A review of marine protected areas in the northwestern Mediterranean region: siting, usage, zonation and management

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ABSTRACT

1. We present in this review a general description of marine protected areas (MPAs) in the northwestern Mediterranean and some general principles for the establishment of protected areas, including their size, location, biotope composition, regulation, and management.

2. Many Mediterranean MPAs are located around or adjacent to islands, but the placement of a marine reserve close to a large urban area is not necessarily a handicap, as has been demonstrated by some examples. It is not, therefore, necessary to restrict future MPAs solely to regions of low human density.

3. The conceptual question of MPA size (single large or several small SLOSS debate) has never been explicitly considered in the selection of Mediterraneenan MPAs. However, studies of fish recruitment in MPAs, and the development of a network of small MPAs between Spain and France have highlighted the importance and value of small sized MPAs (200–2000 ha).

4. Whatever the location of a future MPA, its success as measured in terms of stock restoration will depend on whether (i) sufficient suitable habitat is available, (ii) the variety and abundance of prey species are adequate and (iii) the possibilities for recruitment of the biota are reasonable.

5. The initial choices of zonation and legislation regulating the management of any future MPA are of primary importance. The zonation plan should be as simple as possible (gradation of 2 or 3 levels) and it should be acknowledged that the significance of management conflicts within a MPA will be inversely proportional to the extent of preliminary consultations with all of the users, both professional and amateur.

6. The examples of semi-protected areas where professional fishing is still allowed demonstrate without ambiguity the negative impact of spear-fishing, and the limited impacts from regulated professional activities on fish assemblages. The means of regulating consist essentially of (i) a prohibition of certain type of fishing methods (trawling); and (ii) a limitation of the numbers of fishermen by a system of restriction or authorization.

7. In the MPAs examined, there is a great diversity of situations in relation to the size of and distribution of duties between staff assigned to their management. However, the single most
important factor underlying whether or not a MPA will be successful and beneficial is the presence of a dedicated staff.

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INTRODUCTION

In the Mediterranean region, the term marine protected area (MPA) can cover a wide variety of different situations, which may differ as much in their oceanographic and ecological contexts as in their practical uses. They can also differ according to the options chosen or imposed at the time of their planning and establishment — such as in their levels of protection and usage zonation, their plans of management, their administrative jurisdictions, and the resources available to manage them.

Various publications have described MPAs in the Mediterranean region (Cognetti, 1986; PNUE-IUCN, 1990; Ramade, 1990), their jurisdictional and legislative arrangements (Meinesz et al., 1983; Beuttler, 1994; Ramos-Espí and McNeill, 1994; Batisse and Jeudy de Grissac, 1995), their role in biodiversity protection (Saldanha, 1992; Boudouresque and Ribera, 1995), and their potential economic value (Boudouresque, 1990; Ribera-Siguan, 1992). However, there is no existing synthesis that outlines the choices offered to managers in creating a MPA in the Mediterranean Sea, from the selection of the site through to the establishment of the reserve and its regulations and management regime. As stressed by Allison et al. (1998), the marine reserves are essential to marine conservation, but their efficacy can be greatly enhanced if their design and implementation are scientifically sound (but see Gray, 1999).

Such a synthesis has already been presented in the cases of New Zealand (Ballantine, 1991), Australia (McNeill, 1994, but see Ward et al., 1999), the UK (Jones, 1999) and for tropical environments in general (Salm and Clark, 1984). In the Mediterranean region, several studies have taken a step towards this goal by examining and identifying littoral zones of ecological, faunistic or floristic interest (e.g. Dauvin et al., 1993; Tunesi and Diviacco, 1993; Chemello and Riggio, 1995; Monbailliu et al., 1996); others have presented, in a more theoretical context, opportunities for the creation of such MPAs (e.g. UNEP, 1987; Boudouresque, 1990; Zoppi, 1992; Ramos-Espí and Mas Hernández, 1995). However, nobody has yet attempted a broad analysis of and suggested some general principles for the establishment of such protected areas, including their size, location, biotopes, regulation and management, in the Mediterranean region.

In this paper, we attempt to isolate the principal features necessary for the successful functioning of a MPA, which can lead to concrete propositions for the implementation of such reserves. This synthesis is supported by the various results presented in available scientific publications relating to the northwestern Mediterranean region, and is based more specifically on our own experiences in relation to various marine protected areas in France (Port-Cros National Park, Var; the nature reserves at Scandola, Corsica, and Cerbère-Banyuls, Pyrénées Orientales; and the Côte-bleue fisheries reserves at Carry-le-Rouet and Cap Couronne, Bouches du Rhône). For those MPAs situated outside of France (Medes and Tabarca in Spain, and Ustica in Italy), close contacts with our colleagues in these countries and visits to these sites have greatly facilitated the acquisition of pertinent information.

This synthesis is arranged in two main parts: (i) a general description of MPAs in the northwestern Mediterranean region (including their geographic positions, their different uses, the control of these uses and the conflicts which they generate, and their manner of functioning and management regimes); and (ii) an analysis of their contribution to the protection on the marine environment. Finally, we conclude the synthesis by evaluating the balance between their costs (i.e. of regulation and management) and their benefits (i.e. in terms of reserve effects and economic returns).

DESCRIPTIVE SYNTHESIS

The main characteristics of the major northwestern Mediterranean MPAs that are reviewed here are presented in Appendix A, site by site (Figure 1).

Choice of sites and zonation for different types of usage

Site selection

The potential for the recovery of the marine flora and fauna within a MPA depends largely on the bottom types and the oceanic conditions in that area (e.g. Carr and Reed, 1993). The effects of protection of such an area have a better chance of becoming evident if the area offers improved resources in terms of shelter and food to populations of those species which have been depleted or impacted on by harvesting or other human perturbations; this chiefly concerns near shore (<50 m in depth) rocky reef bottoms with complex topography where economically important fishes and large decapod crustaceans are found (e.g. Port-Cros, Scandola, Medes). The time for recovery of these populations may vary from one area to another depending on local productivity. In a region where the productivity of the waters is less (e.g. Ustica, in the markedly oligotrophic Tyrrenian Sea; Platt, 1985) this will be longer than in a region with higher productivity (e.g. Carry-le-Rouet and Medes, both influenced by the inputs from nearby rivers, in this case the Rhône and the Ter, respectively).
Many Mediterranean MPAs are located around or adjacent to islands. Accentuated isolation (e.g. Ustica) can also considerably retard the rate of stock recovery of those species, the recruitment of which depends largely upon egg or larval transfer from exterior sources (Harmelin and Marinopoulos, 1993; Vigiola and Harmelin, in preparation). Isolation also increases the consequences of local deficiency of nursery habitats, which cannot be buffered by the presence of adjacent suitable habitats (e.g. the scarcity of habitats suitable for the settlement of Diplodus spp. at Ustica; Vacchi, personal communication).

The placement of a marine protected area close to a large urban area is not necessarily a handicap, as has been demonstrated by the example of the Carry-le-Rouet Reserve near Marseille (Harmelin et al., 1995). In this case, the pressure of human uses on areas adjacent to the MPA are generally higher and less seasonal than when an MPA is located far from urbanized areas, and therefore more intense and constant surveillance efforts are required. On the other hand, benefits in terms of societal returns, particularly through education (e.g. classes for schoolchildren routinely organized at the MPA seaside) are more evident in this type of MPA. It is not, therefore, necessary to restrict future protected areas solely to regions of low human density (e.g. Scandola), or to small islands (e.g. Port-Cros, Medes, Tabarca, Ustica).

Size, shape and layout of MPAs

The conceptual question as to whether a single large protected area or several smaller ones would be more effective (SLOSS debate: e.g. Simberloff, 1988; Rowley, 1994; Lundberg and Jonzen, 1999) seems to have never been explicitly considered in the selection of Mediterranean MPAs. As stressed by Simberloff (1988), the prominent importance of habitat distribution and of other features, such as the life-history traits of species on which conservation efforts must be focussed, prevent the possibility of providing a single answer to this debate. For some reserve goals, biological considerations may make several small reserves more effective. However, for reserves designed to protect biodiversity hot spots in areas of high human impact it is more important to isolate the hot spot from threats as much as possible, and therefore it may be more appropriate to have a single large reserve to reduce the interactions with heavily used areas (Allison et al., 1998). However, networks of reserves have been advocated by numerous researchers (e.g. Salm and Clark, 1984; Ballantine, 1991; see review by Allison et al., 1998).

