Synthesis of Current Knowledge: Marine exclusion zones (MPAs) in Europe & evidence of value

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1. Introduction

The intent of this literature review is to identify and describe seven types of marine protected areas in the Northeast Atlantic, North Sea, and Mediterranean Sea. This review begins by providing a basic understanding of marine protected areas in general and an overview of the benefits and costs associated with them in the European context. For the purposes of this review, the term marine protected area (from here on referred to as MPA) refers to "any area of the marine environment managed for the primary purpose of preserving biodiversity, aiding in the recovery of overfished stocks, and to ensure the persistence of healthy fish stocks, fisheries and habitats either as multi-use, zoned or no-take areas" (Himes, 2002).

This paper reviews available information about the purpose, objectives, management regimes, and, where possible, the biological, economic and/or social effects of MPAs in the European regions previously identified. The concentration is on fishery exclusion zones and MPAs with the purpose of nature conservation in which at least one form of fishing is prohibited for at least part of the year. The types of protected areas that are looked at here include: fishery management areas, including fishery boxes, inshore closed areas and area closures, MPAs for nature conservation, military and industrial closed areas, and research areas.

It should be noted that, in comparison to the Caribbean and the South Pacific, relatively few articles have been written cataloguing, describing and analysing the effects of MPAs in Europe. While resources do exist for many describing their regulatory structure and overall purpose, most information is purely anecdotal and has not been thoroughly researched in the field. One of the biggest areas lacking comprehensiveness is that of the actual effects of specific MPAs in Europe. Many of the studies that do exist concentrate solely on MPAs located in the Mediterranean basin.

2. Background of MPAs

Managers and scientists have rapidly been designing and implementing MPAs throughout the world with the hopes of structuring access to marine resources on an ecosystem level. Within the last 20 years, MPAs and marine reserves have become a widely advocated form of marine conservation for protecting valuable marine resources and interweaving fisheries management and tourism (Agardy, 1997; Bohnsack, 1993; Committee on the evaluation, design, and monitoring of marine reserves and protected areas in the United States *et al*, 2001; Kelleher *et al*, 1995; Ray, 1999). Such an approach has the potential to effectively address several management objectives and allow multiple stakeholders to use the same resources, a must in reducing conflicts and concerns.

MPAs can be one of the most effective tools in marine conservation, if designed and implemented properly. They have the potential to build up fish biomass and facilitate growth and reproduction of a number of over-fished or otherwise endangered species, thus creating positive economic as well as environmental benefits (Pipitone *et al*, 2000; Nowlis, 2000). As a result, MPAs have become 'one of the most effective ways of integrating the precautionary principle into fisheries management' and protecting fish from excess fishing mortality (Roberts, 1997). The MPA integrated approach is a valuable component of a successful fisheries management plan. Environmental management must incorporate socio-economic and physical development planning and stakeholder interests. MPAs provide a unique

opportunity to improve upon vaguely defined concepts in management, evaluate their potential objectively, and demonstrate their usefulness (Agardy, 1997, pg 84-85). MPAs are distinctive tools in marine and coastal management that increasingly incorporate community-based management and socio-economic evaluation techniques.

3. MPAs in Europe

As observed in many regions of the world, the increasing anthropogenic pressures on the European marine environment have necessitated the development of new conservation and preservation methods. In the fisheries sector alone, the growth of the Mediterranean population, technological development to increase fishing efficiency, over-fishing of target populations, and habitat degradation from pollution have all led to a decline in near-shore fish stocks (Vallega, 1999; Juanes, 2001). In response to the increasing environmental degradation, between 1982 and 1994, the Mediterranean saw an expansion in the use of coastal management and protected areas of all types. The total number of protected areas increased from 65 to 135, 53 of which specifically protect the marine environment (Kelleher *et al*, 1995). MPAs in the Mediterranean have been developed to cover a wide range of environments, from wetlands to open water to coral reefs.

The increased development in the region has led to increased public awareness, cooperation and regional agreements to protect the Mediterranean. This is marked by the implementation of the Barcelona Convention designed to limit water pollution, the establishment of the Regional Activity Centre for Specially Protected Areas in Tunisia, the main report of the Blue Plan, and the Genoa Declaration of the Contracting Parties to the Barcelona Convention which called for the creation of an additional 50 new protected areas in the Mediterranean by 1995 (Kelleher *et al*, 1995). Although Mediterranean countries often collaborate in the management of their marine resources, each country must work independently with their unique institutional systems, law-making practices, and the style of policy-making that each country has developed over time. This management regime combines the benefits of working both at the domestic and international level to protect as many marine resources as possible.

The number of protected areas has also been on the increase in northern Europe, although not to the same extent as the Mediterranean. There are many areas in the northeast Atlantic in which fishing activities are restricted in some way, but few in which all forms of fishing are excluded, either on a seasonal or a year-round basis. There are also few cases in which the biological effects of spatially explicit fishing restrictions on commercially exploited species have been evaluated empirically, with the notable exception of the 'plaice box' (see below). Ecological studies of closed areas have focussed almost entirely on marine reserves in tropical and temperate reef fisheries (Babcock *et al*., 1999; Edgar & Barrett, 1999; Moore, 1999; Roberts & Hawkins, 2000), although there have been several modelling studies of closed areas in large-scale fisheries for migratory species (review by Guénette *et al*., 1998; Horwood *et al*., 1998; Guénette & Pitcher, 1999).

While many European MPAs are discussed in this review, there are a substantial number that have been reported to exist; but no or little information about them, including their character and purpose, has been published. Those that have been formally reported in Britain, Spain and France, but cannot be categorized under one of the categories in this report, make up the body of this review. According to Jones (1999), a unique system of MPAs, voluntary marine nature

reserves (VMNR), exist solely in Britain. The functionality of these areas depends on the cooperation of users of the area with conservation measures that are advised and agreed on by the users of the area. Many of these areas were originally pursued due to a lack of statutory protective measures (Jones, 1999). Fifteen of these areas exist around the British Isles, however, very little has been published about their management regimes or overall status and effect. Correspondingly, this current review is focused on statutory MPAs.

Kelleher (1995), Badalamenti *et al* (2000) and a workshop sponsored by The Environment Council (2000) identified the following MPAs in Spain and France. Of note, 12 additional Spanish MPAs were identified. The Cabo de Palos Marine Reserve, located off the southeastern coast of Spain, has been protected since 1995. There is an integral reserve zone where no activity is allowed and an outer buffer zone where artisanal fishing and diving are allowed but sport fishing is not. Off northeast Spain, the Cabo de Creus Marine Park was created in 1998 with restrictions on professional and recreational fishing. The main threats to the exceptional fauna and flora are tourism and alterations to sub-aquatic ecosystems. The Cap de Santes Creus Marine Park, also in the northeast of Spain, was created earlier in 1992 containing an estuary system with extreme levels of impacts from tourism. The Cabo de Gata Nature Park and Marine Reserve consists of 10,000 ha including three integral zones where all activities are banned. The Massis de Cadiretes Nature Reserve, Ses Negres Nature Reserve and El Montgri Nature Reserve in northeast Spain were established in 1992 to protect distinct habitat types, cold-water benthic population, marine escarpments with biocoenotic algal communities, and a high rocky coastline, respectively. In addition to which, the S'Arenal Regional Protected Landscape, Acantilado de Barbate, Donana National Park and Ramsar site, Alboran Marine Reserve, and Formentera Marine Park also exist; however, no additional information could be found about their regulations or effects (Badalamenti *et al*, 2000; Kelleher *et al*, 1995; Ramos-Espla *et al*, 1994).

In France, only one could not be categorized. The Pres Sales d'Ares Lege Nature Reserve at Cap Ferret principally consists of intertidal habitats, such as mud and sand flats, seagrass beds, salt marsh, and seagrass beds. The area is primarily known as a fish nursery area (Kelleher *et al*, 1995).

