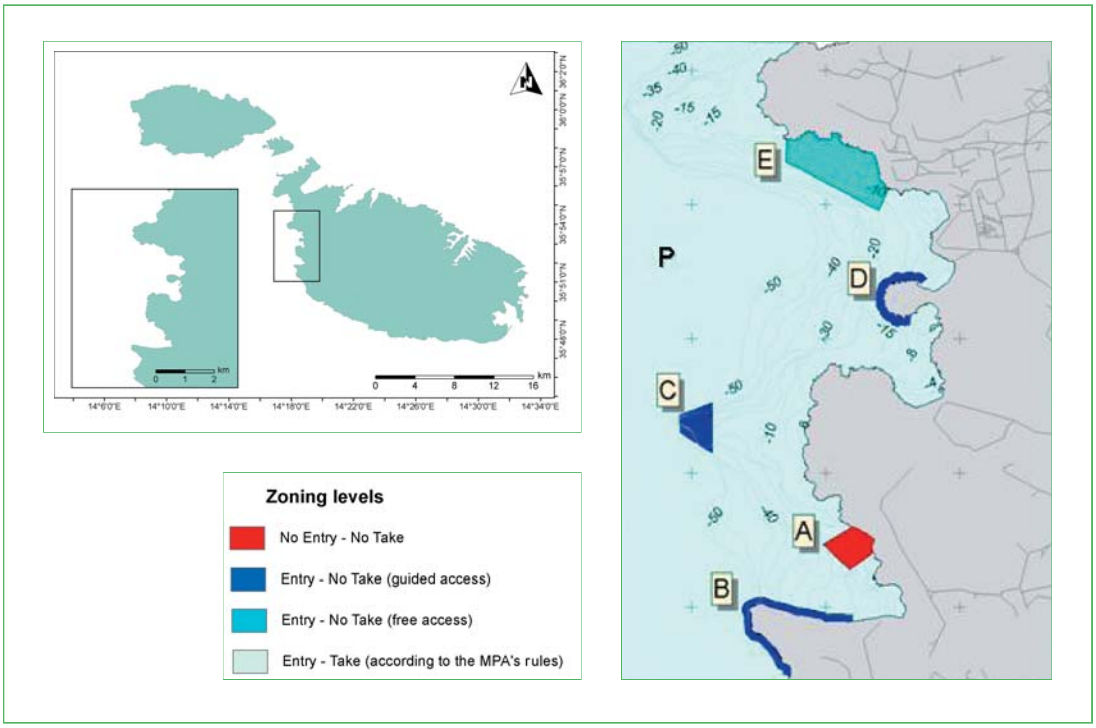
[2]Malta Centre for Fisheries Science (MCFS), Malta.

[3]University of London Marine Biological Station, Millport, Scotland, United Kingdom.



General features

Legal Status	On 18th November 2005, the marine area between Rdum Majjiesa and Ras ir-Raheb was declared as a Special Area of Conservation (SAC) and as a Candidate Site of International Importance in terms of the Flora, Fauna and Natural Habitats Protection Regulations, 2003 **(+)**
International Recognition	Not applicable at present but the Rdum Majjiesa and Ras ir-Raheb SAC will form part of the Maltese component of the NATURA 2000 network of the European Union The Rdum Majjiesa and Ras ir-Raheb area has been accepted as a European Marine Biodiversity Research Site (Focal Site) under the BIOMARE project
Foundation Text	Government Notice 1138 of 2005 published in the Malta Government Gazette of 18 November 2005 (No. 17,843 pp. 11,013–11,014)
Legal References	GN 1138 of 2005 (Government Gazette No. 17,843 of 18 November 2005) published in accordance with the provisions of the Flora, Fauna and Natural Habitats Protection Regulations, 2003 (Legal Notice No. 257 of 2003), published in the Supplement of the Malta Government Gazette No. 17,477 of the 26th September, 2003 **(+)**
Relevant Administration	Nature Protection Unit, Malta Environment and Planning Authority
Management Body	Malta Environment and Planning Authority (MEPA)
Consultative Committee	Still to be established
Main Marine Species	Seagrass meadows (*Posidonia oceanica*, *Cymodocea nodosa*) 'Bare' sandy bottoms Infralittoral algae (*Cystoseira* spp., *Dictyopteris polipodioides, Padina pavonica, Halopteris* spp.*, Flabellia petiolata, Peyssonellia squamaria* and several others) Mäerl Internationally protected species *Posidonia oceanica* [a,b,c] — *Cymodocea nodosa* [b] *Aplysina cavernicola* [a,b] — *Astroides calycularis* [a,b] *Dendropoma petraeum* [a,b] — *Luria lurida* [a,b] *Erosaria spurca* [a,b] — *Tonna galea* [a,b] *Lithophaga lithophaga* [a,b,c] — *Pinna nobilis* [a,b,c] *Maja squinado* [a,b] — *Scyllarides latus* [a,b] *Scyllarus* spp. [a,b] — *Ophidiaster ophidianus* [a,b] *Centrostephanus longispinus* [a,b,c]
Marine Area Surface	Zone A: 7.01 ha Zone B: 7.42 ha Zone C: 6.06 ha Zone D: 44.14 ha Zone E: 23.75 ha Zone P: 796.82 ha Total: 885.20 ha
Web page	http://www.mepa.org.mt/environment/marine_protected_area/mainpage01.htm