Outside the Mediterranean area, McNeill and Fairweather (1993) considered that the choice of several small MPAs was preferable to the establishment of a single large MPA. The ecological justification for this involves the importance of edge effects (i.e. the influence of perimeter:area ratio; Rowley, 1994) in the rate of exchanges (either of larvae or adult individuals) with outside communities. In the same way, Francour and Le Direac’h (in preparation) have proposed that an increase in this ratio may result in an augmentation of the quantity of fish larvae moving out of and away from a MPA to colonize surrounding areas.

The establishment of several smaller MPAs rather than fewer of larger size in Mediterranean countries is more the result of independent local decisions rather than national management plans. The siting and size of MPAs are generally based more on human factors rather than ecological ones (e.g. the maintenance of traditional small-scale fisheries or marine leisure activities, potential user conflicts, opportunities for effective surveillance). From a practical point of view, this is sometimes the only choice possible along an urbanized coastline where the marine environment is exploited by a multitude of different users.

However, although not planned, the present multiplication of relatively small reserves along the Spanish and French coasts represents an interesting trend towards a network of MPAs (Goni et al., 1998). Such a network may have positive consequences on those vulnerable species, such as the dusky grouper (Epinephelus marginatus), which can benefit from series of sheltered places for its ontogenetic migrations. This Spanish–French suite of MPAs could, and should, be improved in terms of its efficiency as an
integrated system of interconnected shelters, i.e. MPAs, (involving both larval and adult transfers of significant species), and extended throughout other areas of the northwestern Mediterranean Sea. Such a consideration of marine conservation problems at a broader level is already occurring in the Mediterranean region with ongoing projects such as the planning for an international marine park joining southern Corsica (including the Lavezzi Reserve) and northern Sardinia across the Bonifacio Strait. Similarly, the Commission’s Demonstration Programme on Integrated Coastal Zone Management (ICZM) of the European Union has looked at the many inter-related biological, physical and human problems presently facing coastal areas. Their causes can be traced to underlying problems related to a lack of knowledge, inappropriate and uncoordinated laws, a failure to involve stakeholders, and a lack of coordination between the relevant administrative bodies. For these reasons, the EU aims to promote a collaborative approach to planning and management of the coastal zone, within a philosophy of governance by partnership with civil society (http://europa.eu.int/comm/environment/iczm/comm2000.htm). This new approach could be a complement to the marine Special Areas of Conservation (mSACs), promoted by the EU’s Habitats Directive as part of the Natura 2000 network, where the lack of provision for stakeholder participation in their management is likely to undermine the potential to successfully achieve marine conservation objectives (Jones, 1999).

The shape of a MPA (e.g. for a given surface area, square versus long and narrow), and its layout relative to the shoreline (and thus to the dominant hydrographic circulation) may influence in different ways the capacity of the MPA’s fish stocks to be replenished, to supply a spillover of adults and to export propagules to peripheral areas (Rowley, 1994; Allison et al., 1998). Part of the (shape-dependent) rate of exchange to and from an area (i.e. the import and export of biomass) is determined by the perimeter:area ratio, which is as strongly related to the shape of the reserve area as it is to its size. The shape and layout of an area are both clear determinants of the types and distributions of the habitats it can include. Thus, a long and narrow area will not have the same functionality if it is perpendicular to the shoreline compared with stretched along it, primarily because of depth-related differences in habitat distribution. This is particularly obvious when the bottom topography is steep, a common situation in the Mediterranean. The Mediterranean MPAs studied present a rather wide range of shapes and designs, determined by both local physical and benthic features and management objectives.

The protected zone is limited to a relatively narrow strip around two of the insular MPAs (Medes, Port-Cros), while the other MPAs are mainly polygonal in shape, extending varying distances along and off the shore. The offshore limits are generally determined by the local extension in depth of the beds of *Posidonia oceanica* or of coralligenous bottoms. However, in the case of Ustica Island, the offshore boundaries of the MPA extend far beyond these biotic limits and correspond in part to upper bathyal bottoms.

In most cases, the protected area is adjacent to the shoreline, except in the fisheries reserve of Cap Couronne (Côte Bleue) where the protected area starts at some distance from the coast (13 m in depth) and extends further offshore. This design resulted from a compromise between the surveillance costs policing of nearshore amateur fishing (both line- and spear-fishing) and the main objective of this reserve, i.e. its protection against trawling with the help of artificial obstacles. The same objective has determined the shape of the Cerbère-Banyuls reserve, which extends offshore over muddy bottoms beyond the deep border of coralligenous rocks.

**Zonation**

A zonation of usages is almost always practised in Mediterranean MPAs. Such zonation is designed for a hierarchical limitation of (i) the utilization of the biological resources present, by both professionals and amateurs; and (ii) degradations and perturbations caused by the users of the MPA. Unzoned
Mediterranean MPAs are either integral reserves (no take areas) over all of their area (e.g. the two reserves of the Côte Bleue Marine Park, Carry-le-Rouet and Cap Couronne), or regulated for a single use throughout their area (e.g. the nature reserve of Lavezzi, with regard to spear-fishing).

The zonation of the other MPAs is founded upon a gradation of two or three levels, with the distinction of a central (core) zone, where all uses and human activities are generally prohibited, except for the mandatory intervention of managers. The size of these zones of reinforced protection is always relatively small (65–100 ha, comprising around 7–10% of the total reserve area). This central zone is bordered by an intermediate (buffer) zone where certain uses are forbidden (generally spear-fishing, but sometimes also scuba diving and amateur line fishing, as at Scandola), or are subject to other limitations or controls. Small-scale professional fishing is usually allowed in this latter zone, but this is generally controlled by limitations on the fishing gear used, and/or by a system of permit limitation which is equivalent to reserving this zone for local fishermen and thus to maintaining the status quo of resource use (e.g. Ustica, Tabarca, Medes, Scandola). Where a third peripheral (general use) zone exists (e.g. Ustica, Tabarca), the regulation of activities there is not very restrictive.

The case of the marine part of the national park of Port-Cros is somewhat unusual, with no zonation having been prescribed for this MPA prior to its creation. This has since resulted in great difficulties when it was later decided to limit certain uses and to further protect a particular part of it. The current zonation is therefore relatively complex, with (i) spear-fishing and trawling prohibited across the whole of the marine park area (1800 ha); (ii) line-fishing limited to a littoral border area 50 m wide along the north and west coasts of the marine park and extended to the whole park area (a 600 m wide border) in the eastern and southern areas; (iii) diving prohibited from 1 April to 31 September in part of the southern area; (iv) no anchoring in several specified zones; and (v) every marine activity prohibited in a small concession of 3 ha.

**Uses in MPAs: their control and conflicts**

The control of different human activities which are either allowed or prohibited within a protected area constitutes a major source of problems for the managers of that area. For each activity, the repercussions on the environment, the conflicts generated and the solutions adopted to regulate these various problems depend upon the past and current context of the MPA and on the regulatory tools at the disposal of the managers. Thus, tourist activities will be more difficult to control if they involve the full spectrum of mass tourism (e.g. Medes), and mainly if the development of these uses has not been previously predicted by a managing plan.

The siting of the MPA directly influences the features of certain uses (e.g. intensity, regularity, etc.). Thus, a MPA remote from urban concentrations (e.g. Ustica, Scandola) will not receive human pressures as regularly as a MPA integrated into an urban environment (e.g. the Côte Bleue reserves close to the city of Marseille), or in a zone with a very high seasonal tourist levels (e.g. the Costa Brava and the adjacent Medes Islands Nature Reserve).

It is notable that different uses and any consequent problems can vary considerably from one area to another. For example, tourism–reserve interactions are very strong at Medes, more moderate at Port-Cros, and weak or absent at Carry-le-Rouet (where tourist activities are generally limited to snorkelling from the shore).