4. Fishery Management Areas

Fishery management areas and reserves (or fishery exclusion zones, FEZs) can be defined as spatially bounded areas in which the harvest of marine resources is restricted or forbidden (Auster & Shackell, 1997). These areas may be closed to all fisheries for short periods of time (weeks to months) or permanently, or they may be closed to specific types of fishing gear. In Europe, as well as in the rest of the world, four types of FEZs have been implemented: (i) fishery boxes, (ii) trawling ban areas, (iii) inshore closed areas, and (iv) area closures and no-take zones. Each of these has the objective of, in the case of overfished stocks, decreasing overall by-catch and landings, reducing fishing mortality on fishes that have not yet reached the age of sexual maturity (growth overfishing), and protecting natural habitats from human disturbances. This section deals with field studies carried out in European FEZs, and briefly reviews the results obtained. It is worthy of note that many other FEZs in the same area (especially those based on short closures) have not been the subject of published papers.

4.1 Fishery "Boxes"

A number of areas have been established in European waters under the Common Fisheries Policy in which fishing is restricted with respect to target species, type of gear or vessel characteristics, on a seasonal or, less commonly, a year-round basis (Anon, 1998a, b). In most cases, the stated objective of these so-called "boxes" is to protect juveniles of commercially important species from mortality caused by fishing for the same or other species (Anon, 1999). Although increased mesh size can reduce the proportion of undersized fish caught, fatal injuries may be sustained through contact with fishing gear, even if this does not result in capture. Undersized fish suffer a high degree of mortality from the cumulative effects of being captured in a towed net, raised to the surface and subsequently discarded (Jennings *et al*., 2001).

The longest-established boxes are the mackerel box, the plaice box, the Norway pout box, the Shetland box and three hake (*Merluccius merluccius*) boxes off the west coasts of Spain and Portugal (Holden, 1996). Most research has, however, been published on the plaice box and the mackerel box.

4.1.1 North Sea

The Norway pout box is an area of approximately 10 Mha off northeast Scotland (UK), which includes the main nursery area for North Sea stocks of haddock (*Melanogrammus aeglefinus*) and other gadoids. Currently, it is prohibited to retain Norway pout (*Trisopterus esmarkii*) caught by any towed gear within the box on board any fishing vessel, exceeding 5% by weight of the total catch (Anon, 1998b). This regulation is designed to protect juvenile haddock and whiting from discard mortality in the 'industrial' fishery for Norway pout (and other species), which uses small mesh sizes.

The Shetland box is an area of approximately 5 Mha around the Shetland and Orkney Islands (UK) in which the number of large vessels fishing for demersal species is restricted by a system of licensing (Clarke, 1998).

The plaice box is an area of approximately 3.8 Mha off the coasts of The Netherlands, Belgium and Denmark established in 1989 to reduce discarding of juvenile plaice (*Pleuronectes platessa*) and sole (*Solea solea*) in the southern North Sea beam trawl fishery (FSBI, 2001). This comparatively well-defined nursery area for plaice and has been established from the funding of scientific surveys and reports of high levels of discarding of undersized fish in the commercial fishery. The initial regulations excluded demersal trawlers with overall length greater than 8 m from fishing within 12 miles of the coast inside the plaice box and beam trawlers with engine power greater than 300 hp (224 kW) from fishing anywhere within the box from 1 April to 30 September. Exempted vessels included less powerful trawlers on an authorised list, vessels fishing for shrimp and otter trawlers of any power using 100 mm mesh, provided that they immediately discarded catches of plaice and sole comprising more than 5% by weight of the total catch. In 1994, a prohibition on trawlers with an engine power greater than 221 kW was applied between 1 April and the end of the calendar year, and in 1995, the period of application was extended to the whole year.

The plaice box is the best-studied partially-closed area in European waters, yet the lack of an appropriate reference area, limited information about prior conditions and the absence of a dedicated research programme hamper efforts to evaluate the biological effects of the

spatially-explicit fishing restrictions (Pastoors *et al*., 2000). In the first 5 years of implementation, there was increased fishing activity within the box by exempted vessels and in the last quarter of the year, total fishing intensity increased markedly when the area was re-opened to larger trawlers. The net result of these changes was that total fishing effort in the box during 1989–94 was around 40% of the pre-box level (Pastoors *et al*., 2000). An early assessment of the effects of the box was that the increased fishing effort by exempted vessels throughout the year and heavy fishing in the fourth quarter had reduced the gain in recruitment of plaice to the fishery from a predicted increase of 25% to 8% (Anon, 1994). However, there was no clear evidence of changes in plaice abundance attributable to the restrictions on fishing within the box, although there were increases in the relative abundance of larger size classes of a variety of exploited species (Piet & Rijnsdorp, 1998).

Closure of the box to heavy trawling throughout the year from 1995 resulted in total effort falling to around 6% of pre-box levels (Pastoors *et al*., 2000; FSBI, 2001). However, the reduction in discard mortality implied by the change in fishing effort was not reflected in increased survival of juvenile plaice. Indeed, survival in the first two years of benthic life fell sharply in the early 1990s and by 1997 had only recovered to a level similar to the 1980–90 average. Furthermore, the yields from the plaice fishery and the estimated spawning stock biomass have decreased substantially since the establishment of the plaice box (Pastoors *et al*., 2000).

A number of phenomena appear to have coincided to counteract the expected benefits of reduced fishing effort in the plaice box (Pastoors *et al*., 2000). There are indications that in the early 1990s, settlement of plaice larvae from the plankton was reduced, possibly as a result of changes in environmental conditions associated with milder winters. Other evidence indicates there was a widespread change in the ecosystem of the southern North Sea at around the time the plaice box was established, with an influx of Atlantic water and southern fish species (Piet & Rijnsdorp, 1998). In addition, the growth rate of juvenile plaice was reduced in the early years of the box by an amount that would be expected to nullify the benefits of reduced fishing intensity (Pastoors *et al*., 2000). This is because slower growth extends the pre-recruit period and, therefore, increases cumulative discard mortality. The reasons for reduced growth are not clear. Part of the reduction may have been related to an increased population density of fish, resulting from high levels of settlement in the late 1980s.

It has also been suggested that, in the box trawling maintains a benthic community comprised of small, productive invertebrates, and that reducing trawling disturbance, therefore, limits the food supply for juvenile flatfish (Rijnsdorp *et al*., 1998). An interesting corollary of this is that juvenile plaice may be attracted to areas of disturbed seabed at the boundaries of the box, where there is intense fishing effort (Rijnsdorp *et al*., 1998), leading to increased discard mortality (Pastoors *et al*., 2000). These explanations remain speculative, however, but need to be tested, owing to their significance to the use of closed areas. Without an appropriate reference area, there is no empirical basis for assessing how the plaice fishery would have developed if the plaice box had not been implemented.

4.1.2 Northeast Atlantic

The mackerel box was instigated in 1980 to protect juvenile mackerel (*Scomber scombrus*) in the western English Channel and Bristol Channel from a fishery for mature fish that overwintered in those areas (Lockwood, 1988; Horwood, 2000). The winter fishery had

intensified during the 1970s and assessments indicated that in the long term the spawning stock would benefit from a delayed age of first capture. However, since juveniles occurred in mixed schools with adults and were highly susceptible to discard mortality, minimum landing sizes and mesh regulations were not effective means for achieving this. It was hoped to redirect effort to the summer/autumn fishery off western Scotland and Ireland, by closing an area around the southwest of Britain to purse seining and pelagic trawling. The size of this area and the period of the year over which restrictions applied were altered in a number of stages, until in 1989, restrictions on fishing for mackerel were applied throughout the year to an area of 6.7 Mha (Lockwood, 1988). The regulations were intended to prevent directed fishing for mackerel with gear other than gill nets and handlines, although derogations to allow fishing for other species permitted vessels to have on board up to 15% by weight of mackerel. Recent regulations permit the use of demersal towed gear, provided that at least 75% by live weight of the catch on board comprises marine organisms other than anchovy, herring, mackerel, horse mackerel, pelagic cephalopods and sardine (Anon, 1998b).