(+) The site was re-declared a "Special Area of Conservation - Candidate Site of International Importance" by means of Government Notice 112 of 2007 (Malta Government Gazette Nº 18032 of 9 February 2007) in terms of the Flora, Fauna and Natural Habitats Protection Regulations, 2006 (Legal Notice 311 of 2006 published in the Malta Government Gazette Nº 18006 of 7 December 2006), which replaced the Flora, Fauna and Natural Habitat Protection Regulations, 2003.

Regulations

Activities	Zone A	Zones B, C, D	Zone E	Zone P
Forbidden	Swimming, diving, spear fishing, boating, anchoring, trawling, angling	Spear-fishing, boating, anchoring, trawling, angling	Spear fishing, anchoring, trawling, angling	Spear fishing
Regulated	Scientific research	Scuba diving	Boating	Anchoring, trawling, angling
Allowed		Swimming, scientific research	Swimming, scientific research, scuba diving	Swimming, boating, scuba diving, scientific research

Other Management Initiatives

The other management initiatives in the MPA can be classified into the following five primary objectives and for each of which details of specific objectives are further given:

A) Protection of marine biodiversity
I) Mapping of protected species and indicator species
II) Mapping of ecosystems in the supralittoral and mediolittoral zones
III) Data collection on fish populations/breeding sites
IV) Studies of ecosystems
V) Compilation of database with species lists for the different ecosystems
VI) Control of user access

B) Rehabilitation of degraded ecosystems
I) Control of non-commercial fisheries
II) Control of recreational activities
III) Control of user access
IV) Setting up of mooring/anchoring systems
V) Identification and quantification of sources of stress for their mitigation
VI) Ensure developments or human activities do not compromise water quality
VII) Contingency plans to combat incidents that could cause damage or constitute a threat to the MPA

C) Maximisation of the sustainable social and economic benefits
I) Promotion of sustainable fishing methods
II) Promotion of low impact user activities
III) Promotion of eco-tourism
IV) Fishermen – surveys of status and catch
V) Sport fishing surveys
VI) Survey of tourist activities
VII) Assessment of fish resources

D) Scientific research and monitoring
I) Research on fish populations to inform management of the fish resource
II) Monitoring programme for *Posidonia oceanica* distribution
III) Monitoring of protected species distribution
IV) Monitoring of main biotope distributions
V) Assessment of the occurence and distribution of alien species
VI) Assessment of links between geology and biodiversity

E) Education and public awareness
I) Publication and dissemination of printed informative material
II) Media promotion

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Rdum Majjiesa / Ras Ir-Raheb: ecological studies

▪ General

There has been only one scientific study on the Rdum Majjiesa to Ras ir-Raheb MPA (reported in Pirotta & Schembri 2000 and Pirotta 2001), the main objectives of which were to assess the biological characteristics of the site. Overall, the assessment was intended to produce an inventory and a scientific description of the major biological complexes occurring within the site's boundaries. The study was also intended to produce the base maps necessary for environmental managers to draw plans and programmes for zoning, managing and protecting the site.

Two surveys were carried out during the study, bathymetric and benthic, using a variety of diving techniques (multidirectional belt transects in proximity of the shore using snorkelling and SCUBA, unidirectional belt transects using diver-operated vehicles (DOVs) and SCUBA spot dives using anchored shot-lines). The data collected from these surveys were used to produce two sets of maps each at a scale of 1:2,500: one set showing the major geomorphologic features (bottom types) of the study area, and a second set showing the major biotic assemblages present. A synoptic version of these maps was also produced at a scale of 1:10,000. The data collected during the bathymetric and benthic surveys were combined to produce a map of the major seascapes present in the study area at a scale of 1:10,000.