In the different protected areas analysed, there appear to be no immediate or decisive solutions to be found to influence the quality and dynamics of tourism (either mass tourism or quality tourism), especially if there is no restriction on usages and no adequate diffusion of information (why protect? why regulate activities? why such an activity can jeopardize habitat, etc). Thus, in the example of the Medes Islands the success of protection in relation to the recovery of fish populations has resulted in a larger underwater tourist industry, the expansion of which tends to destroy certain positive aspects of this MPA;
the natural zone has, in effect, become a ‘leisure park’ (Ribera-Siguan, 1992). The problem has been addressed through enhanced protective measures involving the setting of visitor number quotas thus limiting the number of visitors allowed. Simultaneously, a certain amount of effort has been invested in improving visitor information with the production of well illustrated coloured notices and various brochures outlining the natural heritage values of the area and the damage that can be caused by over-use. A similar problem has been observed at Port-Cros, which has received the same type of human pressure, but to a lesser degree.

**Boating activity and anchoring**

Boating and anchoring are regulated in various ways amongst the different MPAs in France (Table 1) and other northwestern Mediterranean countries. Limitation of boat speed is one measure generally adopted which, for the French MPAs, is based on the application of the French maritime code (which limits the speed of boats to 5 knots within 300-m of the shore; Article 63 of the Disciplinary and Penal Code of the Merchant Marine). Sometimes a supplementary regulation complements this maritime code: at Port-Cros, for example, boat speed is limited to 3 knots in five limited areas highly frequented by divers, to 5 knots within the 300-m band adjacent to the shore (French maritime code), and to 12 knots within the remainder of the park (Decree No. 9/95 made by the Marine Prefect for the Mediterranean). At Monaco, motorized boat traffic is prohibited inside the reserve, although sailing boats are allowed. In Spain, in the Medes Islands Reserve, boat speed is limited to 3 knots, but this very low speed limit is often not respected, and this can sometimes result in accidents. In Italy, in the central zone of the reserve at Ustica, boat traffic is prohibited although it is allowed in the intermediate and peripheral zones of this reserve.

The prohibition of anchoring throughout a MPA is rare (Carry-le-Rouet, Cap Couronne), and such a prohibition usually applies only to the central zone (Ustica, Banyuls, Tabarca, Medes) or to other portions of the area (Port-Cros). The management of mooring by means of the deployment of surface buoys is rare (e.g. in two bays and in the main diving sites at Port-Cros, and at Medes). These installations, either temporary or permanent, have been installed to limit harm to the sea floor by the use of boat anchors (Port-Cros) or to more effectively manage the frequency and number of boats. These buoys can be reserved for different types of users (Medes). The scientific results currently available show that the installation of surface buoys can considerably diminish harm to the sea floor, and to *Posidonia* seagrass meadows in particular (Francour et al., 1999). On the other hand, poor application of these measures or a poor technical choice of mooring device can have negative effects (Robert, 1983).

The limitation of solid or liquid wastes coming from boats which are generally concentrated in the same areas is a difficult problem to manage and is most often neglected. For the managers of many MPAs, the limitation of itinerant anchoring is currently one of their main priorities (e.g. Port-Cros, Scandola).

**Scuba diving**

Scuba diving is prohibited in French MPAs except for most parts of the Port-Cros National Park, the Lavezzi Islands Nature Reserve and the peripheral zone of the Cerbère-Banyuls Nature Reserve. In the other Mediterranean MPAs, scuba diving is generally not allowed in the central part (e.g. Ustica, Tabarca) or it is subject to individual registration (intermediate zone of Tabarca, all of Medes) involving payment of a fee, or in some cases free access (peripheral zone of Ustica). The precautionary principle in relation to the eventual degradation of the habitats due to diving (coralligene bottom, caves, etc.) has also induced MPA managers to propose quotas on divers. These quotas can be a source of conflict but are reasonably easily enforced when they apply to dives organized by clubs. The quota can be fixed by limiting the number of clubs that can have access to the zone, and/or the number of divers (Medes, Tabarca). For individual divers such controls are more difficult to implement and can involve a procedure of individual authorization that the diver must obtain before diving (Tabarca, Medes). This permit can be
Table 1. Date of creation and legislation of MPAs in France, and Monaco. The areas are indicated in hectares for the entire MPA (marine part only) and for the zones in which particular activities are prohibited. The heading ‘surveillance staff’ indicates the number of permanent staff employed on the ground (excluding administrative staff).

<table>
<thead>
<tr>
<th>MPAs</th>
<th>Date of creation</th>
<th>Total area</th>
<th>Harvesting</th>
<th>Amateur angling</th>
<th>Professional fishing</th>
<th>SCUBA diving</th>
<th>Spearfishing</th>
<th>Anchoring</th>
<th>Surveillance staff</th>
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<td>1800</td>
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<td>3</td>
<td>1800</td>
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<td>50</td>
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<td>10 596</td>
<td>9600</td>
<td>10 528</td>
<td>17 910</td>
<td>622</td>
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<td>622</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staff/1000 ha</td>
<td>100.0</td>
<td>19.3</td>
<td>7.1</td>
<td>17.5</td>
<td>100.0</td>
<td>7.0</td>
<td></td>
<td></td>
<td>1.57</td>
</tr>
<tr>
<td>Ha/unit staff</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>639</td>
</tr>
</tbody>
</table>

* Since 23 September 1999, NR Lavezzi, NR Cerbicales, FC Porto-Vecchio and FC Bonifacio are included in 80 000 ha of the natural reserve of ‘Bouches de Bonifacio’ (see Appendix A).
attached to the diver’s buoy, and the number of divers can thus be theoretically regulated over any specific period of time (Medes).

In France, the Port-Cros National Park has made a start in consulting with different partners (diving clubs, French Federation of Underwater Studies and Sports, scientists, Maritime Affairs officials, and legislators) in order to propose new regulations for diving in these waters. Since 1993, a Charter, signed on an annual basis by the different clubs and the park management, aims at limiting the negative aspects of underwater tourism through the education of divers and control of access to the most vulnerable sites. New negotiations agreed to in 1997 will transform this diving charter into an official regulation applicable now to everyone (Robert, personal communication). These negotiations were supported and reinforced by several scientific studies carried out in the national park to assess scuba diving impact on ecosystem (Francour et al., unpublished). The concept of a code of user behaviour in the marine park, as put forward by the Port-Cros National Park in relation to diving, is an important element in reducing the possible risks of degradation of certain fragile species (e.g. sea-fans). The education of users is a primary factor in the successful management of diving in MPAs (Davis and Tisdell, 1995); this has been undertaken in the Port-Cros National Park by means of courses, booklets and, more recently, a free video movie distributed to every club and group of users. This recent adaptation of the scuba diving regulation inside the national park limits, supported by a better understanding of relevant biological, ecological, economic and social processes, is relevant from the principles of adaptative management stressed by Walters and Holling (1990).

Professional fishing

Professional commercial fishing is totally prohibited throughout French fisheries reserves and mariculture concessions (Carry-le-Rouet, Cap Couronne, Golfe Juan, Roquebrune, Beaulieu) and fisheries cantons in Corsica (Table 1). In the other MPAs, only a portion of the protected area is generally closed to professional fishing activities (i.e. integral protected zones of Banyuls, Port-Cros, Scandola, Ustica, Medes and Tabarca). In the latter cases, these activities may be individually authorized and limited to certain fishing gears in the remainder of the marine park. This system of individual authorization, renewed annually by the Office of Maritime Affairs in France, or an equivalent body elsewhere, is, theoretically, a means of controlling the activities of professional fishing; however, too great a permissiveness on the part of these bodies can result in the ineffectiveness of this means of control. A supplementary control of the impact of professional fishing on the habitat can also be achieved by prohibiting the use of certain fishing gears, most often bottom towed gears (e.g. Port-Cros, Medes, Tabarca). Specially designed, massive artificial reefs (Bombace, 1997) deployed at the periphery of the MPA can provide an efficient passive protection against the effects of such bottom towed gears when they are operated illegally (Carry-le-Rouet, Cap Couronne, Tabarca). The principal problems of management in relation to professional fishing appear to be essentially connected with any changes which may be proposed to the existing protection measures: the modification of a regulation where it includes any new restrictions or even a simple change in usage is almost always automatically opposed by the small-scale professional fishermen.