From late 1970s, the overwintering areas of the western stock of mackerel shifted to the west then north, as the timing of migration changed, such that by the mid-1980s the final movement to spawning areas in the Celtic Sea was not made until the spring, rather than the preceding autumn, as previously (Lockwood, 1988). Winter fishing effort therefore moved away from the nursery area around Cornwall, achieving the objective of the mackerel box in an unforeseen manner. However, from the mid-1980s, the distribution of juveniles also extended further north, so that they were taken in the commercial catch in increasing numbers. Nevertheless, it has been argued that the mackerel box should be maintained, since the proportion of juveniles within it appears to remain high (Clarke, 1998). Horwood (2000) reported that in the years just following the introduction of the box, the relative mortality of fish aged 0, 1 and 2 was reduced by 83%, 60% and 20%, respectively. However, there has been little research in this area in recent years (S.J. Lockwood, 2000, pers. comm. with CEMARE).

4.2 Trawling Bans

Fisheries exclusion zones have been instituted with a variety of management regimes, including restrictions on specific types of fishing gear. Trawling bans have been implemented to accomplish a variety of management objectives, including the protection of coastal ecosystems from the damaging effects of trawling gear, the reduced potential of stock collapse and the elimination of user conflicts (Whitmarsh *et al*, 2002; Jennings *et al*, 2001; Horwood, 1998). Trawling bans, in other words FEZs where the prohibition of trawling is the only restriction, have been used widely throughout the world, but in Europe they currently only exist in the Mediterranean.

4.2.1 Mediterranean Sea

Trawling bans implemented in the Mediterranean exhibit a broad range of time duration. A one-month ban within 3 miles of the coast (less than 20 m deep) has been implemented on a yearly basis in the northern Adriatic Sea off Chioggia (Pranovi *et al.*, 1996). A 45-day ban has been implemented every year since 1988 in the Ligurian Sea (Relini *et al.*, 1996). A seasonal ban implemented in 1982 in waters around Cyprus (an area of 1800 km^2) has been used to prohibit trawling from June to October (Garcia & Demetropoulos, 1986). No information was found as to whether these two trawling bans still exist.

Finally, there are also a number of examples of year-round trawling bans. Trawling bans have been implemented at three different locations in Greece, namely the Pagassatikos Gulf, the South Evoikos Gulf and the Orei Channel, over bottoms generally no more than 100 meters deep (Vassilopoulou & Papaconstantinou, 1999). In Italy, a trawling ban has been imposed since 1990 in the Gulf of Castellammare (Italy); a 200 km^2 area extends over the continental shelf and beyond (Pipitone *et al.*, 2000). Two other year round trawling bans exist in Italy, in the Gulf of Patti and the Gulf of Catania, however, no studies have been done focusing on their effectiveness.

A number of interesting findings should be reported from studies undertaken on these FEZs. In the month following the end of a trawling ban near Chioggia the total CPUE of experimental fishing was enhanced 2.8 times in an area within 1 mile off the coast and by 1.6 times in the area between 2 and 3 miles of the coast area compared to CPUE before the ban (Pranovi *et al.*, 1996). However, eight months after the end of the ban there was no evidence of any increase, and the total CPUE showed no significant difference with that of the pre-ban period.

Relini *et al* (1996) report a higher value of the total CPUE of fishes after the enforcement of a 45 days trawling ban in the Ligurian Sea, although *Pagellus erythrinus* and *Spicara flexuosa* showed no significant variation in abundance. On the contrary *Octopus vulgaris* was more abundant before the ban.

In contrast the Cyprus trawling ban enhanced the total catches of the trawling fleet at constant effort by 12% during the year of implementation of the ban (Garcia & Demetropoulos, 1986). The second year, total catches increased by 70% when compared to the previous year (i.e., an increase of 80% of the total catches between 1981 and 1983). The total catch in the third year stabilised at the same level as the previous year. The small-scale fishery also experienced a 6% increase of the total catch in the first year and a 42% increase in the second year. As in the case of the trawling fleet, catches stabilised at the highest level in the third year.

In Greece, year round trawl bans are associated with the Pagassitikos Gulf, Orei Channel and South Evoikos Gulf, while seasonal trawl bans exist in the Trikeri Channel, North Evoikos Gulf and Petali Gulf. Sandy-muddy type substrates dominate in all of these areas. Overall, Vassilopoulou & Papaconstantinou (1999) reported that total biomass was higher in areas totally closed to trawling than in areas where trawling was allowed for six months every year (from 1 October to 31 March). A greater number of species and higher species diversity were also found in the year round ban areas. However, they found no difference in the mean length of *Merluccius merluccius*, *Mullus barbatus* and *Pagellus erythrinus* between the areas.

In the case of the Gulf of Castellammare, a trawling bans applies to a majority of the Gulf. Local small-scale fishers are allowed to fish throughout the area. Four years after implementation of the trawling ban, the total CPUEs obtained in experimental trawl surveys underwent a 8-fold increase as compared to CPUEs obtained two years before the ban (Pipitone *et al.*, 2000; Whitmarsh *et al*, 2002). Similarly, increases in overall CPUEs and biomass were seen eight years after the institution of the ban. Considering individual species, the closure produced an increase ranging from 1.2 (musky octopus) to 497-fold (gurnard). Only the CPUEs of horned octopus, *Eledone cirrhosa,* decreased after the ban.

The species responses to the trawling ban were not uniform within the Gulf of Castellammare; the red mullet, *Mullus barbatus* always showed the highest recovery. Such a reaction is related to the young age at first maturity of this species, which would allow a rapid recovery of the population subjected to a much lower fishing pressure (Garcia & Demetropoulos, 1986; Relini *et al.*, 1996; Pipitone *et al.*, 2000). In contrast Relini *et al* (1996) and Pipitone *et al* (2000) have reported a negative response of the abundance of some species of cephalopods (namely *O. vulgaris* and *E. cirrhosa*) with reductions in abundance seemingly generated in response to the implementation of the trawling ban.

4.3 Inshore Closed Areas

An inshore fishing area can be defined as a semi-enclosed basin surrounded almost entirely by land that allows for water exchange with the sea through an opening, including sea lochs and marine inlets. In inshore fishing areas, a variety of locally agreed exclusion zones have been implemented, mainly designed to minimise conflict between fishermen using static or mobile gears or to decrease fishing pressure on specific stocks within the area (Clarke, 1998).

4.3.1 North Sea

Rogers (1997) catalogues a range of no-trawl zones and 'potting' (baited trap) zones around the United Kingdom. However, these areas relate to practical aspects of fishing operations, and they have not been studied to determine any biological effects on fished species. Various sea lochs and other marine inlets in Scotland have been closed to all fishing or fishing with mobile gears since the 1980s, to protect spawning or nursery areas of pelagic and demersal finfish, or to avoid gear conflicts. Unfortunately, the spatial resolution of routinely collected fishery data in UK inshore fisheries is not adequate to assess the effects of these closures. Several bass (*Dicentrarchus labrax*) nursery areas in estuaries and other coastal sites in the UK are closed to commercial bass fishing. Closed areas for bass are the subject of one of the case studies examined as part of this project.

