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ECOSYSTEM EFFECTS OF FISHING IN THE MEDITERRANEAN: AN ANALYSIS OF THE MAJOR THREATS OF FISHING GEAR AND PRACTICES TO BIODIVERSITY AND MARINE HABITS

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ECOSYSTEM EFFECTS OF FISHING IN THE MEDITERREAN: AN ANALYSIS OF THE MAJOR THREATS OF FISHING GEAR AND PRACTICES TO BIODIVERSITY AND MARINE HABITATS

by

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PREPARATION OF THIS DOCUMENT

The GEF-funded project (Global Environmental Facility) on the "Determination of priority actions for further elaborations and implementation of the Strategic Action Programme for the Mediterranean Sea", an initiative under the framework of the Barcelona Convention, includes the "Preparation of a Strategic Action Plan for the Conservation of Biological Diversity (SAP BIO) in the Mediterranean Region". This last project is led by the Regional Activity Centre for Specially Protected Areas (RAC/SPA) and is aimed at providing a logical basis for the implementation of the 1995 SPA Protocol.

The document presented here is one of the five outputs produced as a result of the Memorandum of Understanding concluded between RAC/SPA and the Fisheries Department of the Food and Agriculture Organization of the United Nations (FAO), with the general objective to produce technical documents and guidelines aimed at facilitating the national process for the elaboration of strategic action plans to face the impact of fishing activities on biological diversity.

This document was originally delivered by the author to FAO in November 2000. Though many new studies have been published since then that would certainly deserve discussion here, only a very limited updating – affecting the section on driftnets – could be done. Indeed, new relevant studies and key legislative moves have recently arisen on this particular issue that have made the original discussion somewhat outdated. As for the rest of topics, this study should be regarded as a document produced in 2000, based on the scientific knowledge then available.

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ABSTRACT

Most of the major impacts of fishing on the ecosystems recorded around the world occur in the Mediterranean. They vary from local effects on the sea bottom caused by trawler gears to large-scale impacts on cetacean populations driven by driftnet bycatch. This variety – which makes the Mediterranean a unique global model for the implementation of the Ecosystem Approach to Fisheries – is due to four main interrelated factors: the huge diversity of fishing gears and practices, the very high intensity of fishing, a high diversity of habitats distributed from the shallow-waters to the deep-sea and the oceanic domain, and an important biological diversity. The latter is demonstrated by the Mediterranean presence of a vast array of vulnerable species, many of them listed in international protection agreements that include emblematic sharks, turtles, whales and seals.

Mediterranean fisheries are not an exception in the context of the general declining trend shown by elasmobranch populations and their fisheries around the world. Information indicating to unsustainable catch rates of rays (including the disappearance of certain taxa from commercial catches) and other demersal species deserves special concern. The high elasmobranch bycatches – and even commercial catches – achieved in many pelagic fisheries, notably longlining and driftnetting, also appear to be a potential danger for several species. Longline fishing is also the main cause of seabird mortality in Mediterranean fisheries. Indirect effects of fishing on seabirds related to food availability, driven by discards, are particularly important. Fishing in the Mediterranean basin is clearly a major threat to marine turtle populations, which are massively bycaught. Longline fleets are a major threat in the whole region, particularly on the Loggerhead turtle population, as are trawlers and small-scale gears in particular areas, such as the Gulf of Gabès. The special vulnerability of marine turtles to high mortality rates of adults and sub-adults makes the maximization of the survival of individuals at sea a conservation priority. As for marine mammals, the information available describes a wide variety of interactions between cetacean populations and fishing fleets in the Mediterranean, involving almost every kind of major fishing gear commonly in use. However, driftnet fisheries and, to a much lesser extent, small-scale fisheries using fixed nets and purse seine fisheries appear to account for the highest impact and are also responsible for the highest rates of direct human-induced mortality. The reduced population of monk seal in the Mediterranean is also victim of both direct mortality by artisanal fishing gears and an increasing scarcity of food resources driven by overfishing. The impact of fishing on the seabed concerns mostly the use of bottom-trawling gears, namely otter trawls, beam trawls and dredges, together with some aggressive practices affecting rocky bottoms such as dynamite fishing and fishing for coral and date mussels. Trawling impacts on seagrass beds by both suspending sediments and directly damaging the vegetal mass, have the most dramatic consequences on *Posidonia* beds. As for particular fishing gears, bottom trawling, longlining and driftnets arise as those with most impact on marine ecosystems in the whole Mediterranean region.

Evidence shows that the effects of fishing in the Mediterranean go far beyond the isolated impacts on overfished target species, vulnerable non-commercial groups or sensitive habitats. The ecosystem effects of fishing in the Mediterranean are also conspicuous at the systemic level, as highlighted by the massive ecological footprint of fishing or the marked effects on the foodweb structure. A holistic approach should therefore be adopted if the overall changes to the structure and the functioning of marine ecosystems caused by fishing are to be remedied.

CONTENTS

1. FOREWORD

This document is intended as a contribution to the strategic action plans to limit the impact of fishing activities on biological diversity in the Mediterranean under the Strategic Action Plan for Biodiversity (SAP Biodiversity), which is expected to provide a logical basis for the implementation of the 1995 Specially Protected Areas Protocol (Barcelona Convention).

The work has been structured around a set of self-contained sections dealing with the main threats to marine biodiversity (including both vulnerable species and habitats) arising from fishing gears or practices in use in Mediterranean waters. The issues have been dealt with in two sections, one on fishing impacts on vulnerable species and habitats, and the other on specific aspects related to selected fishing gears and practices of special interest in the Mediterranean. General single-pecies issues related to the overfishing of commercial species have been deliberately omitted from the analysis, since they are the object of extensive studies elsewhere and a great deal of attention is paid to them in other fora.

The author has prepared an apparently classic analysis, useful for practical purposes, but has tried to avoid the pitfall of a purely reductionist dissecting of reality, aware of transversal or even higher-level issues connecting many of the individual questions analysed. An attempt has been made to give due weight to these interrelations as well as the overall ecosystem effects of fishing on the structure or functioning of the ecosystems (resulting from both past and present practices) throughout the different sections of this document. The document's chief merit is that it collates reliable information from different sources on the different ecosystem effects of fishing in the Mediterranean, and provides a coherent picture of the overall impact of fishing on regional biodiversity. Most of this integrative vision is specifically addressed in the conclusion section.

This work is focused on the Mediterranean, discarding unnecessary or redundant information from other areas of the world, even if better studied. Where information related to some of the major issues is scarce, special attention has been devoted to the few studies available, given their qualitative importance. The aim has been, thus, to produce a specifically Mediterranean document.

2. THE IMPACT OF FISHING ON VULNERABLE GROUPS AND HABITATS

2.1 The impact of fishing on chondrichthyans

2.1.1 Introduction

International concern over the conservation of shark, ray and chimaera (chondrichthyans) populations has been growing during recent years. This group has been revealed as especially vulnerable to human exploitation, fishing mortality resulting from both direct fisheries as well as high bycatches as a consequence of the use of low selective gears. These species, by nature of their k-selected life history strategies i.e. slow growth and delayed maturation, long reproductive cycles, for example incubation in *Squalus* lasts up to 22 months, low fecundity and long life spans, and their generally high position in trophic food webs, are more likely to be affected by intense fishing activity than most teleosts (Stevens *et al*., 2000; Castro, Woodley and Brudek, 1999). In this context, it is not surprising that after reviewing the status of some important shark fisheries, Castro, Woodley and Brudek (1999) concluded that the history of shark fisheries indicates that intensive fisheries are not sustainable and that complete collapses of the fishery are not rare. In the case of chondrichthyans, it seems that increased survival of juveniles rather than increased fecundity provides greater resilience to fishing pressure (Brander, 1981), highlighting this as the key factor for the conservation of these species.

Some international initiatives have been undertaken to deal with the problems related to the conservation of this group. They include the creation of a Shark Specialist Group by the Species Survival Commission of the IUCN, and the agreement at the FAO meeting held in Rome in October 1998 to set up an International Plan of Action for the Conservation and Management of Sharks (IPOA–Sharks). CITES commissioned a study on the status and trade of sharks which resulted in the creation of a Technical Working Group in FAO on sharks. The CITES Convention held in Santiago de Chile in November 2002 listed under Appendix II the basking shark (*Cetorhinus maximus*) and the whale shark (*Rhincodon typus*). In the Mediterranean, only Malta has adopted legislative measures to protect white and basking sharks.

2.1.2 Overview

The worldwide consensus on the serious threats posed by fishing for the conservation of elasmobranch species is consistent with the information available on the Mediterranean. Demersal and pelagic fisheries are described separately given the different species involved and the corresponding impacting activities.

2.1.3 Demersal fisheries

The impact of demersal fishing on Mediterranean elasmobranch populations relates to both direct fishing and the high bycatches due to the low selectivity of fishing practices.

Analyses of historical data on experimental surveys and fishery landings have proved useful in detecting clear population declines in some Mediterranean regions. A study based on historical data from both bottom trawl surveys and commercial landing statistics in the Gulf of Lions points to the clear decline of demersal elasmobranch species populations since the 1960s (Aldebert, 1997). The area is exploited by a large trawling fleet (more than 200 vessels, accounting for 2/3 of the total catch) as well as by other small-scale fleets using various gears. Results from experimental trawl surveys indicate that the decline of elasmobranchs started on the continental shelf, and extended recently to the slope. Only 13 of the 25 species recorded in the years 1957–60 were still caught in the period 1994–95, a reduction in the number of chondrichthyan species of about 50%. It is worth noting that decreasing species were mainly fish with some economic value. This is the case of small sharks such as the smooth-hounds *Mustelus mustelus* and *M. asterias*, the smallspotted catshark (*Scyliorhinus stellaris*) and the longnose spurdog (*Squalus blainvillei*), as well as most of the rays. The latter seem to display a special vulnerability to fishing since only two, the starry ray, *Raja asterias*, and the thornback ray, *R. clavata*, of the ten species commercially exploited in the Gulf of Lions were still present in the last surveys; these were the most initially abundant species. Analyses of data on commercial landings led to convergent results i.e. longnosed skate, *Raja oxyrinchus*, a species reaching maturity at a length of 120 cm in the Mediterranean, disappeared from landings as early as 1976.

The evidence for population declines of chondrichtyan species in the North Tyrrhenian Sea is also conspicuous. Historical data series indicate that sharks and rays formed a bigger part of catches in the 1950s than they do today, to the point that some fisheries directed at species then abundant such as the picked dogfish (*Squalus acanthias*) and *M. mustelus* disappeared, as well as some species of Dasyatidae and Rhinobatidae (Serena and Abella, 1999). This declining trend concerning chondrichthyan populations seems not to be exclusive to this region of the NW Mediterranean: similar situations have been reported concerning areas as distant as the Alboran Sea and the waters surrounding Malta (Aldebert, 1997; Stevens *et al*., 2000).

Ray species appear to be especially vulnerable to fishing. In the Northern Tyrrhenian Sea, where an important trawling fleet operates, rays are reported to be among the most important components of the fish assemblages caught by the local beam trawling "rapido" fleet harvesting in shallow waters. The corresponding catches by the otter trawling fleet are less important (Serena and Abella, 1999). Catches are especially important in the region of Viareggio where high discards of juvenile specimens of the most abundant ray species there, *R. asterias*, not exceeding 28 cm (maturity is reached at a size ranging between 50–60 cm, depending on the sex), are known to occur although the population seems to be stable. As reported in Relini, Bertrand and Zamboni (1999), the most important catches of ray in Italian waters correspond to *R. clavata*, a species abundant in trawling grounds whose juvenile fraction suffers high fishing mortality. Data on this species in the North Tyrrhenian suggest a very high exploitation level. The case of the brown ray (*R. miraletus*) is not very different.