Amateur fishing

In the Mediterranean, amateur recreational fishing is essentially carried out by hook and line- and by spear-fishing. These activities are variously regulated in the MPAs considered. In France, spear-fishing is prohibited in every type of protected area, while a total prohibition of amateur line fishing applies only to the fisheries cantons, the fisheries reserves, and the Scandola Nature Reserve (Table 1). Elsewhere, it is authorized in at least parts of the MPAs (Cerbére-Banyuls, Port-Cros), or throughout the reserve (Lavezzi). In Italy and Spain amateur line-fishing is also prohibited in the central zone (Ustica, Medes,
Tabarca) and allowed in the rest of the MPA; sometimes freely, and sometimes with the need for a permit (Tabarca).

The prohibition of recreational fishing is relatively well accepted by the users, though cases of poaching involving illegal spear-fishing or line fishing are often reported by reserve managers. However, when such a prohibition has not been considered in the initial MPA regulations, or has to be extended (e.g. line-fishing at Carry-le-Rouet and Port-Cros at the time of their creation as reserves), any change in regulations proves to be difficult to implement.

It should also be noted that though systems of special approval or permits are used for professional fishing and spear-fishing, in France they have never been proposed for line fishing: it is either totally prohibited or allowed. By contrast, this type of permit system functions successfully outside France (e.g. Tabarca).

Functioning and management

Land-sea interactions

In the MPAs analysed, and in other Mediterranean coastal protected areas, there is rarely a common management regime for the terrestrial and marine environments, except at Scandola, in the national park of Port-Cros, and in a part of the Medes Reserve. Unsympathetic management of the terrestrial area adjacent to the marine protected zone may thus occur (e.g. excessive housing development on the shoreline at the Carry-le-Rouet Reserve). This can have negative consequences for the marine environment and on the whole reserve landscape. One of the solutions proposed in France has been the acquisition by the Littoral Conservancy (Agency of the ministry in charge of the environment) of part of the littoral zone adjacent to the MPA (e.g. Scandola, Bouches de Bonifaccio). Similarly, the ICZM proposed by EU seeks to integrate the terrestrial and marine components of the large territory, in both time and space.

Such an acquisition of littoral land by this agency (58000 ha, corresponding to 780 km of shoreline, have already been acquired along the French coastline) can be a prerequisite to the establishment of a MPA (e.g. the ongoing protected area project at the Riou Archipelago, near Marseille, France). Associated with a local desire to control development in both the terrestrial and marine environments, such action would permit the complementary management of littoral and marine habitats. When the legislation appropriate to the protected area permits the simultaneous management of the terrestrial and marine environments (e.g. Port-Cros National Park), such an acquisition proves itself to be essential.

Legislative structures

Legislative structures for MPAs can be divided into two main types: permanent systems (national parks, nature reserves), and those which are only temporary (fisheries reserves, mariculture concessions, fisheries cantons) (Meinesz et al., 1983; Beuttler, 1994). In the latter case, for French MPAs, protection is assured for a duration of 5 years, is renewable, and involves either the entire protected area (e.g. Carry-le-Rouet, Cap Couronne) or only a part of it (e.g. the zone around Rascas Islet at Port-Cros). Each renewal is subject to a series of fairly cumbersome administrative steps and justifications in favour of the renewal. This renewal procedure, however, may be considered as an audit of the functioning of the MPA and can, therefore, be useful.

Surveillance

In the analysis of management problems, surveillance very frequently proves to be a major concern. The principal problem is often the very small number of permanent staff involved in such surveillance.
activities. For all French MPAs, excluding the fisheries cantons, less than 15 permanent staff must carry out the necessary surveillance over a total area of 8945 ha (Table 1), which is equivalent to one person for about 640 ha. This unit area covered by each person varies greatly between zones from 147 ha on the Côte Bleue (74 ha in summer) to 600 ha at Port-Cros, and up to 2500 ha at Lavezzi. However, it must be kept in mind that equal areas may not necessarily be equivalent in their surveillance needs. The permanence of surveillance personnel within the MPA management, their strong motivation and their practical approach to the problems encountered, are considered to be most desirable. Management problems can appear or be exacerbated if surveillance officers are replaced too frequently.

Surveillance problems can also be reinforced by other factors such as:

(i) The distance between the terrestrial base of the MPA and the protected marine zone can limit the frequency and extent of surveillance, and thus pose logistical problems. On the other hand, the contiguous nature of a MPA with an accessible littoral base (as in the case of Carry-le-Rouet and Ustica) may greatly facilitate surveillance.

(ii) The mixture of usages allowed and prohibited may require closer surveillance; for example, to distinguish between a snorkeller (allowed) and a spear-fisherman (prohibited) (e.g. at Carry-le-Rouet). In general, the success of an MPA can increase the level of tourist use and thus the problems of surveillance and management may increase proportionally. On the other hand, during periods of heavy usage, poaching may be less likely.

(iii) The occupation of the surveillance staff with other tasks, often administrative or terrestrial, can also seriously reduce the time dedicated to surveillance on the sea (e.g. at Port-Cros).

In considering these problems of surveillance, many managers of MPAs would like to see better cooperation between the different government authorities with the ability to patrol marine areas and to enforce the regulations applying to the protected zone or relevant to the national marine laws (e.g. customs, maritime police). Such cooperation, either permanent (Banyuls) or temporary (Port-Cros), has demonstrated the immediate advantages that can result for the management of the MPA.

**Provision of information about regulations**

Regulations (prohibitions and zonings) must be simple and obvious, but this is a problem which has not always been resolved in many MPAs. The absence of information in the form of notices or signs is generally a cause of involuntary infringements (e.g. Scandola). The good design and construction of information materials is often difficult and costly. The complexity of zones and the absence of indicator buoys delimiting specific zones can also lead to involuntary infringements (e.g. Port-Cros). The buoying of zones is an onerous task which takes significant time and effort to put in place and to maintain (Loffeier, 1992).

The association between the MPA and its user groups through a system of memoranda of understanding (e.g. with the divers at Port-Cros) is a welcome step in limiting the problems of surveillance and of degradation of the environment, and also facilitates the transmission of necessary information.

**ENVIRONMENTAL CONSEQUENCES OF PROTECTION AND CHANGES IN USAGE**

The consequences for the marine environment of different protection measures and, in a more general way, of the modification of uses throughout a MPA, can be divided into positive and negative consequences.
Positive consequences

The totality of consequences in the marine environment of protection measures on benthic and demersal communities is generally termed as the reserve effect (Bell, 1983; Francour, 1989; but see Jones et al., 1993), the evaluation of which can be made by assessing the changes that affect the abundance and demographic structure of the stocks of sensitive vulnerable species and the modification of their distribution and behaviour (Bell, 1983; Harmelin, 1984; Bayle-Sempere and Ramos-Espla, 1993; Francour, 1994; Harmelin et al., 1995).

The scientific findings which indicate this effect are mainly based on fish populations. Results of such studies in Mediterranean MPAs attest to higher abundances of the most vulnerable fished species compared with nearby fished areas, a greater total number of individual fishes in general, and fish of greater average sizes in the protected zone than outside it (e.g. Garcia-Rubies and Zabala, 1990; Francour, 1991, 1994; Harmelin and Bachet, 1992; Harmelin et al., 1995; Garcia-Rubies, 1997; Jouvenel, 1997). A general observation in all of the MPAs studied is a spectacular increase in the habitation of shallow depths by fishes of all sizes. These differences are particularly obvious for those target fish species which are most sought after by amateur and professional fishermen. Regular surveys of only these target species can provide a simple means of measuring the effectiveness of protection or of the local fishing effort. This method has, for example, been developed and put to use (and largely perfected) in the Côte Bleue Regional Marine Park (Harmelin et al., 1995; Harmelin, 1999). Those fishes particularly favoured by these protective measures are the ‘noble’ species, which are normally relatively rare and which attain large sizes in the protected zones, such as the groupers (Epinephelus marginatus, E. costae), the dentex (Dentex dentex), the amberjack (Seriola dumerili), the brown meagre (Sciaena umbra), and also more common species such as the sea breams (Diplodus spp.), the larger wrasses (Labrus merula, L. viridis), the comber (Serranus cabrilla) and males of the rainbow wrasse (Coris julis).