4.3.2 Northeast Atlantic

There are 25 'crustacean reserves' around the English Channel and Atlantic coasts of France, ranging in size from 4 ha to 7000 ha (Latrouite, 1995). The objectives and regulations vary considerably among these areas, but most of them are intended to sustain or enhance lobster (*Homarus gammarus*) fisheries. Most of them were established in the 1960s in response to catches falling from peak levels after the Second World War. 'Berried' (ovigerous) females were bought from the fishery and released into areas closed to fishing, to create a protected spawning stock (Audouin *et al*., 1971 cited in Bennett, 1980). In the 1970s and 80s, reserves were established to protect wild juveniles, for releasing hatchery-reared juveniles, or for experiments with artificial reefs (Latrouite, 1995). Experimental fishing has indicated that protection has given rise to increased abundance and size of lobsters within reserves, but owing to a lack of reliable commercial catch and effort data, it has not been possible to assess the effects of closure on the wider fishery. Similarly, the effects of releasing hatchery-reared juveniles into reserves cannot be evaluated. In the only rigorous study, very few recaptures were recorded over a period of three years, after which the programme was terminated (Latrouite, 1998). In other lobster species, there is evidence of enhancement by market-sized lobsters emigrating from protected areas, but no evidence yet of enhanced larval settlement resulting from spawning stock reserves (Childress, 1997).

4.4 No-Take Zones

In a no-take zone, all living resources are protected from fishing and other harvesting (Johnson *et al*, 1999). In theory, such area closures are designed to protect the biodiversity of an area and enhance local fish stocks so they can be harvested sustainably in the future. Broodstock are also protected from fishing pressure and are thereby able to increase larval production as a whole. The expected result is that fish that live within the no-take zone will live longer, will grow to larger sizes and will produce larger quantities of eggs (Jennings *et al*, 2001; Johnson *et al* 1999). An additional effect is termed the spillover effect whereby the emigration of target species for local fisheries from unfished areas to fished areas results in increased economic benefits for local fisheries (Johnson *et al*, 1999).

4.4.1 Mediterranean Sea

Two aquaculture concessions exist in France on the south central coast near Marseille: the Cap Couronne (1996) and Carry-le-Rouet (1987) Marine Protected Zones. Both zones share the primary purposes of protecting benthic communities against overfishing from trawling, replenishing fished stocks and fulfilling an educational function. Each area also contains experimental artificial reefs. The characteristic habitats of the region are *Posidonia* beds and rocky reefs, however there are distinct areas of red coral and sandy bottoms at Cap Couronne (Francour *et al*, 2001). The regulatory structure is the same in both areas. The entire protected area is classified as a no-take zone where the only activities allowed are snorkeling and navigating across the area. All types of fishing are prohibited within the boundaries of the protected areas. Most importantly, to discourage illegal trawling both within and between the reserves, a series of anti-trawling artificial reefs have been deployed. The total area protected by law, combining both Cap Couronne and Carry-le Rouet, is approximately 300 ha (Francour *et al*, 2001).

4.4.2 Northeast Atlantic and North Sea

Since the collapses of herring (*Clupea harengus*) fisheries in both the North Sea and northern Irish Sea, restrictions on herring and sprat fishing have been imposed in several areas around the British Isles and the west coast of Denmark (Rogers, 1997; Anon, 1998b). These include the year-round closure of nursery areas and the seasonal closure of spawning areas. Herring spawning areas are also designated, because herring eggs, being attached to the seabed for up to three weeks, are particularly vulnerable to destruction by trawling. The spawning period of herring stocks on particular grounds may extend over three or four months.

The European Union and Norway have over the last five years established a number of other year-round or seasonal closed areas, primarily for protecting nursery areas of a variety of commercially important species (Anon, 1998b). This action has been taken in recognition of the fact that fishing and discard mortality of undersized fish is an important component of the chronic overfishing of many exploited stocks (Anon, 1999). In addition to the species previously mentioned, there are spatially explicit restrictions on fishing for salmon (*Salmo salar*), sea trout (*S. trutta*), anchovy (*Engraulis encrasicolus*) and three species of tuna (*Katsuwonus pelamis*, *Thunnus obesus* and *Thunnus albacares*).

Area closures have also recently been applied as an emergency measure, in an attempt to restore certain overfished stocks to sustainable levels. The sand eel (Ammodytidae) fishery in

an area of approximately 1.7 Mha off the northeast coast of England and east coast of Scotland was closed for three years from 2000, on the basis of scientific advice that stocks were insufficient to sustain the fishery and the populations of marine organisms dependent on them (Anon, 2000b). As part of a recovery plan for the Irish Sea cod stock, an area in which spawners concentrate was closed for 10 weeks in the late winter and spring of 2000 to all fishing gears likely to catch cod (Anonymous, 2000a). Similar provisions are likely in subsequent years. The immediate objective of this measure was to maximise the reproductive output of the depleted spawning stock.

Similar emergency measures have been applied in the North Sea to restore cod stocks (Anon, 2001). Recent refinements in the assessment of these stocks indicated that the spawning stock biomass was lower, and the fishing mortality higher, than previously estimated. A large area (approximately 10 Mha) in the eastern North Sea and two smaller areas, in the southern North Sea and to the west of the Shetland Isles, were closed from mid-February to the end of April in 2001. Horwood *et al*. (1998) have cautioned that closure of spawning areas may have little beneficial impact if fishing effort is allowed to redistribute in space and time, such that prior levels of fishing mortality are sustained. Spawning area closures could even have a detrimental effect if they lead to greater fishing intensity on juveniles outside the closed area or closed period (Shepherd, 1993; Horwood *et al*., 1998).

5. Marine protected areas for nature conservation

Many protected areas in Europe have been established primarily for nature conservation, rather than fisheries management. However, MPAs that are created with marine conservation in mind also provide ideal situations to further other interests, such as scientific research and allocating portions of the sea to specific groups of fishers (e.g. small scale artisanal fishers, e.g. Tabarca Marine Reserve). Many marine nature reserves in Europe are expected to have a limited impact on the main commercial finfish fisheries, since they are usually close to the shore and comparatively small in relation to the scale of the major fisheries. Restrictions within reserves are significant at a local level for inshore fisheries, although in many cases, only the most destructive fishing techniques, such as trawling and dredging (Jennings & Kaiser, 1998), are prohibited, while harvesting by other means is permitted (Laffoley, 1995). In many cases, naturalness has been a primary criterion for the selection of existing marine nature reserves (Salm & Price, 1995), implying low pre-existing fishing intensity and consequently limited effects of implementation on fisheries and fished species. In future, however, areas damaged by fishing may be increasingly proposed as candidates for protection (Pullen, 1996; Jennings *et al*., 2001).

There are many publications cataloguing European MPAs, describing their legal basis, the history of their implementation and outlining their management regimes (e.g. Peet & Gubbay, 1990; Gubbay, 1993; Ramos-Espla & McNeill, 1994; Esping & Grönqvist, 1995; Gubbay, 1995; Jones, 1999; Francour *et al*, 2001; Salmona and Verardi, 2001). Nature reserves are frequently in areas of intertidal or shallow subtidal mud or sand, or in rocky areas (van der Zwiep, 1990; Helbing, 1992; Esping & Grönqvist, 1995; Gubbay, 1995). Soft sediment areas have mostly been selected primarily for their importance to sea birds and waterfowl, although some have been recognised as important seal haul-out sites or fish nursery areas (Peet & Gubbay, 1990; Gubbay, 1995). Rocky areas have usually been selected for their importance to sea birds or seals, or for the diversity and aesthetic appeal (to recreational divers) of their

subtidal habitats and species (Jones, 1999; Himes, 2002).

The regulatory structure of these areas is much like that seen in fishery management areas where professional and recreational activities are regulated by law and are enforced by professional staff. All activities, including fishing, are normally subjected to restrictions inside the MPAs, ranging from partial restriction to total prohibition. In the simplest case an MPA is made of an area where all activities are totally prohibited (or where only scientific research is allowed), as in Carry-le-Rouet (France) or in Medes Islands (Spain). In more complex reserves (e.g., Scandola, Banyuls-sur-Mer and Port-Cros (France), Isla de Tabarca (Spain), and all the Italian reserves), the protected area is subdivided in zones each with a different degree of protection, in one of which all activities except scientific studies are prohibited.