The scientific investigations carried out during the study also provided new knowledge, and qualitative and quantitative data on the major geophysical and biotic characteristics of the proposed MPA, that confirmed the suitability of the Rdum Majjiesa to Ras il-Raheb area as a MPA. These baseline studies were subsequently used to make proposals for zoning (Grech 2002; Agnesi *et al.* 2003), for monitoring programmes (Schembri *et al.* 2004) and for management of the area (Anon. 2005).

In November 2005, the proposed Rdum Majjiesa to Ras ir-Raheb MPA was declared a "Special Area of Conservation and a candidate site of international importance" in terms of the Flora, Fauna and Natural Habitats Protection Regulations, 2003. Designation under these regulations is the legal basis for designating MPAs in Malta.

4 BIOMEX project: main results in EMPAFISH case studies[1]

4.1 The BIOMEX project: general objectives and workplan

The EC FP5 research project BIOMEX ("*Assessment of BIOMass EXport from marine protected areas and its impacts on fisheries in the western Mediterranean Sea*", QLRT-2001-00891) was a three-year project (2003-2005) developed by 9 research groups issued from 3 countries, France: EPHE–UMR 8046 CNRS; GIS-Posidonie; WWF-France / Spain: COB-IEO; Universidad de Alicante; Institut de Ciències del Mar - CSIC; Universidad de Murcia; AZTI / Ireland: University College of Dublin (most of them belonging to the EMPAFISH consortium), with the aim of testing and developing methods to estimate spillover from Marine Protected Areas (MPAs; also called herein 'marine reserves') to surrounding areas. The main objective has been to assess the export of fisheries-related biomass from MPAs ("spillover") to neighbouring areas. For doing so, a set of 6 littoral MPAs in the Western Mediterranean were chosen for this study because: a) they are well established (over 10 years of protection); and b) there is a large knowledge base concerning the benthic and nektobenthic fish communities in these reserves. Five out of these 6 sites are EMPAFISH case studies: Cabo de Palos – Islas Hormigas, Tabarca, Medes, Cerbère-Banyuls, and Carry-le-Rouet (plus Cabrera National Park, not included in EMPAFISH).

The specific objectives of BIOMEX were:

1 To look for evidence of the export of adult fishes from MPAs. This component involved methods for estimating 'spillover' resulting from random movements and density dependent process. Evidence of biomass export was obtained by assessing the existence of a gradient of abundance and mean size of target species across boundaries of the reserve. The gradient of biomass was investigated for the littoral fish assemblages in selected MPAs using underwater visual census techniques.

2 To estimate pelagic export resulting from the dispersal of eggs and larvae. As eggs and larvae are often pelagic (see exception for benthic egg strategy), this work package involved investigation of pelagic export, which has always been the most difficult part to quantify in recruitment studies. The hypothesis to test was also that a gradient of abundance should result from the higher egg production expected in MPAs. This survey was linked to a survey of the hydrography of the area in order to describe the dispersal potential of passive eggs and larvae from the MPAs.

3 To estimate the contribution of adult fish export to fisheries, as biomass export of adult individuals of high value species from MPAs should have an influence on the yields and quality of the surrounding catches (consequently on the relocation of fishing effort near MPA borders). To quantify the impact of MPAs on fisheries experimental fishing surveys were carried out at increasing distances from the MPA boundaries to assess gradients of catch per unit effort. In addition, onboard commercial fishing vessels operating in adjacent fishing grounds were sampled to evaluate the impact of MPAs on commercial yields and to estimate the spatial distribution of effort distribution in relation to MPAs.

The three approaches were conducted in the selected MPAs according to a common sampling protocol in order to obtain comparable data and attempt to develop a general model of the factors determining and affecting export of biomass from MPAs.

4 Finally, the BIOMEX project intended to translate the findings from the first three project components into management actions and recommendations for MPA policies in order to ensure transfer of these scientific results into actions for a better management of marine coastal areas.

The BIOMEX project was organised in 6 work-packages (WPs), of which one (WP1) was devoted to coordinate the overall project activities (under the leadership of CNRS-EPHE, EMPAFISH partner #2), as well as disseminate the results at the scientific and stakeholder levels. The five other packages (WPs 2-6) constituted the core of the project, and they were mutually matched by considering the biological (benthic and pelagic export) as well as the fisheries components of biomass export, using different but complementary methodological approaches (visual census, plankton surveys, video recording, experimental/commercial fishing gears). As a consequence, most data issued from the BIOMEX project have been used in EMPAFISH. In the following sections, the main results and conclusions of BIOMEX are summarised.