On the contrary, such protection measures do not seem to directly influence the level of recruitment of juvenile fishes nor their mortality rates within MPAs, as has been demonstrated at Banyuls, Carry-le-Rouet, Port-Cros, Scandola and the Medes Islands (Francour and Le Direac’h, 1994; Macpherson et al., 1997; Vigliola et al., 1998). The precise requirements of recruits for particular juvenile habitats (i.e. nursery areas), which may be specific to each species and which are almost always located at shallow depths, are the principal factors explaining the spatial variability of the recruitment of individual species (Garcia-Rubies and Macpherson, 1995; Harmelin-Vivien et al., 1995; Francour and Le Direac’h, 1997). The distance from the source of production of the larvae is another determining factor: in the case of island MPAs (e.g. Port-Cros), the influx of larvae may be insufficient, explaining the absence or rarity of juveniles of some species despite the availability of suitable recruitment habitats (Vigliola and Harmelin, in preparation). The same phenomenon is observed at Ustica (Vacchi, personal communication), which has a strongly marked insular situation. These findings indicate that the choice of site for a protected area is most important, and can alone strongly influence the speed of recovery of fish stocks, and thus the future success of the reserve.

Most species of marine fish have a bipartite life cycle and undergo significant dispersal by marine currents during their larval development. Furthermore, many demersal species are not sedentary throughout their post-larval life and/or their annual cycle: they must change their habitat at certain stages, either for reproduction or to make use of certain resources. These habitat shifts can take them outside the boundaries of the MPA, and this is also the more likely in the case of the Mediterranean MPAs, most of which are of only moderate size. This suggests that there will be an export of fish from the protected zones to the exterior, either at the adult stage (adult spillover; Rowley, 1994) or in the form of eggs or larvae (larval export; Bohnsack, 1990; Carr and Reed, 1993). This phenomenon is, however, difficult to demonstrate scientifically, and has not been studied until recently in the Mediterranean region (at Scandola; Francour and Le Direac’h, in preparation). Elsewhere in the world, very few studies have
clearly demonstrated the export of either larvae or adults (but see Russ and Alcala, 1996). Conversely, the import of adult individuals of certain vulnerable, fished species into MPAs is one of the most obvious consequences of the protection of a marine area. This phenomenon is particularly evident for species which do not normally reproduce and recruit in the region where the MPA has been established. The most typical example of those Mediterranean species displaying refuge-oriented movements is the dusky grouper (*Epinephelus marginatus*), which, until recently (Zabala *et al*., 1997), did not reproduce successfully north of 41°5′N (Chauvet, 1991): the large populations of this grouper now observed in northwestern Mediterranean MPAs (e.g. Medes, Banyuls, Port-Cros) are largely based on adult individuals which have moved from their more southerly nursery areas (Francour and Ganteaume, 1999).

Two other components of the reserve effect have also been identified in these Mediterranean MPAs: the buffer effect (Francour, 1992, 1994, 2000) and the cascade effect (Sala, 1997; Sala *et al*., 1998). The buffer effect, which has been first demonstrated in relation to the fish communities of *Posidonia oceanica* meadows, is manifested by only small variations in the abundance of fish over the course of an annual cycle. This phenomenon, however, has not yet been demonstrated in rocky reef habitats.

Cascade processes concern interconnected changes in predation interactions involving keystone species at different trophic levels, which are induced by modifications affecting the identity or the activity rate of top-predators. As the latter often are favourite targets of both professional and recreational fishing, abatement of their stocks in overfished areas and conversely their replenishment in protected areas may thus trigger cascade processes (Steneck, 1998). The cascade effect as a consequence of protection was first proposed for a Chilean MPA (Moreno *et al*., 1984, 1986). This effect, however, can only be studied and substantiated when the food resources involved are simple and a few trophic levels are present (Sala *et al*., 1998; Pinnegar *et al*., 2000). In a Mediterranean MPA (Medes), both circumstantial and experimental evidences may indicate that the greater abundance of sparid fishes relative to that in unprotected areas (Garcia-Rubies, 1997) has led to an increased control of herbivorous sea urchins by these predators and consequently to the increased development of large erect algae (Sala and Zabala, 1996).

**Negative consequences**

For those MPAs having a strict reserve status, the principal negative consequence of protection is of a societal nature: total prohibition of activities within protected areas involves cutting some of the direct links of these areas with human society, often at the expense of the function of education as to why the protected area is necessary.

Other negative consequences come, on the contrary, from the uncontrolled opening of the area to visitors (Ribera-Siguan, 1992). As in the landscapes of terrestrial parks, the quality of seascapes may be altered by excessive visitor numbers. The most evident forms of degradation observed are those resulting from the anchoring of boats (Francour *et al*., 1999). Certain studies also indicate partial mortality or breakage of gorgonian sea-fans and of certain elements associated with them such as large bryozoan colonies, caused by the excessive use of certain sites by scuba divers (Garrabou *et al*., 1998), even fishing activities are also reproted (Bavestrello *et al*., 1997). This source of disturbance is also of concern for fragile sites, such as underwater caves, with for example the retention of air bubbles at the ceiling or suspension of mud from the substrate by divers (Ribera-Siguan, 1992).

The difficulty in controlling such an influx of tourists is a problem well recognized by the managers of all of those MPAs where marine tourism is practised (e.g. Port-Cros, Lavezzi, Medes), and does not yet seem to have been resolved.

**The relative importance of the effects of different forms of resource exploitation**

The variation in the zonation of uses which exists in Mediterranean MPAs allows an evaluation of the impacts of certain specific uses on the parameters of the reserve effect. In this context, it is thus
particularly interesting to try to distinguish the respective effects of the three important categories of coastal fisheries in these MPAs: namely small-scale professional fishing, amateur line-fishing, and spear-fishing.

Spear-fishing is prohibited in all Mediterranean protected areas, with the exception of a very small number of the buffer zones (Ustica). The inverse situation, where spear-fishing is allowed and other forms of fishing are excluded, is never encountered over larger areas, and its effects in these circumstances have not been tested. However, one can compare the state of fish communities (i) between two or more strict no-take reserves (e.g. Scandola, Carry-le-Rouet, Medes); (ii) between two or more areas where artisanal professional fishing activities continue (e.g. Port-Cros, Tabarca); or (iii) between two or more of those areas which are totally open to fishing.

The example of a semi-protected area such as Port-Cros demonstrates without ambiguity the negative impact of spear-fishing. Small-scale professional fishing, mostly with nets, has always been carried out there, and yet the fish fauna remains relatively abundant at all potential sites, and includes the most prestigious target fish species such as the dusky grouper (Chauvet et al., 1991; Harmelin, 1999), the brown meagre (Harmelin and Marinopoulos, 1993), the amberjack and the dentex (Francour and Harmelin, 1988). Many individuals of these species are found in the shallower rocky areas less than 15-m deep, and in these same habitats schools of large sea breams and other more common fish species are also very numerous (Harmelin, 1987). This situation does not result from the prohibition of trawling operations at Port-Cros, as in any case this fishing method cannot be undertaken over the shallow rocky bottoms in this area. It is thus clear from the overall quantity of fish inhabiting the reserve (which is the main reason for the success of submarine tourism at Port-Cros), that it is the prohibition of spear-fishing that results in this situation, and that it is not significantly affected by the continuation of small-scale fishing at a reasonable level. The situation observed at Port-Cros is not very different from similar conditions found in strict reserves such as Scandola (Miniconi et al., 1990; Francour, 1994), Carry-le-Rouet (Harmelin et al., 1995; Harmelin, 1999), or Medes Islands (Garcia-Rubies and Zabala, 1990; Garcia-Rubies, 1997).