5.1 Mediterranean Sea

In the Mediterranean, the majority of MPAs have complex management regulations, including, as stated above, multiple zones with increasing levels of restriction on fishing activities. Overall, there are 26 reported MPAs designated for nature conservation in the Mediterranean that are managed by European member states. Mediterranean reserves are usually small. Each fully protected area is smaller than 2 km^2 (0.8 km^2 on average). The total area of each reserve ranges from 0.85 up to 6.5 km^2.

All the available scientific publications on the effect of Mediterranean reserves on natural fish populations are based on work made inside protected areas belonging to three countries in the western Mediterranean Sea, namely Spain, France and Italy (Table 1 in Sanchez Lizaso *et al.*, 2000). Although marine reserves also exist in the other parts of the Mediterranean, scientific data on their monitoring, if any, seems lacking in the scientific press. The prominent fishery reserves in Spain, France, Italy and Greece are reviewed here.

Along with other European countries, Italy has jumped on the bandwagon by putting numerous pieces of environmental legislation into effect, including a number of laws and ministerial decrees, creating a network of 17 marine reserves throughout its waters, with another eight created but not active as they do not yet have management plans (Anon, 2003)[1]. Nine of the 17 MPAs with management plans are situated off the coasts of Sicily (3), Puglia (3) and Sardegna (3), where the waters are the most pristine and biodiversity is highest. Additional MPAs are located in the Adriatic Sea (2), along the west coast of the mainland (4), and bordering the Ionian Sea (1). Very few studies have been published that discuss the success of individual Italian marine reserves.

Although there are slight variations between individual sites depending on their unique characteristics, all Italian fishery reserves (called Marine Reserves by the Italian Ministry of Environment) follow the same regulatory and management structure. All reserves are partitioned off into three zones, A, B, and C, some employing a fourth zone D (i.e. Egadi

[1] Italian national MPAs already established with management plans are the Ustica Island Marine Reserve, Cinque Terre Marine Reserve, National Park of the Tuscan Archipelago, Ventotene and Santo Stefano Marine Reserve, Egadi Islands Marine Reserve, Ciclopi Islands Marine Reserve, Capo Rizzuto Island Marine Reserve, Porto Cesaro Marine Reserve, Torre Guaceto Marine Reserve, Gargano National Park, Miramare Marine Reserve, Maddalena National Park, Mal di Ventre Island Marine Reserve, and Tavolara Island Marine Reserve.

Islands Marine Reserve), with varying levels of restrictions. Zonation within each reserve allows for multiple uses inside the protected areas. This type of management allows for the regulation of individual fisheries as well as tourism, natural resource conservation, and recreational uses. Zone restrictions are as follows: All commercial and recreational fishing, diving, collection, alterations, explosives, navigation are prohibited in Zone A, as a typical no-take zone; however, permitted research and swimming are allowed. In Zone B, navigation within 500m of the coast, trawling and underwater fishing are prohibited while other types of fishing (e.g. pots and trammel nets) and surface based recreational fishing are allowed under permit only. Diving is allowed. Zone C is slightly less restrictive, with the only prohibited form of fishing activity being trawling. Permits are required for all other fishing, while navigation and diving are permitted. Finally, in areas where a Zone D exists, all types of fishing are able to obtain permits; however, managing authorities are able to establish limits on the use of professional fishing gear and the need to stop fishing for biological reasons (Himes, 2002).

The Ustica Island Marine Reserve (UIMR) is one of the most well known Italian reserves. The island is located approximately 65 km north of Palermo in the Tyrrhenian Sea. Created in 1986, the UIMR was established specifically for conservation, scientific research and increasing the level of ecotourism on the island (Francour *et al*, 2001). The reserve is split into zones A-C, where the only fishing allowed is via permits awarded to local fishers. A visitor centre, aquarium, reserve guides, and research have increased overall awareness of the reserve among the general public and scientific research community. However, negative effects have been recorded as well. Although fishing has historically been an important aspect of the local economy, recent years have shown a rapid decrease in the number of registered fishermen; potentially indicating that fishermen are seeing a decrease in the marine resources available to them and, therefore, are leaving the industry (pers. comm. with the port authority). Since the institution of the reserve, an increase of approximately 35,000 visitors in the first four years has also been seen (Badalamenti *et al*, 2000), causing significant potential damage to the resources of the reserve (Himes, 2002).

The Tuscan Archipelago Marine Park is located in northwestern Italy off the coast of Tuscany. The park has several zones under different protection regimes. Many of the islands in the archipelago historically had high security prisons on them; ensuring minimal human impact. Very little research has been done on the effects of the park. However, it is thought that most of the area is in near pristine condition (The Environment Council, 2000).

The Miramare Marine Reserve, off the coast of Trieste, was instituted in 1982 as one of the first MPAs established in Italian waters. The reserve is divided into zones; however, the total area is relatively small. It is relatively well enforced and managed by WWF Italy, who regulates, diving, research and organised visits. Fishing is prohibited and access is only allowed with WWF guides (The Environment Council, 2000).

The Portofino Marine Reserve is one of the eight Italian reserves awaiting a management plan. As part of the process of evaluating how the reserve should be set up, Salmona and Verardi (2001) analysed current impacts on the environment and conflicts that could inhibit the management objectives. In 1998, the area was designated for protection due to unique submarine caves and canyons that provide for rich and varied coral communities seagrass meadows. However, current development and tourism activities are significantly degrading

these local coastal ecosystems. Moreover, local authorities and stakeholders are actively protesting the establishment of a marine reserve because of the potential impacts on tourism and recreational activities in the area (Salmona and Verardi, 2001).

Moving on from the Italian reserves to the rest of the Mediterranean, it is evident that there are many fewer French (4), Spanish (4) and Greek (1) MPAs in the Mediterranean specified for nature conservation. Almost all of Spain's MPAs were specifically created for marine conservation. The main MPAs in Spain are the Isla Tabarca Marine Reserve, Islas de Medes Nature Reserve, Archipelago de Cabrera National Park, and Columbretes Nature Park and Marine Reserve.

The Tabarca Marine Reserve is located off the east coast of Spain near Valencia (Badalamenti *et al*, 2000). The reserve, the first operative MPA of its kind in Spanish waters, was established in 1986. The Tabarca reserve was chosen to protect and promote the conservation of local marine organisms and habitats (i.e. large aggregates of groupers and brown meagre, rocky reefs and *Posidonia* beds), and to support a small-scale fishery and scientific research. The structure of Tabarca Marine Reserve, is similar to the Italian protected areas, and includes three zones of varying protection: (1) a fully protected area where all activities except strictly controlled scientific investigation are forbidden, (2) a partially protected zone where recreational activities are allowed up to a fixed number of tourists, and fishing activities are allowed under license for certain types of gear, and (3) a partially protected area with essentially the same rules as the previous one but with more relaxed constraints (Badalamenti *et al*, 2001).

The only activities that are prohibited in the Tabarca reserve are diving (only 30 divers a year are allowed to enter the reserve due to opposition from local fishers) and angling (Badalamenti *et al* 2000). However, fishing is also strictly reserved for local small-scale fishers. Several artificial reefs have been deployed off the south coast of the island to discourage trawling on the edge of the reserve (Francour *et al*, 2001). Visitors to the reserve have consistently increased since the inception of the reserve, causing a boost in the tourism infrastructure of the island (Badalamenti *et al*, 2000). As a result, *Posidonia* meadows have been regularly trampled. However, the local small-scale fishery has seen an increase in overall catch rates (Ramos *et al*, 1992) and the number of fishers has increased in the reserve while still showing increasing CPUEs (Anon, 1998). Ramos Espla *et al* (1991) reported that five years after the establishment of the reserve in Tabarca, the proportion in the catches of high priced species (*E. guaza, Dentex dentex, Sparus auratus, Seriola dumerili*) increased around the reserve, according to fishery statistics. An indicator of the good economic performance of fishermen in this region was the index of renovation of boats: the Tabarca fleet had the largest proportion of renewed boats (75%) in the district of Valencia since the establishment of the reserve.