[1] This section is a summary of the BIOMEX Final Report presented to, and approved by, the EC. See http://biomex.univ-perp.fr for further details.

4.2 Gradients of biomass and biomass export from MPAs

The objective of the BIOMEX Work Package 2 ("Visual census") was to look for evidence of the export of adult fishes (spillover) from 6 Mediterranean MPAs, by assessing the existence of gradients of abundance and biomass of target species across MPA boundaries. Gradients were investigated for coastal fish communities using underwater visual census techniques (UVC), while controlling for the effect of habitat structure on the studied variables (Harmelin-Vivien *et al.* in press). In parallel, Work-package 3 ('Video survey') of BIOMEX was devoted to estimating fish export from MPAs using Baited Underwater Video (BUV) as the sampling technique. Therefore, WP3 incorporated an important component of technical development of this relatively novel sampling tool (see Stobart *et al.* 2007 for further details).

Underwater visual and baited-video census of adult fishes provided strong evidence of significant increases in mean species richness, abundance and biomass of fishes inside marine protected areas, as has already been reported in the literature. There were some exceptions related to the particular features of each MPA. Depending on the geomorphological structure of the MPAs and adjacent areas, the habitats surveyed, and the species or group of species studied, differences in fish community parameters between inside and outside MPAs generally increased from species richness to abundance, and then to biomass. Based on underwater visual censuses, mean fish abundance (excluding planktivores) for the 6 MPAs combined, was 1.3 times higher inside the MPAs than in adjacent fished areas, while biomass was 4.7 times higher inside the MPAs. The cause of this difference was that mean fish weight is greater inside than outside MPAs. Biomass of fish is therefore the best parameter for studying reserve effects, and was also the most powerful parameter for the assessment of gradients across MPA boundaries.

The difference in abundance and biomass was not as clear from BUV censuses as the technique tended to sample small rather than large fish sizes more effectively compaed with UVC. However, the baited underwater video technique was able to detect a reserve effect for some species and species groups, in certain MPAs. Nevertheless, common trends between the two approaches (visual and video) were found for a few species belonging to the main families targeted by fisheries (Moronidae, Muraenidae, Serranidae, Sparidae, Sciaenidae, Scorpaenidae and Labridae), suggesting that fisheries were mainly responsible for reduced fish biomass outside MPAs. It has to be emphasized that the first time the baited-video technique was used in the Mediterranean was during the BIOMEX project. The technique proved to be a good method for assessing fish species diversity; however, estimates of fish abundance were generally low with mean abundance for most species being <1 per location. Based on our results, BUV improvements are suggested to optimize its use in deep waters where UVC using SCUBA is inoperable.

Overall, both methods showed high variability in results precluding the identification of common trends across MPAs. The pattern we were detecting implied interactions of fishing effort, large distance movement, spillover of post-settlers; competitive density-dependence; response to the spatial distribution of preferential habitats; and behavioural bias of fish towards divers or video equipment. Here we should emphasise that the BIOMEX hypotheses relies heavily on the assumption that conditions are equal across the MPA boundaries studied and that they do not vary with distance (habitat, depth, distance to ports, other uses such as diving, fishermen traditions and knowledge of certain fishing grounds, prevailing weather conditions, past fishing history, etc.). The high variation we found can therefore be expected as most of these parameters cannot be controlled by any sampling design. Therefore, we suggest that the significant trends detected can be regarded as strong trends considering the large number of factors affecting the distribution of fishes.

In conclusion, there is evidence that negative biomass gradients do exist across MPA boundaries in the 6 MPAs studied, mainly detected from underwater visual censuses. It is important to emphasize the gradients detected did not extend far from the borders of the MPAs concerned. The gradients detected are consistent with the theoretical expectation of adult fish exportation from MPAs. However, negative biomass gradients, if caused by fish export from the MPAs, do not allow quantification of export because no information exists on the production inside and outside the MPAs.

4.3 Gradients of abundance of eggs and larvae

Work Package 4 (“Ichthyoplankton survey”) was a challenging one because it started with many uncertainties. Some were linked to technical aspects such as operating vessels on such a small scale and in shallow waters. New plankton nets (fixed net) were therefore developed and appeared to be very efficient in collecting eggs and very young larvae in shallow water. The challenge was also to carry out the biological and hydrological sampling in 6 MPAs, therefore 6 sites, 6 oceanographic models, etc. Furthermore, knowledge had to be gained to identify eggs and very young larvae of certain species not previously described. It led the consortium to develop an identification guide of eggs and early developmental stage larvae.