Italian demersal fleets discard high levels of juvenile blackmouth catshark (*Galeus melastomus*) and smallspotted catshark (*Scyliorhinus canicula*), species captured with bottom trawlnets at different depths (Relini, Bertrand and Zamboni, 1999). The former is mainly caught as a bycatch in the Norway lobster and red shrimp fisheries. Improved gear selectivity based on an increased mesh size has been suggested as a way of reducing these undesirable catches. In the case of *G. melastomus*, a significant reduction of fishing in the nursery areas may also be necessary, especially in the well-known one located in the Northern Tyrrhenian Sea between Gorgona and Capraia at depths around 200 m. Another species, *S. blainvillei*, was formerly quite common in the Northern Tyrrhenian Sea, whereas at present the population has been considerably reduced because of the high bycatches by the bottom trawl fisheries. As far as other minor species are concerned, *S. acanthias* and *M. mustelus* are captured in Italian waters using traditional bottom nets, as well as longlines and gillnets. The gulper shark (*Centrophorus granulosus*) is caught as a bycatch of traditional bottom trawlnets in slope fisheries.

Chondrichthyan species, mainly involving species of *Raja*, *Scyliorhinus*, *Squalus* and *Oxynotus* genera also account for the bulk of discards produced by the Greek trawling fleet operating in the Cyclades area in the Aegean Sea (Vassilopoulou and Papaconstantinou, 1998).

Demersal Mediterranean fisheries also impact on large pelagic species such as the white shark (*Carcharodon carcharias*), a species listed in the Barcelona convention (Annex II) and Bern Convention (Appendix II) and represented by a very low-density population in the Mediterranean. The Sicilian Channel waters, however, are considered as a major area of abundance and reproduction of white sharks within the entire NE Atlantic/Mediterranean region (Fergusson, 1996). This species seem to have been in general decline in Mediterranean waters since 1960. Given the vulnerability of the enclosed Mediterranean population, incidental catches are of special concern. Fergusson, Compagno and Fowler (1999) report that large individuals are incidentally entangled in bottom gillnets set close to Filfla Islet and off Marsaloxlokk in Malta, at seabed depths of 15 to 30 m; the same authors refer to white shark catches in similar circumstances in Sicily, Greece and Turkey in recent years. Young – including young of the year – white sharks are also caught elsewhere in the Mediterranean, off Algeria, France and in the North Aegean. The majority of these catches, however, originate from the Sicilian Channel during high summer, being due to trawlers based in Sicily (Fergusson, 1998).

2.1.4 Pelagic fisheries

Large pelagic elasmobranchs are regularly caught in the Mediterranean, mainly as a bycatch in the longline and driftnet swordfish (*Xiphias gladius*) fisheries. Some of these species are landed and marketed.

The blue shark (*Prionace glauca*) is perhaps the most impacted species, though because of its relatively high fecundity (Compagno, 1984) it seems to rank high on the scale of shark species resilience to fishing (Smith, Au and Show, 1998). The ratio of bycatches varies depends on the area. The swordfish/blue shark ratio for the Ionian longline fleet in Italian waters from 1978–1981 was as low as 1.6:1, pointing to very high shark catches; in other areas the relative weight of shark bycatch was somewhat minor. This is the case in the Southern Adriatic (3.4:1) and in the protected area formerly known as Santuario dei Cetacei in the Western-Central Ligurian Sea, where the ratio was only 18–20:1, perhaps reflecting a low density of the species there, where high densities of other apical predators are recorded (Orsi Relini *et al*. 1999). Much lower numbers of other elasmobranch species such as the thresher shark (*Alopias vulpinus*), the shortfin mako (*Isurus oxyrinchus*) and the porbeagle (*Lamna nasus*) are also part of the commercial fraction of the longline bycatch in the latter protected area (Orsi Relini *et al*., 1999). The monitoring of landings from the Spanish Mediterranean swordfish fishery (longlines) at ports between Alicante and

Algeciras (southern Spain) conducted during summer 1998, revealed that blue shark made up about one-quarter of total landings; more than 500 individuals were recorded (Raymakers and Lynham, 1999). Furthermore, finning, the cutting of the shark fin and the discarding of the rest of the animal, is probably practised in the Mediterranean high seas by longline fleets making long trips. Blue shark game fishing is also a matter for concern, especially in the Adriatic Sea, where a nursery area is known to exist and large amounts of juveniles are caught.

Surface fisheries targeting large pelagics in the Mediterranean also entail incidental catches of white shark (*Carcharodon carcharias*). The bluefin tuna (*Thunnus thynnus*) longline fishery operating from Marsaxlokk in Malta reports bycatches of neonatal white sharks in international waters near Lampedusa and Lybia (Fergusson, Compagno and Fowler, 1999). Similarly, the swordfish longline fleet based at Mazara del Vallo, Sicily is also known to catch neonatal specimens incidentally (Fergusson, 1998). All of them come from the breeding ground located in the Sicilian Channel. Adult individuals are also caught in the vicinity of Filfla Islet by the pelagic line fleet based at the Maltese port of Wied-iz-Zurrieq, while other specimens fall into tuna traps “tonnara” in bays along northern Malta.

Pelagic or bentopelagic stingrays (*Dasyatis spp*.) are also important victims of certain pelagic Mediterranean fisheries. In the longline fleet (about 27 units using “palamito da pesce spada”) fishing in the former Santuario dei Cetacei in the Western Central Ligurian Sea, pelagic stingray (*D. violacea*) largely dominates the fraction of the non-commercial bycatch, being caught in large numbers. Even some specimens of devil fish (*Mobula mobular*), a species listed in Annex II of the Barcelona Convention, are regularly caught in this fishery. *D. violacea* has also been reported to be victim of Spanish fleets in the swordfish longline fishery in the South Western Mediterranean (Aguilar, Mas and Pastor, 1992).

Together with longlines, driftnets are still responsible for considerable mortality in pelagic elasmobranch species, which frequently entangle in them. In Algeria, where this fishery is carried out in spite of being legally banned, catches of blue shark, and to a lesser extent, of other species of the Alopiidae and Carcharhinidae families are known to occur (A. Nouar, per. com.). Important commercial catches of *A. vulpinus* and blue shark, as well as minor discards of *D. violacea*, *M. mobular* and even basking shark (*Cethorhinus maximus*, listed in Annex II of the Bern Convention) have also been reported for the driftnet fishery operating in the Ligurian Sea (Di Natale *et al*., 1992). According to Tudela *et al.* (2005), large pelagic sharks are massively bycaught by the large-scale Moroccan driftnet fleet targeting swordfish that operates in the Alboran Sea: incidental catches of blue shark, shortfin mako and thresher shark there are estimated at about 7 000–8 000 individuals each annually. Estimates of the yearly bycatch by the Tangiers fleet, mostly occurring in the Straits of Gibraltar and nearby Atlantic waters ranges from 24 000–27 000 individuals for each one of these three species. The devil fish has also been reported as a regular bycatch of Turkish driftnets in the Aegean Sea (Akyol *et al*., 2003).

2.1.5 Conclusions

Most recent studies show that Mediterranean fisheries are not an exception in the context of the general declining trend showed by elasmobranch populations and their related fisheries around the world. Information on rays and other demersal species deserves special concern, since they have proved to be highly vulnerable to fishing. The high elasmobranch bycatches (and even commercial catches) associated with many pelagic fisheries, notably longlining and drfitnetting, also appear to be a potential danger for several species e.g. blue shark, white shark and stingrays.

In this context, the accurate monitoring of catches and the assessment of the impacted populations should be implemented in order to decide how and where to launch measures effective in reducing fishing mortality on target or bycatch chondrichthyan species. Given the usually high trophic level of these species, the conservation of the diversity of this group of important predators (some of them apical), is essential for the health of the ecosystems, as population changes could cascade down with unpredictable effects on many trophic webs. The establishment of marine protected areas in nursery grounds or in areas of special interest, the complete elimination of the most impacting gears such as driftnets and the improvement of the selectivity of surface longlining and bottom trawling in order to reduce bycatches are among the necessary shortest-term measures. Given the role of apex predator played by many elasmobranch species, a systemic management leading to the adequate conservation of the whole ecosystems, including healthy levels of other fish populations, appears to be necessary. This would apply to the case of the meagre Mediterranean white shark population, which is though to suffer from the overfishing of its main prey species, large pelagic fishes such as bluefin tuna (Fergusson, Compagno and Fowler, 1999). Finally, the overall management policy regarding the exploitation of elasmobranch populations, including commercial fisheries, and the related commercialisation processes should perhaps be revised in the light of the latest indicators pointing to the non-sustainability of current practices.

2.2 The impact of fishing on seabirds

2.2.1 Introduction

Very little attention had been paid until recently to the impact of Mediterranean fisheries on seabird populations. However, studies carried out in the last years, mainly in the northwestern Mediterranean region, have revealed strong and complex interactions of worldwide interest. The effects of fishing on bird populations may be directly responsible for mortality as when caused by low selective fishing practices, or more indirect as when play the role of external perturbations that fundamentally affect food supplies and subsequently lead to major modifications in trophic habits, demographic parameters and interspecific relationships. The key feature affecting seabird populations are precisely mortality rates. Procellariiforms, as well as Pelecaniforms and Laridae species are generally long-lived and their populations are highly sensitive to changes in survival. The additional mortality induced by accidental captures in fisheries is therefore a significant danger to them (Lebreton, 2000).

In 1999 the FAO Committee on Fisheries (COFI) designed an International Plan of Action for reducing incidental catch of seabirds in longline fisheries, open to the voluntary adhesion of all countries with longline fleets. BirdLife started a Program for the Conservation of Sea Birds in 1997 as a result of the resolution on Incidental Mortality of Sea Birds in Long-lines, adopted by the IUCN at its First World Conservation Congress. Three Mediterranean seabird species are currently covered by specific Action Plans designed by BirdLife International, approved by the Ornis Committee (EU DG Environment) and endorsed by the Bern Convention Standing Committee. They include Audouin's gull (*Larus audouinii*), the Balearic shearwater (*Puffinus mauretanicus*) and the Mediterranean shag (*Phalacrocorax aristotelis desmaresti*).

2.2.2 Overview

The information available on the Mediterranean basin will be presented under two different categories, namely the direct and the indirect effects, following the criterion found in Tasker *et al*. (2000), and given the diversity of fishing effects recorded on seabird populations.

2.2.3 Direct effects

These refer to seabird bycatches related to impacting fishing practices, notably longlining. Data on mortality levels exist only for Spanish fisheries, being Spain only one of the 12 Mediterranean countries known to undertake longline fishing. (Cooper *et al*., 2000). A specific study addressing the impact of longlines on Mediterranean seabird species has recently been carried out in the Spanish fishery around the Columbretes Islands, in the NW Mediterranean (Martí, 1998). A local fleet using both bottom and surface longlines operates there, targetting hake and swordfish respectively. On-board observations during the summer months revealed that six different species preyed on the baited hooks during the process of line setting. These included Cory's shearwater (*Calonectris diomedea*), the Balearic shearwater (*Puffinus mauretanicus*), the Atlantic gannet (*Morus bassanus*), Audouin's gull (*Larus audouinii*) and the yellow-legged gull (*Larus cachinans*). In addition, fishermen referred to the capture of specimens of great skua (*Stercorarius skua*) and Mediterranean shag (*Phalacrocorax aristotelis desmaresti*). Incidental catches affected mostly Cory's shearwater, accounting for 77% of the total bird bycatch, followed by the yellow-legged gull (14%) and the Atlantic gannet (9%). The incidence was higher for bottom longlining (0.72 birds caught per 1 000 hooks, against only 0.22 for surface longlining). Although the average capture rate for the overall fleet was estimated to be 0.44 individuals per gear setting, sporadic massive catches are known to happen: 200 Balearic shearwater were reported to have been caught during a single bottom longline setting in 1997. Several reasons point to both shearwater species as the most impacted seabirds in this fishery. So, whilst Cory's is the most affected in numerical terms, the Balearic shearwater is a Balearic endemic species facing a regressive trend, half its global population wintering in the area of the study. Concerning the former, fishing mortality caused by longlining on the populations breeding in the Columbretes Is. and the Balearic Is. has been estimated at 550 and 1 300 individuals, respectively (Aguilar, 1998). The high sensitivity of Cory's shearwater to high levels of mortality on the adult population make these figures a matter of concern since 60% of individuals hooked are adults (Martí, 1998). All evidence points to the non-sustainability of present bycatch rates (Cooper *et al*., 2000). Another study based on the monitoring of 557 fishing operations carried out during 1999 and 2000 by the Spanish surface longline fleet in the Western Mediterranean also showed that Cory's shearwater, together with the yellow-legged gull, accounted for almost the totality of bycatches (20 out of the total 21 birds caught), which also took place mainly during the setting of the gears (Valeiras and Camiñas, 2000).