The Medes Islands Marine Park is located off the coast of Cataluña in northeastern Spain (Badalamenti *et al*, 2000). The main purpose of the reserve is for scientific research, ecotourism, and the conservation of local rocky reefs, *Posidonia* beds, sea caves, coral communities and grouper spawning aggregations. The park, created in 1983, consists of two zones, a central no-take area where boating is limited and all fishing is prohibited, and an outer area where professional and spearfishing is prohibited.

Ecologically, the park's downfall is that there were no limits on diving until 1990, when a cap was placed on the number of divers allowed per day (Badalamenti *et al*, 2001). On the level of economic input from tourism, the park has had positive benefits reaching US$7 million per year (Capella *et al*, 1998). However, the result has been a severe decrease in biodiversity due to the shear numbers of divers that come to the area (Francour *et al*, 2001). Diving has damaged the *Posidonia* beds and many other important benthic organisms (Sala *et al*, 1996; Zabala, 1996). However, Garcia Rubies and Zabala, (1990a) noticed that some highly spearfished species such as *Epinephelus guaza* and *Sciaena umbra* were observed exclusively in the reserve, and that, in strictly biological terms: species richness; overall abundance; abundance of vulnerable and large species targeted by spearfishing; and density were all significantly higher inside the protected area as compared to outside it.

The Archipelago de Cabrera National Park is located in the Baleares Islands, off the eastern coast of Spain, near the southern coast of Isla de Mallorca (Badalamenti *et al*, 2000). Declared an MPA in 1991, the primary purpose of the reserve is to protect biodiversity and promote educational and cultural activities (Francour *et al*, 2001). The area encompasses many rich ecosystems, including *Posidonia* meadows, rocky reef conglomerations and coralligenous bottoms. As in the Tabarca Marine Reserve, fishing is permitted only for local small-scale fishermen. A set of regulations applies uniformly over the entire park. Angling and spearfishing are strictly prohibited and any entry (boating, diving, and anchoring) is allowed only with special permits (Francour *et al*, 2001). Francour *et al* (2001) indicate that the reserve is biologically successful in terms of sustaining high diversity, due to the park's offshore location and level of protection. However, Pozo (1998) indicated that there has been substantial human impact on the environment due to dramatic increases in tourism and lack of regulatory constraint on growth (10 fold increase in the number of licenses for sail boats, the number of moorings doubled, three fold increase in the number of dive trips).

Columbretes Nature Park and Marine Reserve, located 30 miles off the coast of Valencia, was established to conserve an array of peculiar flora and fauna, including several endemic species. Created in 1990, the presence of the reserve has since caused an increase in the number of recreational boats taking part in the local recreational fishery (Goni, 1998). Before the establishment of the reserve, recreational fishing existed only at very low levels. Under reserve regulations, this type of fishing is only allowed outside of the core no-take zone. Small-scale fishing (except for the use of purse seines) is completely prohibited. Diving is allowed in the reserve only under authorization by local authorities. Goni (1998) reported that diving has experienced similar increases, from almost none before the reserve was instated to 875 times that, in terms of the number of authorizations given out. The reserve was consequently closed to diving between the end of 1994 and beginning of 1996; however, since the ban was lifted in 1996 the number of divers has almost risen to double that which was seen in 1994 (Badalamenti *et al*, 2000; Jimenez, 1996; Goni, 1998).

France has created only four MPAs in the Mediterranean due to its relatively small coastline. Located in the Pyrenees region of France, the Cerbére-Banyuls Natural Reserve was established in 1974 to protect fragile benthic communities of red coral and rocky reefs against overfishing from trawling. Many large target fish are also found in large numbers in the area. The reserve consists of two zones, a general restricted zone and a central no-take area. In the central no-take zone, all activities except research are prohibited. In the outer zone, trawling and spearfishing are prohibited while permits are given for small-scale and recreational

fishing and diving (Francour *et al*, 2001).

The Port-Cros National Park, established in 1963, was the first MPA created in the Mediterranean. It is located along the southeastern coast of France, surrounding the island of Port-Cros. The park's primary objectives are conservation oriented, including the provision of education, research and ecotourism opportunities to teach about and study the diverse habitats of the area, including *Posidonia* beds, coralligenous bottoms, sandy bottoms and rocky reefs. There are several educational activities that take place throughout the year. The area is also subject to intense seasonal tourism (Francour *et al*, 2001). The park is heavily zoned with areas where all boating is prohibited; angling is prohibited; only diving is allowed; strict boat speed limits; and where anchoring is prohibited. Trawling and spearfishing are prohibited throughout the area. There is also a small no-take/entry zone and a 50-m wide belt along the coast where angling is prohibited. Tourism and diving have had a very small impact on the environment and economy of the island (Badalamenti *et al*, 2000).

The French island of Corsica has two protected areas, the Scandola Nature Reserve (1975) on the northwestern corner of the island and the Bouches de Bonifacio Nature Reserve (1999) in the southeast. The Scandola reserve was designated to protect *Posidonia* meadows, rocky reefs, rim-building coralline reefs and sandy bottoms that are home to diverse demersal fish assemblages. In the center of the reserve is a no-take zone where all activities are prohibited. In the outer zone, recreational fishing, angling, collecting and diving are all prohibited. The only permitted activity is small-scale fishing. The reserve is also theoretically protected from the pressures of tourism due to its remoteness (Francour *et al*, 2001).

In a study of the effectiveness of the reserve effect in the Scandola reserve, Francour (1994) reported that for seagrass beds in the Scandola Nature Reserve there were no differences between the protected and unprotected areas. On rocky substrata, however, density and biomass data showed higher values in the integral reserve than in the partially and non-protected zone (Bell, 1983a; Francour, 1993). Francour (1994) also found a higher abundance of rare and vulnerable species inside both habitats of the reserve, as compared to outside areas. Intermediate and large length classes were also more abundant inside than outside the reserve (Bell, 1983b; Francour, 1994; Dufour *et al.*, 1995; Francour, 1996). The results, however, are not completely clear-cut: Dufour *et al* (1995) reported that the abundance of nine fish species, four of which are highly sought after by fishermen (*Diplodus sargus, Oblada melanura, Symphodus tinca* and *Mullus surmuletus*), were greater outside the reserve than inside. Prey-predator relationships and the cascade effect may be responsible for this result.

The Bouches de Bonifacio reserve is a compilation of five previously created nature reserves and fishery cantons. While its primary purpose is for nature conservation and scientific research, many zones within the reserve were also designated to regulate fishing activities. Several sea bird and marine mammal species inhabit the area, along with large populations of dusky grouper and brown meager. Five no-take zones are scattered throughout the reserve where spearfishing, diving and all other types of fishing are prohibited. Fishing is also prohibited in known spawning aggregation sites. In the rest of the reserve, boating, anchoring, snorkeling, diving and swimming are all permitted (Francour *et al*, 2001). The entire reserve spans 80,000 ha, meaning that it is relatively hard to enforce and maintain conservation objectives. As a result, pressure from boating and diving has steadily increased, putting

heaving pressures on the marine environment. To combat this, the French and Italian governments have been investigating the possibility of an international MPA that extends south from the Bouches de Bonifacio reserve to also encompass the Maddalena Archipelago Marine Park off the northern coast of Sardegna (Francour *et al*, 2001).

Greece has only instituted two MPAs in its waters, the National Marine Park of Alonnisos in the Sporades Islands and one off the coast of Patras (The Environment Council, 2000), but no information is available on second of these.