Surveys of the distribution of eggs and larvae were mainly carried out for a few target species that would potentially show evidence of an MPA effect and whose eggs and larval stages could be identified. The surveys revealed high numbers of eggs and larvae inside the MPAs in comparison with adjacent areas, and there was a gradient as one moved away from the MPA area. Such a high production signal from the MPA corroborated WP2 results that demonstrated higher abundance and a larger size of adult fish inside the MPA. Such a major benefit, largely emphasized in the literature, but rarely backed with real data, was unambiguously demonstrated for at least a few target species well represented in the 6 MPAs.

The work on eggs and larvae emphasised high variability in their distribution due to current patterns that vary over time and in three dimensional space, behaviour of larvae that varied from species to species but also at the different developmental stages, and production that varied in space because of habitat and distribution of adults. Nevertheless, it was a great success that even with such a highly variable component, the studies were able to detect gradients of abundance from inside to outside MPAs, consistent with production inside reserves and exportation to outside fished areas. Not all patterns were significant, but the main trends supported the initially formulated hypothesis. Increase in production was mainly visible in commercially targeted species that typically respond best to protection, and show strong increase in abundance and mean size of individuals in MPAs.

4.4 Adult fish export and fisheries

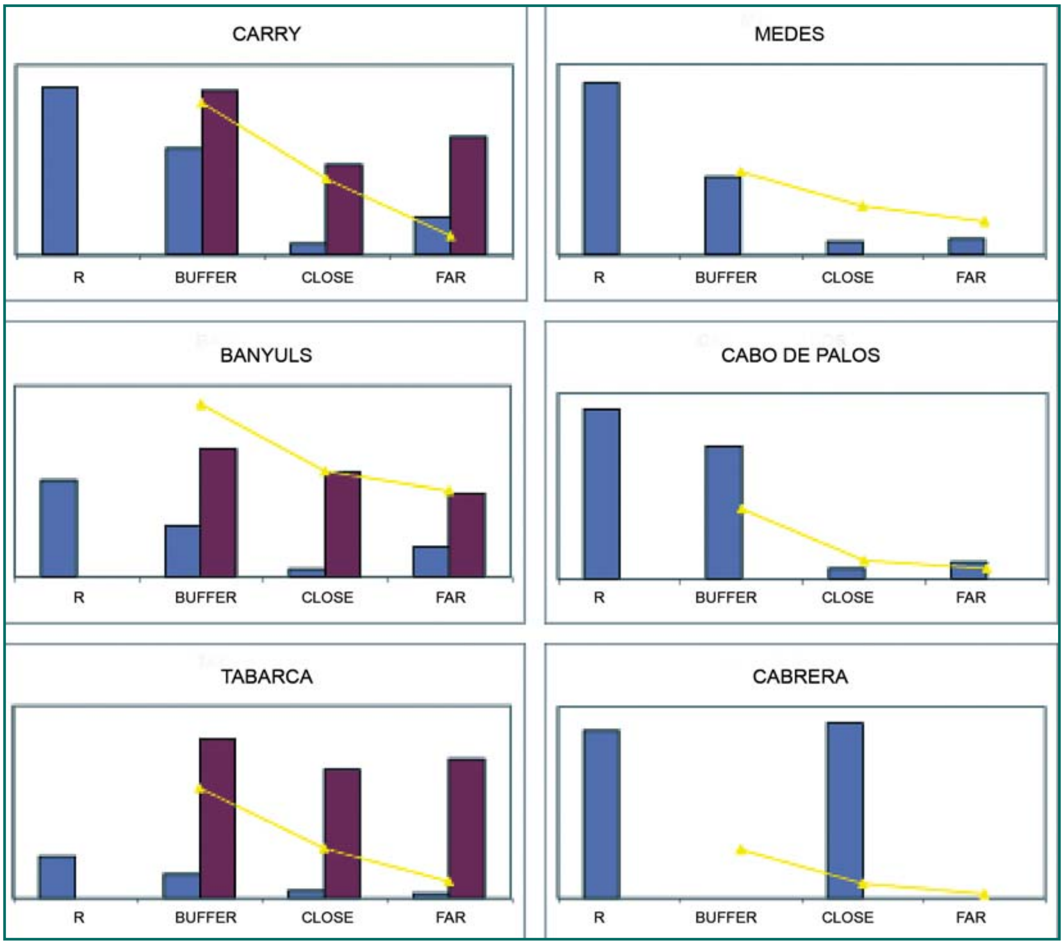
The study of the contribution of adult fish export to fisheries was done by (a) experimental fishing at increasing distance from the MPA boundaries (in order to control sources of variability mainly associated with fishing gear, fisher, distance to MPA and habitat) and by surveying the commercial fisheries operating inside and around the MPAs. For both approaches, fisheries and gears focussed on commercial fish species potentially affected by protection in the studied MPAs were targeted, such as Sciaenidae, Sparidae, Serranidae, Labridae, Scorpaenidae and Mullidae.