Other information regarding longline fisheries from Greece and Malta confirms the results of the Spanish studies, in the sense that *C. diomedea* appears to be the seabird species most affected by this fishing practice in the Mediterranean (Cooper *et al*., 2000).

Nets also cause mortality in seabird species, since both Audouin's gull and the yellow-legged gull have been reported to entangle in nylon mesh in the Chafarinas Islands, the small Spanish archipelago off Morocco (De Juana and De Juana, 1984).

2.2.4 Indirect effects

The effects of fishing-induced changes in food availability on seabird populations have been studied most closely in the northwestern Mediterranean. This region is characterized by being inhabited by the bulk of the world population of the rare Audouin's gull (*Larus audouinii*), whose world's largest colony – accounting for 62% of the global breeding population of 18 690 pairs – is found in the Ebro Delta, in the Iberian Peninsula (Martínez, 2000). This species, a specialist predator on shoaling clupeoids, relies heavily on discards. An important fleet of both otter trawlers and purse seiners operates in the vicinity of the Ebro Delta, supplying the seabird species breeding there with additional food .

An extensive study on the use of discards by seabirds was carried out in the Ebro Delta region and in the Island of Mallorca (Oro and Ruiz, 1997). In the former area, because of the illegal fishing of anchovy by trawlers, a high amount of sardines are discarded, which together with flatfish make up half the total discards (estimated at between 15–45% of catches, and at 41% of fish landed). This resource is mainly exploited by the Audouin's gull, which is the most abundant species and, to a lesser extent, by the yellow-legged gull (*Larus cachinnnans*) and other gulls, terns and shearwaters. The field survey indicated that birds took 72% of total fish specimens discarded. In contrast, in the Mallorca fishery, with fleets mainly targeting shrimp on the slope bottoms, 40% of discards were crustaceans and boar fish (*Capros aper*), groups that are often rejected by scavenging birds. Estimations based on energetic requirements show that discards in the Ebro Delta region are enough to sustain the populations of scavenging seabird species, which is not the case in Mallorca. Discards are also known to constitute the main forage resource for the lesser black-backed gull (*Larus fuscus*) in the Ebro Delta colony (Oro, 1996). Closed seasons for trawling fleets based around the Ebro Delta overlap the breeding season of scavenging birds and negatively affect their breeding performance as reported for the lesser black-backed gull (Oro, 1996), the yellow-legged gull (Oro, Bosch and Ruiz, 1995) and Audouin's gull (Oro, Jover and Ruiz, 1996). Abelló, Arcos and Gil de Sola (2000), based on the attendance of seabirds at experimental trawl haulings on the Mediterranean Iberian coast confirmed the importance of trawl discards for Cory’s shearwater (*Calonectris diomedea*), the Balearic shearwater (*Puffinus mauretanicus*), Audouin's gull and the yellow-legged gull.

Purse seine fleets fishing at night affect the trophic availability of seabirds. A study carried out in the same area around the important bird sanctuary of the Ebro Delta shows that the different species exploit the opportunities offered by this fleet in different ways. Whereas the yellow-legged gull, Cory's shearwater and the Balearic shearwater occasionally benefit from direct predation on discards, this is of limited importance given the low volume generated; Audouin's gull is a nocturnal species specialized in capturing small pelagic fish and takes direct advantage of the fishing operation to capture the fish attracted by the lights or concentrated by the gear (Arcos, Oro and Ruiz, 2000). This association with purse seine fleets has also been confirmed by González-Solís (2000) for the yellow legged gull and Audouin's gull around the Chafarinas Islands, where bottom trawl and purse seine fisheries operate. The two species have a similar diet there and account for as much as 60% of epipelagic fish when both fleets are active simultaneously.

2.2.5 Conclusions

Longline fishing is evidently the main cause of seabird mortality in Mediterranean fisheries. Bottom and surface longlining are both implicated since bird mortality is associated with the process of longline setting and independent of the depth targeted by the gear. The above study on the Columbretes fishery concludes that nocturnal setting prevents bird predation of baits, and reports that this measure, which involves a change in fishing habits, has already been implemented spontaneously by fishermen in the area in order to prevent the negative economic consequences arising from the interaction with birds. This appears to be the most realistic remedy for artisanal fisheries, though its efficacy is reduced on full-moon nights. Other complementary measures such as training lines with floats attached to frighten birds away are also in use in that region to some effect. As for the industrial fleets i.e. large surface longlines targeting large pelagics potentially affording higher investments, Martí (1998) acknowledges the feasibility of using pipe devices, that is the Mustad design, which allow the underwater setting of lines, precluding any possibility of bait predation by birds.

Tackling the issue of the impact of fisheries on seabirds related to the increase in food availability appears to be very difficult since a clear consensus on what human effects are positive or negative at an ecosystem level is apparently lacking. The above reported case of trawling discards in the Ebro Delta is a good example of this. Whilst some authors refer to the negative effects of closed seasons on several gull species, it should be pointed out that seabirds there benefit largely from discards arising from an illegal fishing activity, since the use of trawling to catch small pelagics is forbidden in Spain. Moreover, the very discards constitute a negative effect of fishing on the overall ecosystem that should be minimized. Demersal populations in the region are heavily fished or even overfished and limitations on fishing are urgently needed (Lleonart, 1990; Irazola *et al*., 1996).

The distinction between direct (fishing mortality) and indirect (trophic availability) effects of fishing is nonetheless somewhat vague, highlighting the complexity that underlies ecosystems. In two very different Mediterranean areas, the NW Mediterranean and the Alboran Sea, the predatory behaviour of the yellow-legged gull on Audouin's gull (even adults) was reported to increase following the elimination of discards caused by temporary fishing moratoria (González-Solís, 2000; Martínez-Abraín *et al*., 2000). Martí (1998) noted that the majority of Audouin's gulls caught by the longline fleet operating around the Columbretes Islands were caught during the trawling closed season, suggesting that trawling moratoria could enhance the incidence of longline bycatches.

2.3 The impact of fishing on turtles

2.3.1 Introduction

Loggerhead turtle (*Caretta caretta*), green turtle (*Chelonia mydas*) and leatherback turtle (*Dermochelys coriacea*) are the most common species of marine turtles in the Mediterranean, though only the former two are known to nest on Mediterranean beaches. All three are endangered species (UNEP/IUCN, 1990). It is estimated that only 300–400 green turtle females and about 2 000 Loggerheads nest annually in the Mediterranean (Groombridge, 1990), the latter laying between 3 000–4 000 nests every year (Groombridge, 1989 and UNEP/IUCN, 1990). Total adult populations are somewhat higher given that most of the individuals do not breed every year. In the case of the Loggerhead, an additional contingent of individuals of Atlantic origin is known to migrate into the W Mediterranean across the Gibraltar Strait, during the first half of the year (Camiñas, 1997a, b). A third nesting species, not strictly marine, the Nile soft-shelled turtle (*Trionix triunguis*) is found in a few coastal wetlands in the Eastern Mediterranean. The 1991 Bern Convention on the Conservation of European Wildlife and Natural Habitats recommended to the Council of Europe that this sub-tropical species be given better protection. Turkey is a key country regarding the total number of nesting females for the three mentioned species breeding in the Mediterranean, though fishing practices around the entire basin affect their populations. A demographic model for the Mediterranean population of Loggerhead turtle showed that adult survival was the main factor affecting population growth rates, fecundity being less significant (Laurent *et al.*, 1992). This emphasizes the importance of limiting fishing bycatches of these species.

International concern about the general decline of the marine turtle population in the Mediterranean led the parties to the Barcelona Convention to adopt an Action Plan for the Conservation of Mediterranean Marine Turtles in 1989, acknowledging that catches by fishermen are the most serious threat to the turtles at sea, and that the conservation of the green turtle deserved special priority.

2.3.2 Overview

Mediterranean fisheries have an enormous impact on the local turtle stock: more than 60 000 turtles are caught annually as a result of fishing practices, mortality rates ranging from 10% to 50% of individuals caught (Lee and Poland, 1998). The problems related to the interaction between fisheries and turtles in the Mediterranean are, to a large extent, common to the different species. However, local features can affect breeding or wintering populations of turtles differently in different areas. These, and other considerations related to the status of different populations suggest the convenience of reporting separately on each of the most important species.

2.3.3 Loggerhead turtle

The Loggerhead turtle (*Caretta caretta*) is the most abundant marine turtle species breeding in Mediterranean waters. The Ionian Sea constitutes its major breeding ground, the coasts of Western Greece being of paramount importance. The gulf of Laganas off the island of Zakynthos, has one of the highest densities of nests in the world and the beaches of the island of Kefalonia and other Ionian islands, as well as the west coast of the Peloponesus (Margaritoulis and Dimopoulos, 1995; Margaritoulis, Pappa and Teneketzis, 1995) are also important. Other nesting areas are found in Turkey, Cyprus, Tunisia, Egypt and Libya (Demetropoulos, 1998; Laurent *et al.*, 1995).

Surface longline and driftnet fleets operating in the Mediterranean are the major threats to the survival of this species, although bottom trawls and gillnets are responsible for some catches.

A study addressing the bycatch of turtles by the swordfish longline fleet based at Kefalonia, which operates mainly in the Central and South Ionian Sea, lasting from 1989 to 1995, showed that each vessel caught an average of 7.7 loggerhead turtles every year (Panou *et al.*, 1999). Although nesting season in that area coincides with the peak of the swordfish fishery, 77% of individuals caught were immature, highlighting the especial vulnerability of this group to fishing (though Salter (1995) alternatively suggests that this fact could reflect the capture of adults by driftnets). Extrapolating these data to the total professional Greek longline fleet in the Ionian Sea (which accounts for more than 50% of total Greek fishing effort in western Greece), an estimated figure of 280 turtles caught per year is obtained. The additional impact of the 30–50 Italian driftnet vessels operating in the same area gives a total estimateed annual bycatch of 600 individuals.

A former study referring to the Spanish longline fleet targeting swordfish in the South Western Mediterranean (up to 60–80 vessels in the summer months, in the early 1990s) suggested that turtle bycatches in this region are dramatically higher (Aguilar, Mas and Pastor, 1992). Rates as high as 6.5–9.8 turtles per day and boat were recorded during 1990 and 1991, allowing for an estimated total catch ranging from 22 000 to 35 000 individuals each year, 66% of catches being concentrated in only two months (July and August). Estimates of total catches by the Spanish longline fleet in the Mediterranean for the period 1988–1996 oscillate from 1 953 individuals in 1993 to 23 888 in 1990 (Camiñas, 1997b). Bycatches by the foreign industrial longline fleets operating in the area (Japanese, flag of convenience,) could lead to even higher figures. A recent survey carried out from July to December 1999 to assess the bycatch by the Spanish longline fleets targeting swordfish and albacore in the Mediterranean, under a EC DG XIV research project, showed that 280 fishing hauls yielded a total bycatch of 496 loggerhead turtles (Camiñas and Valeiras, 2000). The albacore fishery (with hooks set deeper in the sea) resulted in higher bycatch rates: 1.05 turtles per 1 000 hooks, against 0.33 from swordfish longlining. All the individuals caught in the South Western Mediterranean are juveniles, reflecting the demographic structure of the population in the W Mediterranean, where adult individuals are only found, in small numbers, in winter. It is important to note that individuals caught by the Spanish longline fleet have two different origins: Atlantic individuals entering the Mediterranean during the spring, and others belonging to the Central and Eastern Mediterranean breeding populations. Both groups migrate into the Western Mediterranean feeding grounds in spring and summer (Camiñas, 1997a, b).