The Alonnisos Park, created in 1992, is located in the north central Aegean Sea and is the biggest MPA in the Mediterranean at approximately 2,200 km^2. The park was designated for "the conservation of the unique natural marine and terrestrial environment of the area, of the rare species of fauna and flora and of the largest Mediterranean monk seal population in Europe," and the development of the area for sustainable use (Kotomatas *et al,* ____; Badalamenti *et al*, 2000). The park also has the objective of preserving the educational and research value of the area. There are extensive *Posidonia* beds throughout the reserve, along with multiple endemic and rare sea turtles, sponges, molluscs, tunicates and annelids.

The park is divided into three zones: a) core zone, containing multiple monk seal habitats, where only scientific research is allowed; b) zone A where tourism and small-scale traditional fishing is allowed, but strict restrictions are placed on purse seiners, trawlers and recreational fishing; and c) zone B where the only restrictions are on purse seiners and trawlers. Purse seining and trawling are strictly prohibited throughout the park. No management body has been put in place yet; national bodies, such as the Ministry of Environment, are responsible for management. As of 1999, the park was not fully functional (Badalamenti *et al*, 2000). In addition, research has been very limited in the park due to the absence of a research plan (Kotomatas *et al,* ____). These problems indicate that active steps need to be taken to rectify the present management failures for the reserve to achieve its management objectives.

5.2 Northeast Atlantic

Few MPAs in northwest Europe have been studied to determine their ecological effects (other than within-area monitoring) or even their overall characteristics, in contrast to the number of Mediterranean marine reserves investigated (García Charton *et al*., 2000). No information was found concerning MPAs directly off the coast of Portugal or the northern coast of Spain.

Off the northern coast of France, the Iroise Marine National Park is the most prominent, covering 2000 km^2 off the coast of Brittany. The park was established with the primary objective of integrating the management of the entire area, including eelgrass meadows, intertidal boulder flats and maerl beds, as well as seven fish species and eight bird species that are on the national red list. Parts of the area have also been designated as part of the worldwide Biosphere Reserve program and as EC Birds Directive sites (Kelleher *et al*, 1995). Environmental gradients in the area have created a diversity of habitats and very productive benthic and pelagic ecosystems. According to Christian Hily of the Institut Universitaire Europeen de la Mer (WWF, 1999 pg. 6), the Iroise is a valuable conservation area because it is "a representative area of the habitats and communities of the French Atlantic and Channel coasts, a refuge area for threatened species, a source area for recruits for other down-current areas, and also as a reference area for global climatic change and for modelling, research and education." As of 1999, researchers and park authorities were in the process of developing a

zoning scheme with a multiple use area (to conserve ecosystem function), no-take zones (targeting spawning areas, nurseries and sedentary species), management areas for special habitats (e.g. intertidal bird nesting areas, resting areas for seals, eelgrass meadows), and selective use areas (prohibiting use of destructive fishing gear) (WWF, 1999).The Iroise Marine Park is the subject of one of the case studies of this project.

Also off the coast of Brittany is the Archipel des Sept Iles Nature Reserve. Created in 1986, it comprises important habitats for seabirds and seals. Archipel des Sept Iles was the first marine reserve to protect seabirds in French coastal waters. Both fishing and hunting are prohibited inside the reserve and overall access to the area is limited (Kelleher *et al*, 1995). Very little is known about its overall effect.

Very little information is available on Irish MPAs; as a result, only one is discussed here. The Strangford Lough Marine Nature Reserve, located in eastern Northern Ireland, was declared in 1985 for the purpose of conserving the Lough's almost decimated marine life and for research (Stranford Lough Information Network, 2003). Recreational uses, such as sport fishing, sailing and other water sports are only restricted in limited areas and seasonally. The fishing industry agreed in 1991 to limit their catches and to voluntarily zone the use of mobile gear, such as trawls. The current statutory regulations include: a ban on suction dredging, beam trawls, tickler chains on trawl nets, fishing for horse mussels and using dredges to capture fish; a closed season on scallops between May 1 and October 31; a two zone system where trawling is only permitted in the north and scallop fishing only in the south; and a size restriction on fishing vessels to a maximum of 15.24 m (Stranford Lough Information Network, 2003).

The Lough has a massive tidal flow carrying large amounts of nutrients, providing food for more than 2,000 species making it one of Europe's most diverse marine life resources. The Lough also contains an assemblage of sponges, soft coral, mudflats, mussel and oyster beds and the largest colony of common seal in Ireland. The most detrimental threats to the area are an increase in tourism and shellfish harvesting. No studies have been done to determine the effect of reserve designation (Strangford Lough Country Holidays, 2003).

In Britain, legislation was enacted in 1981, under the Wildlife and Countryside Act, to designate statutory marine nature reserves (SMNR) at a national level. According to the Act, all British SMNR's have the common purpose of "conserving marine flora and fauna of special interest, and providing special opportunities for study and research" (Jones, 1999). However, the Act has two strong weaknesses that effectively inhibit the ability to protect the marine environment in SMNRs. First, the management body of any SMNR cannot create rules restricting fishing practices, as this is the responsibility of the government fisheries agency. Second, when a proposal for a new SMNR is put forward, any interested body can effectively block the passing of the proposal, making it very difficult for Nature Conservation Agencies to effectively establish beneficial SMNRs (Jones, 1999).

Only two SMNR's have been established in British waters, both in the southern Irish Sea. Britain's first marine nature reserve was declared at Lundy in the Bristol Channel. Although officially designated as an SMNR in 1986, the area has been classified as a voluntary marine nature reserve (VMNR) since 1973. Fishing restrictions comprise the main component of the management regime. Two zones exist in the reserve, potting is banned in one area, trawling and tangle fishing banned in a second. Spearfishing is prohibited throughout. Diving is

permitted throughout the reserve; however, divers are expected to adhere to a voluntary ban on shellfish collection in both zones. The most important weakness of the reserve is that the area that is the most vulnerable to damage (i.e. where sea fans and cup corals are present) remains unprotected (Jones, 1999).

Skomer, located off the Pembrokeshire coast in west Wales, was designated as an SMNR in 1990. It too was previously classified as a VMNR, originally designated in 1976. The main concern in the area was that scallop dredging caused significant damage to local seabed communities. The only statutory law put in place prohibits fishing for scallops; however, a voluntary code of conduct exists governing diving and fishing behavior. The managing body, however, has very little power to actually enforce any fishing conservation or diving behavior rules (Jones, 1999).

6. Military and industrial closed areas

There are many areas in northwest Europe in which fishing is excluded strictly for military security or industrial reasons, such as exclusion zones around military bases, oil and gas installations, ports, submarine cables and archaeological sites (Rogers, 1997; Clarke, 1998). One of the best examples in Europe of an area closed to fishing may be the British Underwater Test and Evaluation Centre (BUTEC), a site for testing underwater weapons in the Inner Sound between the island of Raasay and the west coast of the mainland of Scotland (DERA, 2001). This site occupies approximately 65 km^2 in an area of productive Norway lobster (*Nephrops norvegicus*) grounds. It was established in 1975, with an outer zone closed to fishing with mobile gear types and an inner zone of approximately half the total area closed to all fishing. Anecdotal evidence from fishermen indicates that catch per unit effort and the average size of *N. norvegicus* caught are higher along the zone boundaries than elsewhere (Clarke, 1998), reflecting the expected demographic effects of reduced mortality within the closed area. Unfortunately, commercial catch data are not collected on a fine enough spatial scale to quantify these effects and no scientific sampling of *N. norvegicus* has been undertaken within the BUTEC closed area (N. Bailey, Marine Laboratory, Aberdeen, pers. comm.).