This observation might seem paradoxical, for the catches of the professional fishery are certainly not negligible given the number of boats operating in the waters of Port-Cros (Aboussouan; Francour, unpublished). The explanation may probably lie in (i) the multispecific nature of the fish catches, a typical feature of Mediterranean small-scale fisheries (Farrugio et al., 1993), which may buffer their observable impacts; (ii) in the limited effectiveness of the nets used to catch fishes in the target species category; and (iii) because the rocky bottom habitats along the littoral zone are not easily exploitable by this method, while they can be impacted by both spear-fishing and amateur angling in unprotected areas. If the pressure of professional fishing is moderate, the fish communities present do not show any particular signs of over-exploitation and are not deterred from inhabiting those shallow water habitats which they normally prefer (Harmelin, 1987, 1990).

The means of regulating this professional fishery in the northwestern Mediterranean region consist essentially of: (i) a prohibition on certain types of fishing methods (e.g. towed bottom gear at Port-Cros, Medes and Tabarca); and (ii) a limitation of the numbers of fishermen by a system of restriction or authorization by local authorities (e.g. Scandola, Ustica). The mainly positive relationship which is observed between small-scale professional fishing and MPAs in this area of the Mediterranean depends on the fact that the fishing effort remains relatively moderate and that the fishing gears most generally used are nets. An increase in fishing effort and/or a modification of fishing practices with, in particular, the intensive utilization of more selective gear such as long-lines (which tend to target the larger noble species) could reverse this situation.

The quantification of catches from the amateur fishery at Port-Cros before its partial prohibition indicated that this fishing effort resulted in astonishingly high catches, incompatible with the ethic of a protected area (Combelles, 1991). The evident impact of this form of fishing has also been demonstrated by comparisons carried out between the Carry-le-Rouet Reserve and the area outside it, utilizing as
indicators two fish species which are important species in the line fishery, *Coris julis* and *Serranus cabrilla* (Harmelin *et al*., 1995; Jouvenel and Bachet, 1998). Furthermore, and conversely to regular professional fishing, amateur fishing is not limited by any cost-benefits threshold and can thus continue to develop without any economic restrictions. The potential for the development and growth of this fishing pressure is thus very significant considering that marine leisure activities are taking on more and more importance. By comparison, the growth of small-scale professional fishing pressure is limited by both profitability considerations and regulations, such as restrictions on the number of fishermen authorized, the types of fishing gear used, and the sizes of their boats.

**COST–BENEFIT ANALYSIS**

Several professional categories benefit from the positive returns of a MPA. We do not here propose to demonstrate economic mechanisms and their returns, which have been analysed in detail by Boudouresque (1990) and Ribera-Siguan (1992). We will simply synthesize their most important characteristics according to the type of activity.

Professional fishermen generally make a direct profit from a protected area, whether the fishery is regulated or prohibited. They also profit from prohibitions of, or regulations on, other forms of fishing (e.g. amateur line fishing and spear-fishing). Their catches are generally thought to be higher in protected areas (e.g. Port-Cros, Scandola) or in their proximity (Carry-le-Rouet, Tabarca), but there are few results available to sustain this assertion in the northwestern Mediterranean region. In any case, the indirect indicators are very numerous, such as the rate of renewal of boats, the sizes of the boats used, and the numbers of young fishermen taking up this profession in these localities (Ribera-Siguan, 1992; Ramos-Esplá, 1990, 1996). On the other hand, small-scale professional fishermen have been strongly involved in the creation of the Côte Bleue Marine Park (Carry-le-Rouet) and are actually supportive of its renewal every 5 years. They have also proposed, and recently obtained, the creation of a further MPA, at Cap Couronne. In a general way, fishers also profit from the strong tourist frequentation of the protected zone, often selling the fish they catch directly to local restaurants (e.g. Medes, Port-Cros, Ustica, Tabarca).

Scuba diving is one of the activities which can benefit the most from the creation of a MPA, even if it is forbidden within the core area. The biological and ecological consequences of protection measures attract numerous divers who come to the protected areas and the areas around them looking for an underwater spectacle, which they are rarely able to observe elsewhere. Several economic studies carried out have indicated that MPAs have generated a very active underwater tourism industry (Jego, 1992; Ribera-Siguan, 1992; Richez, 1992), clearly demonstrating the importance of returns for the region concerned, either directly (through diving club activities, accommodation, meals) or indirectly (through transportation, purchase of materials and equipment, and other induced commercial activities). This tourist activity supports the creation of numerous jobs in peripheral areas around the MPAs, which can also benefit from, and broadly participate in, the national and international renown of the nearby protected area (Ribera-Siguan, 1992). Also, when diving is partially or totally prohibited in the reserve, local dive clubs frequently still use the image and status of the MPA for their publicity (e.g. Scandola, Ustica).

Pleasure boating also benefits from the image offered by a MPA. The boaters can use their boats to come and practise specific activities in a protected area (e.g. snorkelling, sea watching, scuba diving) or to simply enjoy the setting. The studies so far completed (e.g. at Port-Cros and Scandola; Francour *et al*., 1997) show that a significant proportion of pleasure boaters chose their destinations because of the existence of a protected area, even if certain activities are prohibited there. This category of users is generally more independent than the others (with no need for accommodation, for example), but the economic returns to the region are still important (e.g. the use of restaurants at Port-Cros).
People living directly from tourism and practising their profession in proximity to a MPA generally make the significant part of their income from the frequentation of the area by tourists or through the indirect returns that they provide. The protected areas can be arranged according three categories: (i) areas having a high density of infrastructure dedicated to tourism; (ii) areas with a limited amount of such infrastructure; and (iii) those with no infrastructure.

In the first case, the Medes Nature Reserve distinguishes itself by a very high level of tourist usage, with a significant amount of infrastructure linked to tourism in its immediate vicinity (at L’Estartit). In this case, the reserve does not include any inhabited land portion but borders on a shoreline that is heavily exploited by traditional tourism, especially in summer. One benefit often put forward in relation to the Medes Reserve is that the exploitation of the marine and underwater domain of the reserve has resulted in an extension of the tourism season by attracting a new category of clients. This is also the case for Ustica and Tabarca.

In the second case, the Port-Cros National Park is an example of a MPA adjacent to a terrestrial park area where the addition of new infrastructure is limited by the park regulations. This control clearly restricts the expansion of tourism within the park as a whole. However, this limitation does not particularly concern the peripheral continental zone, from which the greatest proportion of the visitors to the park come, and the overall economic returns should be considered in terms of the region as a whole.

Finally, the last case can be illustrated by the Scandola Nature Reserve, which is a closed area and remote from any concentration of tourism. Prohibitions (and those in relation to scuba diving in particular), and the isolation of the reserve, seem to limit the economic returns to the immediate region. Thus, sightseeing visits to the reserve by boat can only be made by departing from two towns (Porto and Calvi) which are, respectively, 15 and 28 km away from the reserve.

In the protected areas analysed here, it seems that the balance between economic returns and environmental protection is in general roughly equivalent, although this can sometime incline towards either the economic return side (Medes) or the environmental protection side (Scandola). The development of activities which increase the appreciation by the public of the marine environment and its protection is one way which can be utilized to equalize the balance between economic returns and environmental protection in those MPAs which are open to tourism. These educational activities themselves generate both an economic flow and increased employment (e.g. Carry-le-Rouet, Medes); they comprise, amongst others, such activities as the use of underwater discovery trails for marine life watching (by snorkelling), glass-bottomed boats or ‘aquascopes’, the organization and running of courses or classes about the sea, and the design and production of signs and publications identifying the marine flora and fauna. The involvement of scientists in these activities (Medes, Carry-le-Rouet) can only help to reinforce the effectiveness of such developments.

**CONCLUSION: THE IMPORTANCE OF INITIAL CHOICE**

In this critical analysis of the different protected areas reviewed, the notion of ‘initial choice’ regularly returns. By initial choice, we mean the choices made before or during the creation of the protected area. We emphasize the importance of these choices in the title of this conclusion, in insisting particularly that there be: (i) a preliminary selection of potential sites; (ii) secure reserve legislation; and (iii) a choice of staff to employ.