Loggerhead turtles have also been caught in high numbers by the Italian and Maltese surface longline fleets, the former mostly operating in the Gulf of Taranto, the South Adriatic and the Aegean Sea, including those targeting albacore (Camiñas and De la Serna, 1995; Panou *et al*., 1999; De Metrio *et al*., 1997). Turtles are also victims of fishing bycatches in Tunisian waters, which are thought to be important wintering grounds for the species (Panou *et al*., 1999). Longline fleets annually catch an estimated 4 000 individuals there (Salter, 1995; Demetropoulos, 1998).

Loggerhead also get entangled in driftnets, as reported by Di Natale (1995) for the Italian driftnet fishery taking place in the Ligurian and Tyrrhenian Seas (catch rates of 0.057 and 0.046 loggerhead per day and vessel, respectively). 40% of turtle catches occur in July. About 16 000 turtles were estimated to be caught annually by an Italian driftnet fleet operating in the Ionian Sea in the 1980s (De Metrio and Megalofonou, 1988). As for the Spanish swordfish driftnet fleet operating in the Alboran Sea until 1994, Loggerhead turtles constituted 0.32% of the catch in 1992 and 0.92% in 1994 (Silvani, Gazo and Aguilar, 1999). An estimated 236 animals were caught incidentally in 1994, being released alive at sea. Further on-board observations regarding this Spanish driftnet fishery showed that important catches of Loggerhead in the Mediterranean side of the Gibraltar strait were recorded through July and August, when an important migration from the Mediterranean towards the Atlantic takes place (Camiñas, 1995; 1997a). The large-scale Moroccan driftnet fleet operating in the Alboran Sea (SW Mediterranean) also entails significant turtle bycatch (0.21 individuals/haul from December to May; Tudela *et al*. (2005).

Fixed nets also cause turtle mortality since turtles get caught in them when trying to feed on the entrapped fish, as happens in Kefalonia (Sugget and Houghton, 1998). Loggerhead captures by trawlers and purse seiners have also been reported for the Spanish Mediterranean coast (Camiñas, 1997c). Small annual catches of turtles (a mean of 1.5 individuals per year and boat) by the Spanish tuna purse seine fleet do not seem to be a mortality factor since turtles are released alive (University of Barcelona, 1995). Total annual bycatches by the Tunisian small-scale fleet (comprising fixed nets, purse seines, bottom and surface longlines, and tuna fishing gears) operating in the Gulf of Gabès are estimated at 5 000 individuals (Bradai, 1995). Another 2 000–2 500 turtles are caught by the trawling fleet, composed of 300 units, whereas illegal small trawlers are thought to capture additional hundreds to thousands of individuals annually. The highest catch rates in the region correspond to bottom longliners (an average of nearly 23 turtles per boat and year).

Experimental studies on mortality rates of individuals injured by fishing gears show that 20–30% of the turtles caught by the longline Spanish fleets may die (Aguilar, Mas and Pastor, 1992). An estimated 80% of specimens caught in this fishery are released with the hook still fixed in the mouth, pharynx or oesophagus (Camiñas and Valeiras, 2000). Furthermore, the probability of drowning at the gear seems to be higher for turtles caught by the albacore longline fleet than for those captured in the swordfish fishery. Other studies report mortality affecting 10% to 50% of the individuals incidentally caught (Lee and Poland, 1998). On the other hand, some observations seem to point to a rather fast degradation of non-stainless hooks in the mouth of the turtles released (2–3 months) (Panou *et al.*, 1999). An estimated 30% of turtles caught entangled in the Italian driftnet fishery are drowned (De Metrio and Megalofonou, 1988).

Finally it is worth mentioning that experimental tagging is susceptible to make turtles more vulnerable to fishing by increasing the chance of entanglement (Suget and Houghton, 1998) as has been reported for the loggerhead population of Kefalonia.

2.3.4 Green turtle

The green turtle (*Chelonia mydas*) is represented in the Mediterranean waters by a reduced population nesting on only a handful of beaches in Cyprus and Turkey. The local stock seems to be the remnant of a former larger population. Present recruitment rates are probably much lower than deaths related to fishing, and this could lead to the virtual collapse of the population in the near future (Demetropoulos, 1998). The Turkish localities of Kazanli, Akyatan and Samandag, with about 1 000 nests laid annually and scattered along more than 40 km of beaches, are the most important nesting areas for this species in the Mediterranean (Goombridge, 1990). Fishing activities, especially in the two former areas cause significant mortality at sea (Demirayak, 1999). A fleet of trawlers, longliners and small-scale boats using nets operates intensively, even within the fishing-restricted coastal strip, off Kazantli. Fishermen blame turtles for the damage they supposedly cause to their nets and dead specimens are often washed ashore. Fishermen from Karatas, the main port near the Akyatan nesting ground report numerous turtle captures, even in winter. Trawlers there also violate the three-mile coastal limit and seriously impact the green turtle population. Five trawling boats alone operating over 28 weeks have been reported as catching a total of 160 green turtles as well as 26 additional Loggerhead turtles.

A survey based on interviews with artisanal fishermen (using both nets and longlines) in northern Cyprus and on the Turkish Mediterranean coast yielded estimated bycatches of 4 and 2.5 turtles per boat and year respectively, giving a total minimum estimate of about 2 000 turtles for the whole region (Godley *et al.*, 1998). Even though 90% of the specimens were reported as having been caught alive, an unknown fraction of them could have been killed on board as fishermen perceive turtles as a nuisance. The authors of the report suggest that green turtles could possibly account for a significant proportion of turtles caught; this worrying given their demographic status.

The green turtle is also sporadically caught as a bycatch in fisheries from other areas, for example by the Greek longline fleet operating in the Ionian Sea (Panou *et al.*, 1999).

2.3.5 Other species

The Nile soft-shelled turtle (*Tryonix triunguis*) is an endangered species found in only three major populations: the wetland of Dalyan and the Dalaman area, in southwestern Anatolia, and the Alexandre River, in Israel (Kasparek and Kinzelbach, 1991). The two former Turkish populations were discovered in the early 1970s (Basoglu, 1973), and a new locality for the species has recently been reported in Patara. Populations are extremely low, consisting of only 50 adult individuals in Dalyan and a further 75–125 adults and sub-adults in Dalaman. Fishermen catch them at sea and usually kill them deliberately as happens in the Cucurova region and the Göksu delta (Kasparek, 1999) because of the damage they cause to the nets. This poses a major threat to the species. Fishermen from the Karatas harbour acknowledge that a remarkable amount of soft-shelled turtles are taken as a bycatch, and that they are commonly killed because they find them dangerous (Demirayak, 1999).

The leatherback turtle (*Dermochelys coriacea*) is also sporadically caught by the fleets operating in the Mediterranean. Cumulative evidence points to the existence of a reduced non-breeding population distributed in the whole Mediterranean Basin, where the species appears to be common or regular (Camiñas, 1998). Some incidental captures were reported in Tunisian waters during the 1990s, mostly by trammel nets, bottom trawls and driftnets (Bradai and El Abed, 1998). Swordfish longlines appeared to be responsible for most of the incidental catches recorded in western Mediterranean waters (Crespo, Camiñas and Rey, 1988; Camiñas, 1998), though some additional captures arose until the mid-1990s from the activity of the former Spanish swordfish driftnet fishery in the Alboran Sea (Camiñas, 1995). Monitoring of 15 longline vessels targeting swordfish in Spanish waters showed a catch of two specimens during two months of activity in the summer of 1991 (Aguilar, Mas and Pastor, 1992). Two further individuals were entangled in longlines in the course of 217 fishing operations in 1999 (Camiñas and Valeiras, 2000). This species is also taken as a bycatch in Italian longline albacore fisheries (De Metrio *et al.*, 1997).

2.3.6 Conclusions

Fishing in the Mediterranean basin is clearly a major threat to marine turtle populations. The especial vulnerability of these species to high mortality rates of adults and sub-adults makes the maximisation of the survival of individuals at sea a priority, and this could be achieved by reducing the mortality caused by fishing gears.

In surface longline fisheries, the hook should be removed whenever possible and the individuals immediately released; fishermen's collaboration is essential. Specimens caught and released alive with hooks in their oesophagi or stomachs do not necessarily survive. Turtles are not gastronomically appreciated in Greece, in contrast to some areas of Italy (the Apulian coast) and Egypt, but as stated by Panou *et al.* (1999), there is a danger that Greek crews, increasingly composed of foreign fishermen, may change this. The delay in the total extirpation of driftnets from European waters, particularly Greek and Italian, and the continued and growing use of driftnets in key turtle conservation areas in waters off the north African coast and Turkey are further matters for concern. Turtles discarded from driftnets can also die because of anoxic brain damage as a result of prolonged immersion (Lee and Poland, 1998). This and other above-mentioned factors point to the reduction of bycatches as the only effective way to eliminate fishing mortality. Special restrictive fishing measures affecting large pelagic fisheries could be applied in areas described in recent years with big populations of immature and adult Loggerheads.

More specific measures should be taken in the vicinity of nesting beaches to prevent capture of adults. This is particularly urgent for the green turtle because of its small breeding stock. Various fishing practices, even artisanal fleets, in these areas cause turtle mortality and fishing restrictions are frequently violated in most coastal waters. In this context, the Standing Committee of the Bern Convention recommended that the Turkish government strictly control the fisheries in the three main nesting beaches of the green turtle (document T-PVS (98) 62). The Turkish authorities have repeatedly been asked (from as early as 1994) to completely banning fishing at the Kazanli area during the nesting period, with little success to date. The improvement of trawling gears by means of turtle excluding devices (TED), in use in several tropical regions (Villaseñor, 1997), could be an effective measure in some cases where the impact of trawling on turtles is high (i.e. the Gulf of Gabès). Reducing trawl times is effective in reducing turtle mortality; trawls not exceeding 60 minutes give a turtle mortality rate in the gear close to 0%, but this rises to 50% if fishing time increases to 200 minutes (Henwood and Stuntz, 1987). Kasparev (1999) recommended stopping all kinds of fishing around Dalaman (including nets, lines, guns and dynamite) in order to protect the small local population of the soft-shelled Nile turtle. In addition, methods for experimental tagging should be improved so as to reduce potential harmful effects such as entanglement in nets.

Finally, campaigns designed to raise the awareness of stakeholders, primarily fishermen, should be undertaken along all the Mediterranean coasts to promote turtle-friendly fishing practices.

2.4 The impact of fishing on Mediterranean monk seal populations

2.4.1 Introduction

The Mediterranean monk seal (*Monachus monachus*) is a highly endangered species whose distribution has shrunk considerably during the last decades. The bulk of the world population (about 300–500 individuals) is currently limited to only two nuclei, one in the eastern Mediterranean and the other in the north-east Atlantic, off the coast of north-west Africa. The seal is listed as critically endangered by the International Union for the Conservation of Nature and Natural Resources (IUCN) and is also included in Appendix I of the Convention on International Trade in Endangered Species (CITES). It is also covered by the UNEP Bonn Convention on Migratory Species and the Bern Convention on the Conservation of European Wildlife and Natural Habitats. An Action Plan for the Management of the Mediterranean Monk Seal was adopted in 1987, launched under the Barcelona Convention.