Another military exclusion zone is a sea loch in the Firth of Clyde on the west coast of Scotland. Although closed to fishing for more than 25 years, it has recently been opened after the decommissioning of a naval base. Biological research here has focussed on the effects of fishing on the seabed, rather than the effects of closure on commercially important species (Tuck *et al*., 1998). Elsewhere in the Firth of Clyde, Hall-Spencer & Moore (2000) studied the effects of scallop dredging on maerl (*Lithothamnion* spp.) habitat with experimental fishing at a site previously closed for 30 years, owing to the presence of a submarine cable, and at commercially fished sites. In the unfished site, the abundance and mean age of scallops (*Pecten maximus* and *Aequipecten opercularis*) and the proportion mature were significantly higher than in fished areas.

7. Research areas

Although the effects of MPAs on commercially important species in Europe have not been studied frequently, there has been increasing interest in recent years in the environmental impacts of fishing techniques (Jennings & Kaiser, 1998), which has prompted the study of

closed areas. Recently established marine reserves have been studied to monitor the recovery of the seabed from destructive fishing techniques (e.g. Service & Magorrian, 1997; Magorrian & Service, 1998). Other studies have compared changes in the benthos over time in established exclusion zones with heavily fished areas nearby (e.g. Lindegarth *et al*., 2000; Hansson *et al*., 2000). Most studies of this type have focussed on benthic communities of invertebrates, but Hoffmann & Dolmer (2000) have also sampled fish as well as epibenthos within and outside an area of 40 km^2 closed to towed gears in Limfjord: a shallow, brackish inlet in Denmark. The closure was provoked by concerns that mussel (*Mytilus edulis*) dredging had damaged the seabed and local fin-fisheries. However, 9 years after closure, there were no significant differences in the abundance or species composition of fish or mobile invertebrates between the closed and open areas. Unfortunately, eutrophication and environmental hypoxia in Limfjord probably masked any effects of protection from fishing (Hoffmann & Dolmer, 2000).

As an example, an area of approximately 2 km^2 of scallop (*Pecten maximus* and *Aequipecten opercularis*) fishing ground off the southwest coast of the Isle of Man was closed in 1989 to commercial fishing with mobile gear. This closure was to provide an undisturbed area in which scallop fishery enhancement and culture techniques could be trialled (Brand *et al*., 1991). Subsequently, the area has also been studied to assess the effects of scallop dredging on the seabed and benthos (Bradshaw *et al*., 1999).

An area of 1.05 km^2 on the west coast of Sweden was closed to fishing for lobsters (*Homarus gammarus*) in 1989, specifically to investigate the potential fishery benefits of protecting a portion of the spawning stock (Ulmestrand, 1996). This approach was prompted by a long-term decline in catch and CPUE, associated with increasing fishing effort. As expected, the total mortality rate of lobsters in the closed area decreased and a greater proportion of lobsters survived to larger sizes, implying greater egg production per unit area. Similar results have been obtained for spiny lobster (Palinuridae) in reserves elsewhere in the world (Chubb, 1994). There was an indication of reduced female growth rate in the Swedish reserve, however, perhaps as a result of increased population density. Unfortunately, since no contemporaneous samples were taken in fished areas, it is not possible to know whether growth rate was reduced only in the reserve (Ulmestrand, 1996). Quantifying the benefits of such a closed area to surrounding lobster fisheries is hampered by a lack of information about the effects of population density on growth rate, size at maturation, the body size-fecundity relationship and recruitment. However, the benefits may be significant, as it has been suggested that intense exploitation of lobster stocks in some inshore areas is largely sustained by the reproductive contribution of large individuals in relatively inaccessible locations offshore (Fogarty 1998; Sheehy *et al*. 1999).

8. Conclusions

The overall effects of marine protected areas in Europe have varied greatly both within and between the regions of the Mediterranean Sea, the North Sea and the Northeast Atlantic. In a general sense, it can be said that while many probably have problems with enforcement, community support and achieving the overall objectives of the management regime, evidence has been presented showing that when MPAs are managed well they can provide substantial benefits to stakeholders that utilize the area and its resources.

A prime example of this has been seen in trawling bans. The major effect of a short trawling ban (1 or 2 months) implemented in the correct period and area seems to be saving useless waste of undersized fishes by delaying catches for a period equal to the duration of the ban, thus contributing to avoid growth overfishing. In turn it does not have any significant long-term influence on fish populations and on catches. Short trawling bans seems to be effective immediately after their implementation (Pranovi *et al.*, 1996). On the contrary, long fishing bans (5 to 12 months) have long-term effects by enhancing catches for the whole period following the prohibition. As this management tool affects more deeply the population dynamics of fish populations, the new equilibrium of the fishery is reached after a longer time (3 years in the case of Cyprus). A similar example was seen in the Gulf of Castellammare (Italy) where a 8-fold increase in biomass was found (Pipitone *et al*, 2000).

Other major benefits have been seen in the mackerel box off the Cornish coast where juvenile mortality was significantly reduced and the Tabarca Marine Reserve where local fishers have realized increased economic returns as they catch more fish in areas adjacent to the reserve. In many reserves, it was reported that overall abundance, species diversity and higher abundance of large and rare species are all significantly higher inside the protected areas compared with unprotected areas (Francour *et al*, 2001; Garcia Rubies and Zabala, 1990a). However, there have been some unplanned for consequences as a result of MPA implementation. This can be seen in the Ustica Island Marine Reserve where CPUE has decreased because of the overall isolation of the reserve from other spawning areas and in the Bouches de Bonifacio Nature Reserve where boating and diving have increased substantially since the installation of the reserve causing intense pressure on the environment that is unregulated.

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Marine Protected Areas (MPAs) encompass a range of protection levels, from fully protected no-take areas to restriction of only particular activities, gear types, user groups, target species or extraction periods. We synthesized the results of empirical studies that compared partially protected areas (PPA) to (i) no-take marine reserves (NTR) and (ii) to open access areas (Open), to assess the potential benefits of different levels of protection for fish and invertebrate populations.Â Synthesis of available evidence suggests that while PPAs resulted in higher values of biological metrics (density and biomass) than unprotected areas, greatest benefits were apparent in NTR areas when NTRs and PPAs were compared. Different MPAs have different goals. The main focus of many MPAs is to protect marine habitats and the variety of life that they support. For example, the GalÃ¡pagos Marine Reserve, which lies about 1,000 kilometers (600 miles) off the west coast of South America, protects a series of small islands and the surrounding waters. This reserve includes a tremendous variety of habitats, from coral reefs to cold ocean currents to mangrove swamps, where trees grow directly in salty seawater. The waters around the GalÃ¡pagos are home to 3,000 different plant and animal species, including unusual species ...Â Many MPAs are divided up into different zones. Marine protected areas (MPAs) are one policy instrument available that have the potential to address several of the pressures on marine biodiversity (Table 2), in particular over-fishing and exploitation and habitat destruction. In addition to protecting rare and threatened species and their habitats and other areas of ecological importance, MPAs can help ensure the sustainable provision of multiple other ecosystem services that are fundamental for human well-being, including for fisheries, coastal protection (buffering against storms and erosion), tourism and recreation.Â They can also provide more sustainable tourism and recreational benefits, as well as enhance other non-use values such as cultural and heritage values. Use values to anglers and divers could increase as a result of restrictions on other users (these effects were assessed) or ecological improvements and increased site visits (these effects were not assessed).Â The NEA follow-on synthesis and technical reports will be released in 2014. Methods. 4. Data was gathered using an online questionnaire.Â Our contingent valuation design elicited non-use value, including option-use value, existence and bequest value associated with conservation of potential MPAs, again under different sets of management restrictions.Â 14. For England, the average current recreational value of the sites proposed for Current European marine biodiversity studies include some of the most extensive investigations into the description, production and maintenance of biodiversity patterns, as well as quantification of the consequences of changes in biodiversity for system sustainability and production of ecosystem goods and services [21â€“24].Â taxa are records for European Seas,.the results.revealed no evidence of a present in different systems and different regions are characterised decline in meiofauna with increasing water depth, whilst the by a different biodiversity [34].Â values of ecosystem ecosystem function and goods and services provisioning.