**Siting**

It is without doubt rare to have the opportunity to choose amongst several potential sites in any project to establish a MPA (Jones *et al.*, 1993). Nevertheless, for the Mediterranean region we can imagine such
an ideal situation and underline the elements of wise choice in relation to the examination of the northwestern Mediterranean MPAs which we have analysed. Taking into account that the species and communities that one seeks to protect are most often inhabitants of rocky bottoms and dependent on a planktonic larval stage (dispersed by water masses), the success of restoration of stocks (both in terms of rate and intensity) will depend on whether:

(i) The available resources in terms of habitat types (e.g. bottoms with a heterogeneous topography, with all types of exposure) are extensive.
(ii) The extent to which nutritional resources, in terms of their variety and abundance (e.g. numbers of food types and productivity), are adequate.
(iii) The possibilities for recruitment of the biota (e.g. suitable nursery areas in the MPA or nearby, and a good influx of currents carrying fish larvae) are adequate.

To these ecological parameters can be added a logistic parameter which is related to the effectiveness of surveillance: the site chosen should be easily accessible throughout its extent from a terrestrial base. Finally, several MPAs of relatively limited size may be preferable to the option of a single large protected area, as much for ecological reasons as socio-economic ones. But it is important that into such a system of marine parks, MPAs are tightly interconnected to each other and fully integrated in their management (Bianchi and Morri, 2000).

Even with a lack of scientific study allowing us to determine an optimal area, it seems that, based on experience with existing northwestern Mediterranean MPAs, an area of between 200 and 2000 ha may be a satisfactory compromise. However, a relatively dense network of smaller MPAs, which can still function well if they include significant habitats, may represent an interesting alternative, particularly for promoting the stepping-stone dispersal of vulnerable species.

Legislation and management

The initial choice of legislation regulating the management of the future MPA is of primary importance. Most often management conflicts, which need to be resolved, arise because the problem has not been anticipated in the original legislation. The process of drawing up the management plans, once the protected area has been selected, should ideally be completed before the reserve’s declaration. The creation and management of a protected area, however, generally depends on the use of various existing pieces of legislation, but to be effective this legislation must have the power to be amended by additional arrangements without the involvement of too complex a legislative procedure. This comes back to saying that the success of the creation of a protected area depends not only on the analysis of its ecological and economic resources, but must also take into account the management of existing human activities and those which could potentially develop in the future (e.g. the modification of fishing practices and the development of certain new leisure activities, such as the use of sea scooters, tourist submarines, glass-bottomed boats which illuminate the sea floor at night, etc.). The greatest flexibility in the regulatory arrangements and a certain amount of decision-making autonomy for the managers is thus most necessary and appropriate.

Moreover the results of past (e.g. Carry-le-Rouet on the Côte Bleue) and present (e.g. the Riou Archipelago near Marseille) experiences indicate that the significance of management conflicts within any future MPA will be inversely proportional to the extent of preliminary consultations with all of the users (both professional and amateur) of the area to be protected.

Staffing

In the MPAs examined, there is a great diversity of situations in relation to the size of and distribution of duties between staff assigned to their management. Responsibilities for large parts of the necessary
administrative duties can often monopolize a large section of the available personnel at the expense of work in the field, and in particular surveillance activities. This latter task and the presence of staff in the field, which are essential for the credibility of a protected area, are rarely easy to assure. This demands the regular availability and a strong motivation of the staff, who are often too limited in numbers. The management structure put in place must take account of these imperatives in the distribution and choice of personnel and their activities, and must also foresee specific training needs.

MPAs, like their terrestrial equivalents, are rarely directed by a scientist or a person with extensive ecological or biological training (the exception being the Medes Islands), and the managers of most MPAs are often primarily administrators by training. The functioning of a protected area involves the input of scientific information and an ongoing evaluation of the state of the environment. This work is often, and should also be, programmed and supervised by a scientific steering committee. An active cooperation between this committee and the MPA staff should be the rule to ensure efficient science-based management of the protected area. Even if this work must in large part be undertaken by scientifically qualified teams from outside, it seems important that the MPA should include amongst its personnel a scientist of high standing who takes charge of that part of this work which involves monitoring of the environment and its biological evaluation, and that all of the field personnel are involved in this aspect of adaptive management.

The examples of Mediterranean MPAs examined here and our experience in relation to them indicate that the quality, the cohesion and the motivation of the management team, and thus its independence in relation to pressures of all origins, will be undeniable factors in the success and continuity of future MPAs. This human aspect is without doubt most important for the successful functioning of such MPAs. As Agardy (1997) highlighted it, ‘rather than administrative commitments to marine protected areas and strong capacities for managing marine areas, the single most important factor underlying whether or not a MPA will be successful and beneficial is the presence of a dedicated individual or group of individuals to carry it forward’.

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APPENDIX A

Summary accounts of the main Mediterranean MPAs mentioned in the text.

1 – Cerbère-Banyuls (Natural Reserve)
Country: France
Date of declaration: 26 February 1974
Position: 42°28'N, 03°10'E
Size: 650 ha (zoned; central zone: 65 ha, peripheral zone: 585 ha)
Primary purpose: Conservation; scientific research
Management features: Protection of all benthic communities against overfishing (trawling) on a zone extending across 1.5 nautical miles from the shore
Major habitat types: Rocky shores; rocky reefs; coralligenous grounds; Posidonia beds
Remarkable species: Precious red coral, purple sea fan, dusky grouper, brown meagre
Outstanding features: The development of coralligenous grounds and associated species
Prohibited activities: Central zone: all activities except for scientific purposes. Peripheral zone: trawling, spear-fishing
Permitted activities: Peripheral zone: small-scale fishing and recreational fishing with special authorization; diving
Comments: The central zone shelters large populations of red coral, dusky groupers, brown meagres and other large target fish species

Cerbères-Banyuls (Natural Reserve)
2 – Cap Couronne (Marine Protected Zone: aquaculture concession)
Country: France
Date of declaration: 14 May 1996
Position: Offshore limits: 43°18'N, 05°02'E–43°18'N, 05°04'E
Size: 210 ha (not zoned)
Primary purpose: Protection against overfishing from trawling
Management features: Protection of all benthic habitats from 13 to 50 m depth
Major habitat types: Rocky reefs; sandy bottoms; Posidonia beds
Remarkable species: Precious red coral
Outstanding features: Zone of high productivity (proximity of the estuary of Rhône river)
Prohibited activities: All fishing and collecting activities; scuba diving; anchoring
Permitted activities: Snorkelling; boating across the area
Comments: This zone has been formerly highly impacted by illegal trawling; protection against this activity is reinforced by the deployment of anti-trawling artificial reefs

Cap Couronne and Carry-le-Rouet (Natural Reserves)
3 – **Carry-le-Rouet** (Marine Protected Zone: aquaculture concession)

- **Country**: France
- **Date of declaration**: 8 September 1987
- **Position**: Offshore limits: 43°19’N, 05°09’E–43°19’N, 05°10’E
- **Size**: 85 ha (not zoned)
- **Primary purpose**: Protection against overfishing from trawling; replenishment of fished stocks; experiments with artificial reefs; scientific research; education
- **Management features**: Protection of all benthic habitats from the coastline to 30-m depth
- **Major habitat types**: Rocky reefs; *Posidonia* beds
- **Remarkable species**: Dusky grouper, brown meagre, *Diplodus cervinus, Dentex dentex*
- **Outstanding features**: A strictly protected zone included in an urbanized area (close to Marseille city)
- **Prohibited activities**: All fishing and collecting activities; scuba diving, anchoring
- **Permitted activities**: Snorkelling; boating across the area
- **Comments**: Several types of artificial reefs including anti-trawling types have been immersed in this area; educational programme comprises field courses for youngsters and guided visits via an underwater trail for snorkellers

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*Production artificial reefs
▲ Anti-trawling artificial reefs