All studies report that the Mediterranean monk seal population, consisting of only a few scattered groups of individuals breeding in the last isolated, undisturbed caves, is suffering a rapid decline. Two thirds of the world's largest surviving population, located on the Côte des Phoques in the Western Sahara, died off in 1997, victim of an epidemic. The remaining seals are extremely vulnerable and all evidence points to fishing as one of the main agents pushing the species to the brink of extinction, especially in the case of the eastern Mediterranean population (Johnson and Lavigne, 1998).

2.4.2 Overview

The impact of fishing practices on monk seal population has a largely twofold origin: direct mortality caused by incidental entanglement in fishing gears and deliberate killing by fishermen, and food scarcity related to overfishing and subsequent depletion of fish populations. A third related factor is the trophic limitation triggered by overfishing that encourages seals to prey more heavily on fish entrapped in nets, thus increasing the interaction between seals and gears (and fishermen).

Johnson and Karamanlidis (2000) include a review of the entrapment of monk seals in fishing gears partially summarized in the following lines. Monk seals may entangle and drown in fishing nets more often than is generally assumed; although the analysis of historical records shows that seals can be injured by many kinds of fishing gear, including purse seiners (Kiraç and Savas, 1996), they appear to be more vulnerable to static gears (stationary nets set on the bottom) and abandoned nets (ghost fishing effect). As many as 23% of seal deaths recorded in the Greek Ionian Islands, were due to entanglements (Panou, Jacobs and Panos, 1993). Berkes *et al*. (1979), Kiraç and Savas (1996) and Yediler and Gücü (1997) report a total 38 seal deaths between 1965 and 1994 in Mediterranean and Black Sea Turkish waters, 8 of them due to drowning by entanglement in nets, 16 killed by fishermen (1 of them as a result of dynamite fishing) and another 11 killed by dolphin hunters. Entanglement also appear to be a major mortality factor in Moroccan waters, and responsible for 27 of 40 seal deaths reported during the 1980s (Anonymous, 1990). Incidental entanglement as an agent of extinction is exemplified in the small colony inhabiting the cave known as the Grotta del Bue Marino, in the Tyrrhenian Island of Gorgona: all 8 specimens perished entangled in the nets of a local fisherman during the 1980s (Guarrera, 1999). A differential vulnerability to entanglement in nets has been suggested for adult and young monk seals in the Cilician Basin, off Turkey (Yediler and Gücü, 1997). Whereas the trammel and gillnets used there may not be strong enough to trap adults, four pups were found entangled in fishing nets during a five-year period (Anonymous, 1999a). Abandoned nets have caused significant seal mortality in the small population inhabiting the Desertas Is. in the Atlantic (Anselin and van der Elst, 1988).

The analysis of the 130 monk seal deaths recorded in the last 10 years, carried out by the NGO MOm (Anonymous, 1999b), shows that deliberate killing is the major direct threat to adult monk seals. Seals are perceived as a nuisance in many places, as in the Cilician Basin, and are ranked high among pests, together with dolphins and turtles, by fishermen because of the netted fish the seals consume and the damage they cause to the nets (Yediler and Gücü, 1997). Seals can reduce nets to rags, often leaving a characteristic three-hole pattern (Berkes, 1982). Studies carried out in the Ionian Sea showed that gears most damaged by seals were, in order of importance, inshore trammel nets, offshore trammel nets and gillnets; bottom longlines were much less affected (Panou, Jacobs and Panos, 1993). Fishermen report that seals attack nets mostly within 20–30 m of the surface (Johnson and Karamanlidis, 2000). Deliberate killing of monk seal is a common practice in most of its range, and may have a considerablle local impact: six individuals were killed in the Aydincik region (Cilician coast, Turkey) in 1994 alone (Yediler and Gücü, 1997). In general, fishermen's attitudes to monk seals depend on the extent to which they perceive fishing as a capital-intensive economic activity. Thus many fishermen in the Aegean Sea believe that killing seals brings bad luck whilst younger fishermen who have invested heavily in fishing equipment seem to display the most aggressive and even cruel behaviour (Yediler and Gücü, 1997; Berkes, 1982). In this context, it is worth mentioning that the length of net per fisherman increased by five along the coast off south-west Turkey bewteen 1950 and 1980 (Berkes, 1982). Aquaculture exploitations are also related to the deliberate killing of monk seals, at least in the Bodrum peninsula (Turkey), and exacerbate the impact of small-scale fishermen. Aquaculture businesses apparently prefer to shoot seals rather than set predator nets limiting the damage seals can cause because it is cheaper to do so (Anonymous, 1999b).

Three main actors seem to play a role in the interaction between seals and fisheries, namely small-scale fisheries, medium-scale fisheries (trawlers and purse seiners) and seals. Whilst the conflictive relationships between fishing and seals are limited mainly to small-scale fleets using nets, medium-scale fleets worsen the situation because they are largely responsible for the overexploitation of fishing grounds. Illegal fishing by trawler fleets within the three-mile coastal limit reserved for artisanal fleets, as reported for the Cilician Basin waters where a small monk seal population is found along the Anatolian coasts (Oztürk, 1992), is also common. Overfishing exacerbates the conflict between small-scale fishermen and monk seals, which may be forced to take fish from the nets. As reported in Johnson and Karamanlidis (2000), some studies strongly suggest that seals may become dependent on commercial fishing for food, and exhausted fisheries have been linked to both the decline of monk seal populations and an increased frequency of their attacks on nets. Particularly destructive fishing practices also affect seals: illegal dynamite fishing in Kefallonia contributes to the scarcity of resources for the local monk seal population. Johnson and Karamanlidis (2000) also refer to fishing with chemicals and the capture of small fry for aquaculture seed as negative harvesting practices threatening fish resources in the monk seal's range in the eastern Mediterranean. Tourism results in a rising seasonal demand for fish and may therefore be indirectly responsible for increased seal attacks on nets and the subsequent mortality associated with entanglements and deliberate killing (Panou, Jacobs and Panos, 1993; Karavellas, 1994).

The illegal but widespread practice of dynamite fishing has an overall negative effect on the ecosystem as mentioned above, and injures and kills monk seals directly; several deaths, some of them very recent, due to this practice have been reported in Greek and Turkish waters (Anonymous, 1999b).

2.4.3 Conclusions

Given the critical status of the Mediterranean monk seal remnant population, the only acceptable level of fishing-related mortality in the region is 0. Action must be taken to prevent deliberate killings by fishermen, incidental entanglements in nets and to manage fisheries so as to prevent overfishing and rebuild depleted food resources (Johnson and Karamanlidis, 2000). The participation of small-scale fishermen appears to be essential.

Initiatives undertaken in recent years suggest that an integrated approach, comprising the protection of ecosystems through marine protected areas and the involvement of local artisanal fishermen, is likely to be most effective; this includes increasing artisanal fishermen's awareness that they themselves, as well as the seals are victims of overfishing driven by commercial fisheries, mostly by medium-scale fleets. The immediate financial compensation of fishermen affected by seal attacks and information campaigns to destroy negative myths about seals appear necessary. One such myth is that the wild seal population consumes a huge amount of fish; in fact, the entire Greek Aegean monk seal population consumes an estimated 750 kg of fish daily (Ronald, 1984). SAD–AFA's Central Aegean Programme started in 1992 as the Foça Pilot Project, operating in association with the local community and the Turkish Ministry of the Environment, and covers the NW corner of the Bay of Izmir. Industrial fishing is prohibited there and data suggest that the project is succeeding in its goal of recovering fish stocks (Johnson and Karamanlidis, 2000). The implementation of more restrictive measures such as the banning of small fry fishing for aquaculture seed or the seasonal prohibition of the lampara fishery in the Bay of Izmir is still a priority. In the context of the Cilician Basin Project, the Turkish Ministry of Agriculture has banned all types of trawl and purse seine fishing in 15 square miles covering seal habitats. Small areas surrounding breeding caves have special protection as no-fishing zones. Other technical measures such as the improvement of fishing nets and the development of techniques for repelling seals from fishing equipments are envisaged by the Action Plan for the Management of the Mediterranean Monk Seal.

In summary, whereas some specific measures such as the enforcement of current regulations banning dynamite fishing and other highly damaging fishing practices known to affect monk seals should clearly be undertaken, the overall problem of monk seal conservation in the Mediterranean is clearly related to the sustainable management of entire marine ecosystems, in which monk seals are apex predators. Marine reserves, no-fishing zones and the involvement of artisanal fishermen, including educational programmes, are fundamental tools in ecosystem-based fisheries management.

2.5 The impact of fishing on cetacean populations

2.5.1 Introduction

About 17 different cetacean species have been reported in Mediterranean waters, some of them being only occasional visitors from the Atlantic (Duguy *et al.*, 1983a). They range in size from the small common (*Delphinus delphis*) and striped (*Stenella coeruleoalba*) dolphins to large whales such as the sperm whale (*Physeter catodon*) and the fin whale (*Balaenoptera physalus*). In general, both the diversity and the abundance of cetaceans are higher in the Western Basin.

The state of conservation and the size of the different populations are highly variable, depending on species and regions. The striped dolphin is the most abundant cetacean species in the western Mediterranean, with an estimated population of 117 880 individuals in 1991 (Forcada *et al.*, 1994). The study of the distribution of this population, however, revealed important geographic heterogeneities, often related to specific oceanographic conditions resulting in higher food availability (Forcada and Hammond, 1998). The most important population is found in the north-west Mediterranean, in the Ligurian Sea and Provenzal Basin (n: 42 604). The other outstanding area for the species, in terms of population density, is the Alboran Sea, especially its western part neighbouring the Strait of Gibraltar. The common dolphin, in contrast, has become increasingly rare in the Mediterranean in the last few decades; its best remaining population in the whole basin is that found in the Alboran Sea (with an estimated size of 14 736 individuals in 1991–1992). The Mediterranean population of *D. delphis* has been given in 2003 the status *Endangered* in the IUCN Red List of Threatened Species. The coastal strip of Morocco and Algeria seem to be a particularly important area for the species (Bayet and Beaubrun, 1987). Maximum concentrations of fin whale in the Mediterranean are again recorded in the Ligurian-Provenzal Basin, where its summer population was estimated at 1 012 specimens in 1992 (Notarbartolo di Sciara, 1994). There are probably only a few hundred sperm whales in the Mediterranean (Di Natale, 1995). Other less abundant species include the harbour porpoise (*Phocoena phocoena*), whose population outside the Black Sea has declined to the verge of extinction, though some sightings point to its sporadic presence off North African coasts.

This variety of species of different sizes, displaying different life histories, together with the equally high diversity of gears and fishing practices found in the Mediterranean lead to complex interactions between cetacean populations and fisheries.

As for marine turtles and monk seal, a specific Action Plan for the Conservation of Cetaceans in the Mediterranean Sea was adopted under the auspices of the Barcelona Convention in 1991. The reduction or depletion of food resources, incidental catches in fishing gears and deliberate killings are recognised as some of the most serious threats to cetaceans in the Mediterranean. The Action Plan called on all parties to adopt and implement legislation to prohibit the deliberate taking of cetaceans, the prohibition of driftnets longer than 2.5 km and the discarding of fishing gears at sea, and required the safe release of cetaceans caught accidentally. Contracting parties also agreed to promote the creation of a network of protected areas and marine sanctuaries in cooperation with RAC/SPA . The Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) has been signed by 18 states, and entered into force the 1st January 2001. Among other measures, its conservation plan (Annex 2) envisages the implementation of measures to minimize the adverse effects of fisheries with explicit emphasis on driftnets.

This section focuses on the most indisputable effects of fishing on the Mediterranean cetacean population. The issue of massive natural or pollution-related deaths such as those of striped dolphins in the Mediterranean in the early 1990s following viral epizootic events, is deliberately avoided since it falls outside the scope of this work.

2.5.2 Overview

Cetacean populations suffer principally from the direct mortality caused by fishing gears whilst small cetaceans also compete for the fish taken in nets; furthermore, fishermen deliberately kill dolphins to reduce the damage these inflict on their gears. The most significant issue (in terms of both quantitative incidence and potential effect on cetacean populations), however, is the mortality derived from fishing bycatches, which is largely due to drifnetting practices. Information on the different interactions between cetaceans and fisheries is given below, with emphasis on the specific features of different fishing practices related to cetacean mortality.