Results from experimental fishing showed a significant reduction of biomass with distance in those MPAs where habitat was continuous. Overall, this study recorded higher yields near the boundaries (up to 1000 m) that declined rapidly with distance to the MPA.

The survey of the commercial fisheries indicated that globally effort concentrated in the vicinity of the MPAs. The catch per unit effort (CPUE), the catch per unit area (CPUA), and the mean body size showed significant negative trends with distance in about 20 to 30% of the cases studied (MPA/species or group combinations). Variability dominated the results of the survey of commercial fisheries; variation in target species, seasons, gears, habitats, traditions, prevailing weather conditions, past exploitation and socio-economic factors strongly affected fishery data.

4.5 Combining evidence of exportation

Similar trends were obtained when comparing the results of biomass gradients from visual censuses of adult fish with experimental fishing and commercial fishing effort estimated from onboard sampling in the 6 different MPAs. This is in agreement with the hypothesis of exportation from the MPAs. A joint plot is shown in the figure below to compare trends, with the same pattern suggested for the 6 MPAs with (1) a decline in adult fish biomass from the reserve areas to the buffer, close and far areas; (2) a decline in catch from experimental fishing from the reserve areas to the buffer, close and far areas; and (3) a decline in global commercial fishing effort as one moves away from the boundaries of the reserve. These three features are consistent with biomass export from MPAs benefiting local fisheries. The results of these 3 types of surveys (visual census, experimental fishing, and commercial fishing) suggest the occurrence of spillover of some species of adult fish from the MPAs to fished areas. Visual censuses indicated that fish biomass was higher in MPA than outside and decreased with distance from MPA border (blue bars). Experimental fishing demonstrated that catches were higher near MPA boundaries and decreased farther (red bars). The analysis of commercial fisheries data indicated that total fishing effort was higher near the MPA borders (yellow lines). The fact that, where data were available, experimental CPUE was higher near the MPA borders in spite of a higher fishing effort is a good indication that fish export from MPAs should occur.



Schematic representation of the biomass estimates obtained in WP2 (visual censuses, blue bars), WP5 (experimental fishing, red bars) and WP6 (commercial fisheries, yellow lines). The first three MPAs (Carry, Banyuls and Tabarca) combined estimates of biomass from underwater visual census, experimental fishing and fishing effort, while the remaining 3 other only combined estimates of biomass from underwater visual census with commercial fishing effort data. Arbitrary scales were choosen on the axes, but for each series of data (fish biomass, catches and fishing effort) the difference between MPA and fished areas were respected.

4.6 Conclusions

The existence of gradients in fish biomass and mean fish size supports the existence of spillover from the MPAs studied and therefore support the BIOMEX hypothesis. However, this exportation would benefit local fisheries only at a small spatial scale, from tens to hundreds of meters, even if fishes were able to migrate longer distances. The small spatial scale (100 to 1000 m) on which fish biomass gradients from the MPAs studied were revealed was probably related to the high fishing pressure existing in the Western Mediterranean outside MPAs and, where relevant, to habitat discontinuities.

In conclusion, results of the BIOMEX project have brought evidence of fish biomass export from MPAs to fished areas in the Western Mediterranean both for adults as well as for eggs and larvae of some species or groups of species. Even if fish biomass export from MPAs varies greatly in space and intensity according to fish species, and is restricted to a small distance from MPA border, it is likely to have positive effects on adjacent fisheries. Studying these effects was outside the scope of BIOMEX and should be the target of future research. It should be noted, however, that proper quantification of fishery effects of MPAs will be restricted to MPAs for which relevant fishery data existed before the creation of the MPA. None of the BIOMEX MPAs benefit from such data.