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Cap Couronne and Carry-le-Rouet (Natural Reserves)
4 – Port-Cros (National Park)
Country: France
Date of declaration: 14 December 1963
Position: Around 43°01’N–42°59’N, 6°21’E–6°25’E
Size: 1800 ha (marine part: 600-m-wide belt around the islands of Port-Cros and Bagaud; zoned). In addition, 700 ha of island are protected.
Primary purpose: Conservation; education; scientific research, ecotourism
Management features: Protection of marine biota and habitats
Major habitat types: Rocky reefs; seagrass beds; sandy bottoms
Remarkable species: Dusky grouper, brown meagre, *Pinna nobilis*; purple sea fan, *Centrostephanus longispinus*
Outstanding features: Wide variety of marine habitats including extensive *Posidonia* beds and gorgeous coralligenous bottoms, which are protected from direct anthropogenic influences
Prohibited activities: Trawling and spear-fishing in the whole area, angling in a 50-m-wide belt along the coastline; anchoring and diving in several areas; all fishing activities in a small sanctuary area
Permitted activities: Small-scale fishing, recreational fishing and diving in open zones
Comments: A multiple use MPA subject to heavy seasonal maritime and submarine tourism pressure; educational activities through exhibitions, guided visits via an underwater trail, publications, courses, etc.
**5 – Scandola (Natural Reserve)**

**Country:** France (Corsica)

**Date of declaration:** 9 December 1975

**Position:**
- 42°14′N–42°25′N, 8°37′E–9°00′E
- Size: 1000 ha (zoned; central zone 72 ha; peripheral zone 928 ha)

**Primary purpose:** Conservation; scientific research

**Management features:** Protection of marine biota and habitats

**Major habitat types:** *Posidonia* beds; rocky reefs; coralligenous bottoms, sandy bottoms

**Remarkable species:** Precious red coral, *Pinna nobilis*, *Patella ferruginea*, dusky grouper, brown meagre, *Dentex dentex*

**Outstanding features:** Particular development of rim-building coralline *Lithophyllum lichenoides*, *Posidonia* beds, *Cystoseira* belts and coralligenous bottoms associated with large demersal fishes; outstanding underwater landscapes

**Prohibited activities:** Central zone: all activities; peripheral zone: recreational angling and spearfishing, collecting, diving

**Permitted activities:** Small-scale fishing with obligate registration; anchoring during 24 h

**Comments:** The Scandola Reserve also comprises a terrestrial part; due to its remoteness and restrictive regulations, the marine part is protected from excessive touristic pressure and has no direct educational activities
6 – Bouches de Bonifacio (Natural Reserve)
This natural reserve includes the ‘Réserve naturelles des îles Cerbicale’ (natural reserve created the 3 March 1981), the ‘Réserve naturelle des îles Lavezzi’ (natural reserve created the 6 January 1982), the ‘Presqu’île et îles Bruzzi et îlot aux Moines’ (reserve created the 6 May 1992), the ‘Cantonement de pêche de Porto-Vecchio-Cerbicales’ (fishery canton, created the 20 June 1978), and the ‘Cantonement de pêche de Bonifacio’ (fishery canton, created in 1983).

Country: France (Corsica)
Date of declaration: 23 September 1999
Position: South Corsica
Size: 80 000 ha (eight central zones: 12 000 ha; no-take areas: 1200 ha)
Primary purpose: Conservation; scientific research; ecotourism
Management features: Protection of marine biota and habitats
Major habitat types: Posidonia beds; rocky reefs, terrestrial habitats, offshore waters
Known remarkable species: Patella ferruginea, Pinna nobilis, dusky grouper, brown meagre, several seabird and sea mammal species
Outstanding features: Large population of groupers; outstanding underwater landscapes
Prohibited activities: Spear-fishing (central zones and no-take areas); diving and fishing (no-take areas and establishment of fish stock production zones)
Permitted activities: Boating and anchoring, snorkelling and swimming
Comments: This reserve is subject to an increasing pressure from boating and diving activities; an international marine park including the natural reserve of Bonifacio and the national park of Madallena archipelago (Sardinia, Italy) is at the planning stage (international convention between France and Italy signed in January 1993)
7 – Medes Islands (Natural Reserve)
Country: Spain
Date of declaration: 27 September 1983
Position: Around 42°02′N, 3°13′E
Size: 418 ha (central zone: 93.2 ha)
Primary purpose: Conservation; scientific research, ecotourism
Management features: Protection of marine biota and habitats
Major habitat types: Posidonia beds; rocky reefs, sea caves
Known remarkable species: Particular development of rim-building coralline Lithophyllum lichenoides, red coral, Posidonia beds, and coralligenous bottoms associated with large demersal fishes; outstanding underwater landscapes
Outstanding features: Large population of groupers; outstanding underwater landscapes
Prohibited activities: In central zone: amateur and professional fishing, boat speed limited at 3 knots, anchoring, mooring limited at 24 h. In peripheral zone: professional fishing, spear-fishing
Permitted activities: Diving everywhere, angling in peripheral zone
Comments: The Medes Island Natural Reserve is a well example of important tourism activities (75,000 diving/year) with positive (economic inputs) and negative effects (biodiversity erosion)
8 – Tabarca (Marine Reserve)

Country: Spain
Date of declaration: 4 April 1986
Position: Around 38°10′N, 0°25′W
Size: 1400 ha (central zone: 100 ha; limited access zone: 630 ha; peripheral zone: 670 ha)

Primary purpose: Conservation; scientific research
Management features: Protection of marine biota, habitats, and human uses (small-scale fishery)
Major habitat types: Posidonia beds; rocky reefs
Known remarkable species: Cymodocea nodosa, Ophidiaster ophidianus, Dendropoma petraeum, groupers (at least four species), brown meager
Outstanding features: Large population of groupers
Prohibited activities: Diving, angling
Permitted activities: Anchoring and snorkelling in some place; small-scale fishery for local fishermen (trap nets, trawl-line)
Comments: Several types of artificial reefs including anti-trawling types have been immersed in this area. The small-scale fishing is reserved to Tabarca’s fishermen and a well balance has been found between biodiversity protection and sustainable fisheries.

Tabarca (Marine Reserve)
9 – Archipiélago de Cabrera (National Park)

Country: Spain (Balearic Islands)
Date of declaration: 29 April 1991
Position: Around 39°10’N, 2°55’E
Size: 9715 ha (1836 ha of islands and islets and the rest to the sea)
Primary purpose: Protection of biodiversity and promoting educational and cultural activities
Management features:
Major habitat types: Posidonia beds; rocky reefs; coralligenous bottoms
Known remarkable species: Large groupers, Posidonia oceanica beds, Pinna nobilis, several large seabirds, e.g. petrel, shags, osprey, and shearwater, sea turtles
Outstanding features: Angling and spear-fishing
Prohibited activities: Boating, anchoring, diving allowed with special permits; small-scale fishery by local fishermen
Permitted activities: Angling and spear-fishing
Comments: The offshore location of this reserve and the good level of protection sustain a high marine and terrestrial diversity (invertebrates, fish, birds, turtles, sea mammals)
10 – Ustica Island (Marine Reserve)
Country: Italy
Date of declaration: 12 November 1986
Position: Around 38°42’N, 13°10’E
Size: 7500 ha (zoned; central zone or zone A 65 ha; two other zones, zones B and C, sharing equally the remaining area)
Primary purpose: Conservation; scientific research; ecotourism
Management features: Protection of marine biota and habitats
Major habitat types: Rocky reefs; seagrass bottoms
Known remarkable species: Laminaria rodriguezii, Plesionika narval, dusky and golden groupers, brown meagre, Balistes carolinensis, Astroides calcicularis, Petrobiona massilliana
Outstanding features: Large population of groupers
Prohibited activities: In central zone: fishing, boating and anchoring; spear-fishing in zone B
Permitted activities: Small-scale fishery and diving outside the central zone; spear-fishing in zone C
Comments: The small-scale fishery is prohibited only in the central zone, and authorized outside with a special permit, delivered by local authorities. In fact, this situation limits the professional fishing activities to local fishermen