2.5.3 Driftnets

There is a wide consensus about the high figures for cetacean bycatches and the very high mortality of individuals entangled in Mediterranean swordfish fisheries using driftnets. A total of 37 cetaceans were caught in the Ligurian Sea in the summer of 1988 alone (Podestà and Magnaghi, 1989). Di Natale (1995) studied the activity of the Italian driftnet fleet operating there and in the Tyrrhenian Sea in the early 1990s (1990–1992). On-board monitoring of 100 commercial trips revealed the entanglement of 15 cetaceans, 13 striped dolphins, one Cuvier's beaked whale (*Ziphius cavirostris*) and one pilot whale (*Globicephala melaena*); only two animals could be released alive. The estimated catch rate was much higher in the Ligurian Sea, 0.29 cetaceans per fishing day and vessel, against 0.08 in the Tyrrhenian Sea. In the Ligurian Sea again, 35 fishing operations alone harvesting 144 swordfish accounted for bycatches of 10 cetaceans belonging to three different species (Di Natale *et al*., 1992). These high incidental captures of marine mammals, related to the important numbers of cetaceans in the area led in 1992 to the establishment of a driftnet-free "Santuario dei Cetacei" in Ligurian Sea waters.

An estimated 1 682 cetaceans were taken by the whole Italian driftnet fishery in 1991 (Di Natale, 1995), including 1 363 striped dolphins, 132 pilot whales, 62 other delphinids, 79 Risso's dolphins (*Grampus griseus*), 35 bottlenose dolphins (*Tursiops truncatus*), 8 sperm whales, 2 Cuvier's beaked whales and 1 fin whale. The fishing effort of this fleet was concentrated mainly in the Tyrrhenian and Sardinian Seas during 1990–1991, and an estimated 946 striped dolphins were captured there. The author concluded from these figures that the most impacted species appeared to be the striped dolphin, the sperm whale, the pilot whale and Risso's dolphin. Other studies on the impact of the Italian driftnet fishery confirm these high figures for cetacean bycatches, even pointing to the capture of species uncommon in Mediterranean waters, such as the Minke whale (*Balaenoptera acutorostrata*) (Di Natale and Mangano, 1981).

Other authors confirm that sperm whales are especially impacted by driftnets in the Mediterranean waters. A study of stranded animals found on Italian coasts (Nortarbartolo de Sciara, 1989, cited in Aguilar *et al*., 1991) attributed the death of 24 sperm whales and 126 other cetaceans between 1986–1989 to driftnets. 20 sperm whales had been recorded caught by Italian driftnet boats between 1978 and 1982 (Di Natale and Mangano, 1983), leading the authors to state that “the incidence of human activities on the mortality of the sperm whale in the Italian seas is very high”. The high incidence of sperm whales stranded on the Spanish Iberian and Balearic coasts showing signs of entanglement in Italian driftnets (12 individuals from May 1993 to June 1994, most of them calves, of which only 3 could be released alive; University of Barcelona, 1995) suggests that this problem applies wherever driftnet fleets operate.

The Italian driftnet fleets although important, are not the only ones operating in the Mediterranean, as described in some detail in section 2.4 of this report. Cetacean species regularly caught by the large-scale Moroccan driftnet fleet in Mediterranean waters include common dolphin, striped dolphin, bottelnose dolphin, pilot whale, sperm whale, fin whale and minke whale, though the first two dolphin species are by far the most impacted ones (Tudela *et al*., in press). Annual bycath estimates by this fleet amount to 3 647 dolphins (50% of *D. delphis* and 50% of *S. coeruleoalba*) in the Alboran Sea and further 13 358 in the Straits of Gibraltar and adjacent Atlantic waters (Tudela *et al*., in press). These latter authors reported that only four boats captured a total 237 dolphins (both common and striped) during a eight-month period. Estimated catch rates for this Moroccan fleet are 0.64 individuals (both dolphin species combined) per fishing operation (worth 0.06 dolphins per km of net set). Take rates for striped dolphin and common dolphin were estimated at 10.2% and 12.3% of the respective population sizes in the Alboran Sea, which pointed to the extreme threat to their populations (take rates above 1–2% are considered unsustainable for small-cetacean populations). This study completed the one carried out by Silvani, Gazo and Aguilar (1999) on the Spanish driftnet fleet operating until 1994 in Alboran Sea waters. The Spanish fleet was composed that year by 27 boats. Mortality for the two species combined was estimated at 366 individuals in 1993 and 289 in 1994, with approximately equal numbers for each species. Almost all were already dead when brought on board. The resulting bycatch rate of dolphins was 0.1 individuals per km of net set per fishing operation. Most of the common dolphins caught were extremely young calves and the majority of striped dolphins were juveniles; less experienced younger animals are more likely to get entangled in driftnets than adults.

Driftnets also entail cetacean bycatch along the Turkish coast of the Aegean Sea (Akyol *et al*., 2003; Öztürk, Öztürk and Dede, 2001). Species affected include striped dolphin, Risso’s dolphin and bottelnose dolphin.

Current mortality levels of striped dolphins in the Mediterranean have been considered potentially unsustainable by the International Whaling Commission (IWC, 1994). Incidental catches of common dolphins in the Alboran Sea and Strait of Gibraltar may have caused a significant decline in numbers (Forcada and Hammond, 1998). On the hand, the peculiar head shape of the sperm whale seems to make this species especially prone to entanglement in driftnets. The recorded or estimated rates of incidental catches are of special concern given its small Mediterranean population (probably a few hundred individuals).

2.5.4 Purse seines

Fishing for bluefin tuna by local purse seine fleets in Mediterranean waters doesn't, as a general rule, involve the practice of setting nets around cetaceans, in contrast to the well-known case of the yellowfin purse seine fishery in the eastern tropical Pacific Ocean (Donahue and Edwards, 1996). Subsequently, the information available for the Mediterranean seems to confirm that dolphins are not being massively caught in purse seine operations directed at tuna. Interviews with fishermen in the small Spanish tuna fleet in the Mediterranean, suggest very few dolphin catches (estimated at six individuals each year, all of them being released alive; University of Barcelona, 1995). Fishermen from other fleets in the area, on the contrary, claim that dolphin catches by this tuna purse seine fleet are very important. Some reports point to occasional catches in other Mediterranean regions. Di Natale (1983a) reported the capture of 21 striped dolphins in two separate incidents in the Ligurian Sea involving tuna purse seine nets. Magnaghi and Podesta (1987) reported another incidental capture of eight striped dolphins in the same area, off San Remo in the Ligurian Sea. Tuna purse seiners have also been reported to catch pilot whales and other Delphinidae sporadically (Di Natale, 1990).

The activity of the more widespread purse seine fleets targeting small pelagic fish in the Mediterranean does not seem to lead to the high dolphin mortalities caused by driftnets (Silvani, Raich and Aguilar, 1992; Di Natale, 1990), although Aguilar *et al*. (1991) described frequent accidental bycatches of common and stripped dolphins by purse seiners off the coasts of southern Spain, southern Italy and northern Africa. The Spanish purse seine fleet targeting small pelagic species (sardine and anchovy) in the Alboran Sea appears to be especially impacting on dolphin populations: a field study conducted under an EU-funded project yielded a related estimated mortality of about 300 dolphins annually, the majority of them common dolphins (University of Barcelona, 1995). This Spanish purse-seine fleet, however, may catch as many as 5 700 individuals annually, though the majority of them are released alive. This dolphin bycatch is exceptionally high in the context of Spanish purse seine fleets in the Mediterranean, an exception that has been explained by the disappearance or strong regression of common dolphins, the most abundant small cetacean in inshore waters, along the rest of the Spanish Mediterranean coast. Striped dolphin, much less abundant than common dolphin in shelf waters, are less likely to interact with coastal fisheries, though estimations indicate that a further 100 striped dolphins might perish annually in the Spanish purse seine fishery in Catalonia and the Gulf of Lions (University of Barcelona, 1995).

2.5.5 Other gears

A five-year field survey in Italian waters around the Pontino Campano archipelago (Southern Tyrrhenian Sea) revealed that local cetacean populations interacted with several gears for trophic purposes (Mussi *et al*., 1998). Striped dolphins, Risso's dolphins, long-finned pilot whales and sperm whales were observed taking advantage of the squid fishery using illuminated handlines, by preying on the squids attracted by the lights. Striped and bottlenose dolphins also fed opportunistically around and in trawlnets, especially at the end of the haul. Bottlenose dolphins were also observed feeding on the bottom gillnets set by artisanal fishermen around the islands of Ventonene and Ischia, and inflicted large rips on them. Catalan fishermen report dolphins feeding around trawlnets and preying on fish caught in trammel nets.

Reports on incidental captures point to the entanglement of sperm whales, Risso’s dolphins, common dolphins and bottlenose dolphins in artisanal fixed nets (gillnets and trammel nets) (Di Natale and Mangano, 1983; Di Natale, 1983bc; Duguy *et al*., 1983b). Duguy *et al*. (1983b) refer to striped, common and bottlenose dolphins and a few fin whales incidentally caught by trawlers off France and Italy, and to striped dolphin, false killer whale (*Pseudorca crassidens*), Risso’s dolphin, and fin and sperm whale killed by surface longlines in Italian and Spanish waters. More recently, Mussi *et al*. (1998) referred to the case of another sperm whale found entangled in a surface longline in southern Tyrrhenian waters. The Spanish surface longline fleet operating in the Mediterranean is estimated to entangle between 12 to 32 cetaceans a year, mostly common and striped dolphins and pilot whales. With an estimated mortality rate of 10%, one to three individuals would be killed yearly (University of Barcelona, 1995). Other less common gears might also involve the incidental capture of cetaceans, as shown by the sporadic records of killer whales entering tuna traps and then being killed by fishermen off southern Spain (University of Barcelona, 1995). Di Natale and Mangano (1983) also reported the killing by explosives of a sperm whale in Italian waters.

2.5.6 Other fishing-related interactions

Human consumption of dolphin meat in the Mediterranean (as in some Italian and Spanish localities; Aguilar *et al*., 1991) has been recorded, though it is far from being common or usual. Conversely, the deliberate killing of cetaceans, mostly dolphins, appears to be closely related to fisheries in one way or another. Dolphins, especially the bottelnose dolphin, are considered as a pest by artisanal fishermen in many parts of the Mediterranean and blamed for the destruction of nets (gillnets or trammel nets) when preying on trapped fish. Aguilar *et al*. (1991) confirm that bottlenose dolphins often destroy trammel nets; Greek, Turkish (Cilician Basin) and Balearic small-scale fishermen are annoyed by the the costs associated with damage to gear caused by dolphins (Northridge and Pillery, 1985; Yediler and Gücü, 1997; M. Gazo, pers. comm.). The only significant conflict involving small-scale fisheries and dolphins along the entire Spanish Mediterranean coast is in the Balearic Islands, home to the largest bottlenose dolphin population in the region: important damage to trammel nets and gillnets has been reported. An estimated 30 bottlenose dolphins die every year, most of them deliberately killed by Balearic fishermen (though a few deaths result from incidental entanglements), a rate that may not be sustainable given the reduced population there (estimated at only a few hundred) (University of Barcelona, 1995). Fishermen have also killed large number of cetaceans in Malta (Aguilar *et al*., 1991) and there are records of dolphins stranded in Italy showing signs of having been killed by fishermen (Anonymous, 1987). Duguy *et al*. (1983b) reported that shooting was one of the main causes of common and bottlenose dolphin mortality in French waters, the latter being the most conflictive species.