5 Epilogue: available data

5.1 The MPAs

From 19 out of 20 case studies included in EMPAFISH, we effectively have data usable within the Work Package 1 (WP1). Each case study usually comprises several datasets (one dataset is one particular study with a particular sampling design, even if it is done over several years). The minimum number of dataset per study is one and the maximum number is 8, the mean number being 3 studies per MPA. The total number of dataset for all the MPAs is 55.

5.2 The studies with regard to the WP1 framework

In the approach developed within the WP1, we need to model differences between two zones of different protection levels through the use of effect sizes (e.g. fully protected vs. unprotected). Therefore, only the studies with at least two zones sampled of respectively different protection levels can be used in this framework. From the above 55 studies, 11 highlight a sampling design with only one zone sampled and then 44 studies can contribute to the WP1 analyses.

5.3 Data collected

The datasets, disregarding the MPA from which they belong, can be a collection of several types of data. The main types of data collected are fish, algae and invertebrates. 29 studies are focused on fish assemblages, 9 studies on algae and invertebrates, the others being focused on specific target species. The data consist mainly in densities (e.g. abundance per transect, per quadrat). In some cases biomasses are available and for one third of the studies on fish assemblages, sizes of fish are present. More than 80% of the studies have been done on rocky bottoms. In the other cases, sandy or muddy bottoms, artificial substrates or seagrass beds have been sampled. 435 species are present in the overall dataset, 334 of them being fish species.

5.4 The designs

32 studies have a year component in their design. Nine have a sampled event done at least once before the MPA establishment. Some of these designs have not been conducted after the MPA establishment or have been done in only one similar protection level. Considering this, only six studies highlight a proper BACI (Before-After-Control-Impact) design. The whole range of years covered by all the studies is of 35 years. Even if in some cases the same sampling designs have been realised in different MPAs, the great majority of them differ from one MPA to another and from one study to another, whatever the MPA. They mainly differ in their temporal and spatial replication and in their spatial hierarchy. Six studies have spatial replication without any temporal replication and without a spatial hierarchy in the design. 30 studies have more than 2 levels of spatial hierarchy.

5.5 Additional data

Further fieldwork has been accomplished in a few EMPAFISH case studies during first years of the project, in order to complete the available information on the ecological effects of Atlanto-Mediterranean MPAs. In brief, this data collection consisted on the following:

During successive summers of 2005 to 2007, field data were obtained by members of the University of Murcia (partner #1) from sampling operations using fish UVC transects, benthos digital-photography quadrats, and gorgonians visual quadrats, to continue with the monitoring and assessment of the ecological effects of Cabo de Palos - Islas Hormigas marine reserve (case study #1) . Particular attention was paid to the impact of recreational divers on this protected area. This work has been partially funded by the Regional Fisheries and Aquaculture Service at Murcia, as management body of this MPA.

During the summer 2005 field observations and sampling (UVC and quadrats sampling) were carried out in Sinis – Maldiventre (case study #10) by members of the International Marine Centre at Oristano (Sardinia) (partner #5) to compare fish assemblages, *Paracentrotus lividus* populations and seaweed assemblages among areas with different level of protection (integral reserve, partial reserve and reference areas outside the MPA). The main aim was to assess the effects that the establishment of the reserve produced on fish abundance and *Paracentrotus lividus* density. Moreover, they tested the possibility that protection-related changes in abundance may occur in both sea urchin predators targeted by fishing activity (e.g. *Diplodus sargus* and *Diplodus vulgaris*) and in phytobenthic species potentially involved through cascade effects. *Posidonia oceanica* meadow density was estimated by counting the total number of shoots within ten replicate quadrats (2500 cm^2) at each site and reporting the mean value to 1 m^2. At each rocky site, the percent cover of any conspicuous seaweed was assessed in three replicate quadrats (2500 cm^2) placed on sub-horizontal surfaces, by means of the visual-estimation method. In order to assess the density and the size structure of populations at 4-6 m depth, sea urchins were collected from 5 m^2 surfaces (three replicates at each site); all individuals > 20 mm diameter (test without spines) were measured with callipers; data were reported to 1 m^2 and clustered into three size classes: small (20-35 mm), medium (35-50 mm), and large individuals (> 50 mm). Sea urchins < 20 mm were not considered to reduce the bias due to the difficulty to find them, particularly within the meadow. At each location and for both substrata, three replicate transects (125 m^2) were covered at 4-7 m depth, in order to visually assess the total fish abundance and the abundance of fishes predators of sea urchins.