The use of dolphin meat as a bait for fishing gears, for example in the Andalusian ports of Garrucha and Algeciras, in the Alboran Sea (Aguilar *et al*., 1991; University of Barcelona, 1995) is yet another fishing-related interaction that contributes to cetacean mortality. Dolphin meat appears to be particularly suitable for shrimp fishing with traps. An estimated 180–260 dolphins (common and striped) are killed illegally every year for this purpose (University of Barcelona, 1995).

Dynamite fishing, quite a common illegal practice in some places, inhibits the normal feeding behaviour of the bottlenose dolphin in Lebanese waters (Evans, 1987). The use of dynamite in purse seine fishing (to push small pelagic shoals upwards) is currently practised off Algeria (A. Nouar, pers. comm.) and probably in many other waters.

2.5.7 Conclusions

The information available describes a wide variety of interactions between cetacean populations and fishing fleets in the Mediterranean, involving almost every kind of major fishing gears commonly in use. However, driftnet fisheries and, to a much lesser extent, small-scale fisheries using fixed nets and purse seine fisheries appear to account for the highest impact and are also responsible for the highest rates of direct human-induced marine mammal mortality.

Driftnet fisheries are clearly inherently harmful to cetacean populations, and a major factor of direct mortality in Mediterranean waters. As described in detail in section 2.4, an important international fleet still operates in the Mediterranean, although current provisions issued by ICCAT (Recommendation 03–04) and the European Union oblige to the complete eradication of this fishing practice. Compliance with legislation in force must lead to the disappearance of driftnet fleets from the Mediterranean in the shortest possible time frame. This is especially urgent in the Alboran Sea, where the very high bycatch entailed by the Moroccan driftnet fleet poses a high threat on the survival of the last remaining healthy population of common dolphin in the whole Mediterranean. This is especially urgent after the listing of the Mediterranean population of this species as Endangered in IUCN Red List. Striped dolphin bycatches by Italian driftnets in Balearic waters, where the population appears to be low, are also a matter of concern, as is the current fishing-induced sperm whale mortality rate; this species particularly would benefit greatly from the elimination of driftnet fishing.

Fishermen in small-scale fisheries need to be encouraged and motivated not to kill dolphins. A project to prevent dolphin predation from nets is on-going in Balearic waters, with the support of the Balearic government and fishermen associations. Overfishing here may increase the dolphin pressure on fishing nets as happens with the monk seal in Greek and Turkish waters. More systemic approaches focussed on the rebuilding of degraded ecosystems could benefit both fishermen and cetacean populations directly. Among other management measures, the effective enforcement of dynamite fishing banning, once more, appears to be necessary for the conservation of cetaceans (mostly dolphins) in some Mediterranean areas. Solutions to local conflicts, such as the putting an end to the illegal use of dolphin meat as bait in two Spanish ports, need immediate attention.

Adequate monitoring of the fleets in the recent rapidly growing Mediterranean tuna purse seine fishery is advisable to ensure that their activity doesn't unduly affect dolphin populations. The most important fleets, such as the French one, responsible for massive tuna catches need watching most closely. The results of inquiries in the Spanish ports referred to above suggest that monitoring the activity of other Mediterranean purse seine fleets targeting small pelagic fish, especially in areas with important common dolphin populations, the species potentially more vulnerable to this fishery, (i.e. those operating in North African coasts) is necessary. The University of Barcelona (1995) has also pointed out that the potential impact of mid-water pelagic trawling for small pelagics on cetacean populations by a French fleet in the Gulf of Lions and in other Mediterranean areas (i.e. Italy) should be assessed.

It is arguable whether the lack of significant interactions between cetaceans and fisheries in some Mediterranean regions is due to the very reduced populations there, or to low-impact fishing practices. Purse seine fleets have been reported as having a significant impact on the common dolphin in the western Mediterranean only in the Alboran Sea where the biggest population lives. Conflicts between artisanal fisheries and bottlenose dolphins are also limited to areas with the highest populations of the species such as the Balearic waters. Conservation policies focusing on the recovery of cetacean populations should probably take into account the potential fishing interactions that might eventually emerge, thus simultaneously tackling the issue of responsible fisheries. Educational programmes for fishermen, focusing on building awareness of cetacean conservation and providing them with basic guidelines on how to reduce both cetacean bycatches and mortality are essential.

2.6 The impact of fishing on seagrass beds

2.6.1 Introduction

Mediterranean seagrass beds are mostly constituted by the endemic angiosperm species *Posidonia oceanica*. This species inhabits large areas of coastal seabed down to depths of 40 m in optimal conditions and covers a total surface of about 20 000 square nautical miles, that is, 2% of the surface area of the littoral sea (Ardizzone *et al*., 2000; Bethoux and Copin-Montegut, 1986). Seagrass beds are spatially complex and biologically productive ecosystems that provide habitats and food resources for a diversified fish fauna and act as an important nursery area for many species (Harmelin-Vivien, 1982). Red mullets (*Mullus* spp.) are among the commercial species recruited in seagrasses, and are most abundant in summer and autumn, depending on the species (Jiménez *et al*., 1997). Meadows regress significantly for two main reasons, anthropic changes in sediment structure and composition, and the direct mechanical impact of fishing (Ardizzone *et al*., 2000). Bottom trawling has the most dramatic consequences on *Posidonia*, though other fishing practices such as dynamite fishing may also be destructive at a more local level.

International concern about the conservation of this particular habitat led to the banning of trawling on seagrasses in EC waters (Regulation No 1626/94), and the listing and designation of *Posidonia* beds in Annex 1 of the EC Habitats Directive as special conservation areas.

2.6.2 Overview

Trawling impacts on seagrass beds by both suspending sediments and directly damages vegetal mass. Sediment suspension affects macrophyte photosynthesis by decreasing light intensity. This is believed to have contributed to the disappearance of sea-grass meadows, and to affect fish recruitment and the quality of juvenile feeding areas in the Mediterranean Spanish coast (Sánchez-Jerez and Ramos-Espla, 1996).

The quantification of the short-term impact of otter trawling on *Posidonia* beds has been extensively studied only in Murcia (southeastern Spain), home to an important trawling fleet (Martín, Sánchez-Lizaso and Esplá, 1997; Jiménez *et al*., 1997; Ramos Espla *et al*., 1997). Trawling is the main agent causing the degradation of deep seagrasses off this part of Spain, where up to 40% of the total *Posidonia* surface is highly damaged (Sánchez Lizaso, Guillén Nieto and Ramos Esplá, 1990).

There, comparison of the structure of a *Posidonia* bed in a non-trawled area to that of a heavily fished one shows profound changes in the latter, where the surface area occupied by dead shoots was much higher than in the undisturbed seagrass 85.2% and 5.9% respectively. Experimental trawling hauls show that a medium-size typical trawler would root out an estimated 99 200 and 363 300 *Posidonia* shoots per hour in the disturbed and undisturbed areas respectively. The mechanical impact of the gear was higher in the most degraded area, otter doors causing a continuous furrow on the bed because of the loss of complexity and consistency of the bottom. The relative effect of the gear thus in turn depends on the state of conservation of the grass. Whereas otter doors were responsible for rooting out 93% of *Posidonia* shoots in the healthiest seagrass, their contribution was limited to only 51% in the damaged area because the meadow there was also vulnerable to other parts of the gear. Differences in fish assemblages inhabiting healthy and disturbed *Posidonia* beds have been recorded and point to major changes in the structure of demersal communities caused by otter trawling. Whilst ichthyofauna typical of deeper detritic bottoms (*Pagellus erythrinus*, Triglidae, etc.) or of sandy or muddy-sandy bottoms (*Lithognathus mormyrus*, *Blenius ocellaris*, etc.) are found in the degraded seagrass, they seldom occur in a well-preserved *Posidonia* bed. The contrary applies to some typical species inhabiting seagrasses (*Labrus merula*, *Symphodus rostratus*, etc.) or hard bottoms (*Muraena helena*, *Chromis chromis*). The effects of trawling on the megabenthos in *Posidonia* beds are also very evident. These included the reduction or elimination of species typical of hard bottoms and their replacement by ubiquitous species and others typical of sandy/muddy bottoms, as a result of the sediments being enriched with finer particles. Other effects were the increased numbers of active filter feeders and sedimentivorous species, such as solitary ascidians (*Microcosmus* spp.) and holothurians, perhaps because of the raised concentration of organic matter in the water and sediment. The higher catch of macrobenthos in disturbed seagrasses could also reflect an increase in the vulnerability of benthos to trawling in the latter habitats.

The negative effects of trawling on seagrasses have been confirmed by studies in other parts of the Mediterranean. Ardizzone *et al*. (2000) concluded that degradation of *Posidonia* beds in the Middle Tyrrhenian Sea, on the Italian coast, was caused by both increased water turbidity due to anthropic causes and bottom trawling, the latter affecting non-rocky, trawlable bottoms. Seagrass beds in southern Tunisian waters are trawled for penaeid shrimps, whose early life stages are associated with this habitat (Caddy, 2000).

Dynamite fishing still occurs in some Mediterranean waters and is not good news for seagrass beds. Although strictly prohibited in Algeria, it is practised close to the shore at shallow depths (0–10 m) (A. Nouar, pers. comm.). Poacher fishermen target salema (*Sarpa salpa*) shoals and cause extensive damage to rocky bottoms and coastal seagrass beds.

The negative physical impact of the above reported fishing practices aside, the fishing of seagrass communities significantly affects trophic webs and, therefore, ecosystem structure and function. Comparison between fished and protected *Posidonia* beds in France and Italy, indeed, pointed to a decrease in top predators, mainly Scorpaenidae and Serranidae feeding on fish and large crustaceans, and to a parallel increase in mesocarnivores (Labridae), probably because of the lower predation pressure of the former, more susceptible to fishing (Harmelin-Vivien, 2000). The decrease in the mean weight, density and biomass of fish in the exploited seagrass, as well as the higher indices of animal diversity found in the reserves have been reported in several studies (Buia *et al*., 1999; Harmelin-Vivien, 2000; Francour, 1999).

2.6.3 Conclusions

Many of the studies referred to above found a direct relationship between the health of the seagrass ecosystem and the level of effective protection. Most of them also point to its important ecological function and its vulnerability to physical damage and the fishing mortality associated with human exploitation. Seagrasses must therefore be protected from bottom trawling and other destructive practices, and fishing pressure reduced as much as possible; current regulations banning trawling on *Posidonia* beds in most Mediterranean coastal areas need to be enforced and greater areas of seagrasses included in marine protected areas totally closed to fishing. Campaigns to build awareness together with effective monitoring and surveillance are other useful tools. Additional technical measures such as the deployment of artificial reefs (if justified) could offer further protection.

2.7 The impact of fishing on the seabed (soft and hard bottoms) and its associated benthic communities

2.7.1 Introduction

Seagrasses are exceptional seabed bottoms. The vast majority of Mediterranean seabed surfaces lack such a massive vegetal cover and are muddy, sandy or, in some places, rocky. These apparently modest habitats, far from being lifeless, are inhabited by complex biological communities, often part of fragile ecosystems. Current fishing practices, notably trawling on seabed sediments, profoundly disturb the physical support system and undermine the structure and functioning of the benthic ecosystem.

2.7.2 Overview

Soft and hard bottom habitats are fished differently, the effects of fishing on them are different and the information available distinguishes between them: they are therefore described separately below.

2.7.3 Soft bottoms

Heavy fishing disturbs muddy and sandy bottoms, causing dramatic changes in the structure of both the physical support system and the related biological assemblages. As synthesised by Pranovi *et al*. (2000), “trawls and dredges scrape or plough the seabed, resuspend sediment, change grain size and sediment texture, destroy bedforms, and remove or scatter non-target species”. To these effects can be added the increase in the amount of suspended nutrients and organic matter (Jones, 1992). Highly impacting bottom fishing (trawling, dredging,…) mainly affects shelf areas. In the Mediterranean basin deep trawling fisheries targeting Norway lobster or red shrimps also affects slope muddy bottoms. In general, muddy sediments, which form in high depositional areas with low external disturbance, are much more sensitive to trawling disturbance than more dynamic coarser sediments; trawl doors penetrate them more deeply than other sediments, with potentially greater effects on infaunal species (Ball, Munday and Tuck, 2000).