In Bouches of Bonifacio (case study #11), an observational study has been carried out by the Instituto dell'Ambiente Marino Costiero (IAMC, partner #6) on the reaction distance of fish to spearfishing, with the aim to studying the effect of protection on the anti-predator behaviour of fish. The main hypothesis under investigation was that the reactivity of fish is affected by the fact that low (or no) fishing is being developed within the MPA. To approach this problem, a high speed video technique has been applied to measure reaction distance to the presence of spear-fishers. Results are being analysed at present.

The University of La Laguna team (ULL, partner #9) conducted new field sampling activities to complement existing data in La Restinga MPA (El Hierro island, Canary Islands, case study #15). This observational study focused on the fish community, using UVC, with the aim of collecting new “after” data in both control (unprotected) and impact (protected) zones, for comparisons with previous data. Abundance and size of all fishes observed where surveyed in two locations (protected and unprotected), three sectors in each location (three different protection levels inside the MPA and three different orientations in the island outside the MPA), and two sites in each sector.

A research cruise was undertaken to the Formigas islet and Dollabarat bank MPA (case study #17) onboard the N/I Arquipélago of the University of the Azores (IMAR, partner #10) between 23rd August and 3rd September 2005. The main objectives were to monitor the local fish communities and to evaluate the effects of protection within the marine reserve. Additionally the study gave the opportunity to study post-recruit dispersion and migrations, to detect and assess the expansion of potential invasive species and to evaluate the ‘tropicalization’ of local communities as a potential response to the warming of coastal waters. Two sampling techniques were used: experimental fishing with bottom longlines to study the deepwater demersal fauna and underwater visual census (UVC) to study the shallow water fish community. The bottom longlines, locally known as stone/buoy longlines, were identical to those from the commercial fishery to allow comparison with seamounts open to fishing (in particular Mar de Prata). Four sets were deployed between 35-1192 m depth with a total effort of 9580 hooks. All sets were stratified by depth intervals of 50 m. A total of 521 individuals representing 32 species were caught and sampled of which 153 fish (16 species) were ID-tagged with T-bar anchor tags and plastic tipped dart tags and released. The UVC consisted of non-fixed strip transects of 50x5 meters, stratified by major ‘habitat type’ (inshore protected habitats, exposed refs, offshore reefs), depth and substrate. The numbers and size of individuals were recorded pertaining to the shallow water fish community, including the mobile, ‘off the bottom’ fish community, and the large, cryptic predators that hide in crevices and holes during the day (dusky groupers, forkbeard, eels, etc.).

A mensurative field experiment was undertaken by researcher at the University of Pisa (UPI, partner #14), aiming at assessing whether the efficacy of MPAs in protecting biodiversity on islands of the Tuscany Archipelago (case study #18) changes according to the extent of the area of complete human exclusion, and whether MPAs can function as a source of individuals for nearby impoverished areas and how features of habitat (e.g. complexity and heterogeneity) can modulate the effects of protection. First, they tested the hypothesis that the efficacy of MPAs on fish, invertebrates and macroalgae can vary according to their extension. This has been done by comparing assemblages between islands totally protected and islands where only some sectors are protected from human activities. Secondly, they are testing the hypothesis that MPAs represent a valid tool for re-stocking of over-exploited species through the movement of individuals from the protected areas towards nearby unprotected areas (spillover effect). This has been achieved by sampling along a gradient of distances from the boundaries of sectors where human activities are totally banned. Finally, the hypothesis that effects of protection are still detectable once the influence of spatial processes (e.g. geographical position) and environmental covariables (e.g. habitat complexity) are partialled out is being approached. Response variables included the density and size of fish, density of sea urchins and the percentage cover of benthic sessile organisms (macroalgae and invertebrates). Furthermore, the proportion of each type assemblage (e.g. seagrass, sand, canopy algae, etc.) along each transect was recorded. Organisms were sampled by means of non-destructive visual techniques. Fish were counted along 25 m long and 2 m wide transects (UVC). Five transects were replicated in different sites selected inside and invertebrates) were sampled by means of photographic technics. Pictures were taken by means of a digital camera equipped with metal distancer following the same sampling design described for sea urchins. The percentage cover of sessile taxa and number of mobile animals were then quantified by superimposing a grid of 25 subquadrats on a PC screen. The complexity of the habitat was estimated, in each transect of visual census, by measuring the distance between the extremities of a 10 m long chain after this was deployed on the bottom. The difference between the linear and *in situ* length of the chain provides an estimate of the complexity of the habitat (i.e. the reduction is greater when the complexity increases).

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