An Italian fleet with hydraulic dredges, otter and "rapido" trawls (Ardizzone, 1994) exploits a large trawlable shelf area in the northwestern Adriatic. The latter gear is similar to the beam trawl, and is used in the Adriatic for fishing scallops in sandy offshore areas and flatfish in muddy inshore areas, though it also catches small fish (Pranovi *et al*., 2000; Giovanardi, Pranovi and Franceschini, 1998). The study carried out by Pranovi *et al*. (2000) on the short-term impact of this gear on the sea bottom revealed that it causes extensive damage, digging and furrowing the sediment to a depth of 6 cm. Negative effects on the structure of the macrobenthos community were recorded: these included the increase in the abundance and biomass of taxa a week after the perturbation because of the increase in the trophic availability benefiting a few oportunistic scavenger species. Commercial exploitation appears to result in cumulative disturbance as evidenced by the higher biomass of scavenger Crustacea and Echinodermata at the expense of Porifera, Mollusca and Annelida. Commercial fishing may therefore be selecting epibenthic species most able to cope with physical disturbance by gear and endure the discard process. Experimental studies seem to conclude that "rapido" trawling causes greater short-term disturbance on macrobenthos in muddy areas than in sandy bottoms, although short-lived fauna associated with the former recovers quite rapidly (within two weeks) (Pranovi, Giovanardi and Franceschini, 1998).

Bottom fishing has deeply affected some Mediterranean invertebrate species, the endemic sponge *Axinella cannabina* or the bryozoan *Hornera lichenoides* (De Ambrosio, 1998). Otter trawling fisheries on muddy bottoms targeting shrimp *Parapenaeus longirostris* in Algeria destroy the benthic communitiy associated with the seapen (*Funiculina quadrangularis*, Anthozoa) (A. Nouar, pers. comm.). The hydraulic dredge (known in Italian as "cannellara"), which ploughs sediment to a depth of 20–30 cm is particularly destructive (Relini, Bertrand and Zamboni, 1999). This fishing practice is especially common in the Adriatic Sea (50 boats in Monfalcone, Venice and Chioggia) and takes shelled molluscs such as the sword razor shell (*Ensis minor*), smooth callista (*Callista chione*), the striped venus (*Chamelea gallina*) and the golden carpet shell (*Paphia aurea*). The use of hydraulic dredges to catch warty venus (*Venus verrucosa*), a species inhabiting detritic, conchiferous or sandy bottoms and *Posidonia* beds, was banned in Italy in 1992 because of the extensive damage it inflicted. In the southwestern Adriatic, the smooth scallop (*Chlamys glabra*) fishery operating on coastal detritic bottoms inside the Gulf of Manfredonia makes big discards, 395 kg from only an hour's dredging, principally of green sea urchins (*Psammechinus microtuberculatus*), molluscs and crustaceans (Vaccarella *et al*., 1998).

Deep slope fisheries targeting high value crustacean species operate out of Spain, Italy, Algeria and Tunisia, fishing down to a depth of 1 000 m depth in the northwestern Mediterranean red shrimp (*Aristeus antennatus* and *Aristeomorpha foliacea*) fishery. Although there is no information on the effects of deep sea trawling on muddy bottoms in the Mediterranean (or anywhere else in the world), the few authors touching on the subject warn of the extreme vulnerability of such sea beds to physical perturbations. It appears that recovery rates are much slower and the impacts of trawling may be very long lasting (many years or even decades) in deep water, where the fauna is less adaptable to changes in sediment regimes and external disturbances (Jones, 1992; Ball, Munday and Tuck, 2000). Otter trawling in red shrimp grounds is injurious to the *Isidella elongata* facies of the bathyal mud biocenosis. This octocorallian species is very much affected by fishing (A. Nouar, pers. comm.; Sardà, 1997).

The ecosystem effects related to the use of bottom gears may extend far beyond the direct, straightforward impacts discussed above. Eutrophic processes may be enhanced leading to hypoxia in sensitive soft bottom areas (as in the northern Adriatic) and the quantity of hydrogen sulphide released from sediments may increase (Caddy, 2000). The anthropic re-suspension of sediment enriched in organic matter can eliminate macrophyte, benthos and demersal fish approaching their hypoxia tolerance limit; the changed ecosystem structure favours species adapted or tolerant to hypoxic conditions. Trawling and dredging can also play a role affecting the intensity and duration of naturally occurring seasonal hypoxic crises in some places. These fishing practices, carried out in hypoxic conditions in the Adriatic, can exacerbate the summer killings of young shellfish. Trawling can also remove large-bodied, long-lived macrobenthic species and subsequenty reduce the bioturbation zone (Ball, Munday and Tuck, 2000). This could increase the danger of eutrophication and result in longer recovery rates (Rumohr, Bonsdorff and Pearson, 1996). On the other hand, studies carried out on muddy seabeds off the Catalan coast (northwestern Mediterranean) showed that otter trawling operations produce short-term changes in the biomass of taxa within the trawled area. Some pointed to simple depletion caused by the gear catch (i.e. the cases of *Scyliorhinnus canicula* and *Merluccius merluccius*) and others to the concentration of scavenging species (i.e. *Arnoglossus laterna*, *Cepola rubescens*, *Squilla mantis*, *Liocarcinus depurator*) attracted by an increased food supply as a result of the mechanical killing of benthic fauna (Demestre, Sánchez and Kaiser, 2000). This typical of scavenger response lasted only about four days. These results suggest that fishing disturbance may cause shifts in the benthic community structure that particularly affect mobile scavenging species, probably the most food-limited group in muddy seabed environments.

2.7.4 Hard bottoms

There is little information on the impact of anthropogenic disturbance on Mediterranean sub-tidal hard bottoms. These systems are characterised by high habitat complexity and, consequently, high biodiversity indices. Fraschetti *et al*. (1999) conducted a field survey off the Apulian coast (southeastern Italy), an area with a large rocky surface, aiming at correlating spatial biodiversity with damage derived from date mussel (*Lithofaga lithophaga*) fisheries, based on the demolition of substrates by commercial divers. Signs of damage, a high degree of desertification, were detected in all zones; the high spatial heterogeneity shown by natural communities was taken as a potential symptom of stress, and related to intensive date mussel harvesting practices. Desertification of long stretches of rocky shores is caused by destruction of habitats and the associated communities, combined with grazing by sea urchins (Fanelli *et al*., 1994). Other destructive fishing practices are also locally important in some areas. Illegal dynamite fishing along the entire Algerian coast affects rocky bottoms down to a depth of 10 m (A. Nouar, pers. comm.).

The St Andrew Cross, an iron bar hung with chains, used for harvesting coral (*Corallium rubrum*) is a well-known and highly destructive gear deployed on Mediterranean rocky bottoms. Since being banned in EU waters in 1994 (Council Regulation No 1626/94), it has been abandoned in many places in favour of divers who cause more localised impact on rock epifauna (Caddy, 2000). Standard otter trawling also harms rocky bottoms thanks to special rolling devices that prevent the gear from being damaged. This happens off northwestern Spain in rocky fishing grounds rich in sparid fish, is spite of being legally banned.

2.7.5 Conclusions

The impact of fishing on the seabed concerns mostly the use of bottom trawling gears, namely otter trawls, beam trawls and dredges, together with some aggressive practices affecting rocky bottoms such as dynamite fishing and fishing for coral and date mussels. Although it is clear that the latter should be minimized, given the documented damage they cause to seabed bottoms and benthic communities, an ecosystem-based management of the former is difficult since their harmful effects are inherent in their use. The creation of networks of marine reserves totally closed to bottom trawling could help to rebuild degraded benthic communities in adjacent fished areas in the future. Seasonal rotation of fishing grounds through establishing temporal closures could benefit bottoms too since the likelihood of permanent change in bottom communities is proportional to the frequency of gear disturbance, as pointed out by Jones (1992). Ecosystem changes, in any case, should be avoided and the effect of fishing on bottoms and associated communities should be strictly monitored. Bottom trawling in eutrophic areas, prone to anoxia, is a matter of special concern: fishing practices should be significantly limited, at least in the most critical areas and/or seasons. The ecosystem effects of trawling on deep muddy bottoms, i.e. in red shrimp or Norway lobster fisheries, also deserves special attention given the high vulnerability of deep muddy bottom communities to external perturbations.

3. GEARS AND FLEETS OF SPECIAL INTEREST WITH RESPECT TO FISHING IMPACTS IN MEDITERRANEAN WATERS

3.1 The ecosystem impact of bottom trawling

3.1.1 Introduction

Bottom trawling fleets predominate in many Mediterranean fisheries, being responsible for a high share of total catches and, in many cases, yielding the highest earnings among all the fishing sub-sectors. The high profitability of this fishing practice is largely due to its low selectivity with respect to sizes and species caught, and to the high harvests generated. Trawlers have dramatic effects on the ecosystem including physical damage to the seabed and the degradation of associated communities, the overfishing of demersal resources, and the changes in the structure and functioning of marine ecosystems derived from the depletion of populations and the huge amount of bycatches and associated discards.

3.1.2 Overview

Whilst the problems related to the impact of bottom trawling on *Posidonia* beds and soft bottoms have been dealt with elsewhere in this report, the present section focuses on the ecosystem effects of trawling derived from its low selectivity and the issues relating to the capture of undersized individuals and discarding. Bycatches (and subsequent discards) of particularly vulnerable species or groups are covered in other parts of this report, as are the effects of trawl discards on marine seabird populations. The ecosystem effects of discards reported below refer to demersal communities.

3.1.3 Size selectivity on commercial species

Bottom trawling fisheries in the Mediterranean are essentially multispecies. Monospecific fisheries are very rare and are largely limited to deep shrimp fisheries on muddy slope bottoms. The high marketability of small fish in many countries encourages the targeting of the juvenile fraction of some species, often in violation of laws regarding minimum sizes. Demersal populations are consequently overfished, shallow areas (within the three-mile coastal limit or on bottoms less than 50 m deep, depending on the country) are illegally trawled and small, illegal mesh sizes are used. Examples are widespread throughout the Mediterranean and are not detailed here since they mostly concern recurring issues related to classical fisheries management. The well-known massive seasonal harvest of undersized red mullet, which are caught on shallow grounds when they settle, is though worth mentioning. The paradigmatic case of the hake fishery using bottom longlines and otter trawling gears in the Gulf of Lions also deserves highlighting. Data from the late 1980s clearly showed that the trawling fishery exploited the juvenile fraction of the population since the mean size of catches was only 17.9 cm, which strongly contrasted with the 48.2 cm corresponding to longline catches (Lleonart, 1990).

3.1.4 Quantification of discarding in Mediterranean bottom trawl fisheries

Information on discards in Mediterranean trawl fisheries confirm the magnitude of the problem, though they vary considerably in amount and composition depending on region, boat size, season, bottom type and depth of the exploited ground. The first regional study addressing the magnitude of discards in the western Mediterranean involved the monitoring of fishing fleets in seven ports (six Spanish and one Italian). Combined data gave discard estimations ranging from 23–67% of total catch in bottoms less than 150 m deep, 13–62% in bottoms 150 to 350 m deep and 14–43% in slope bottoms deeper than 350 m (Carbonell, 1997; Carbonell, Martin and de Ranieri, 1998). Data from a single locality, the Catalan port of Vilanova i la Geltru (north-west Mediterranean), illustrate this high quantitative variability. Monitoring of the fleet there revealed that the annual average of discards ranged between 13% and 39% of the total catch for small boats (< 150 hp) and between 17% and 48% for larger boats (> 150 hp), depending on the depths exploited. The amount discarded, however, peaked at 75.4% and 66.6%, respectively, in the case of larger boats operating in spring and smaller ones operating in the summer on shelf bottoms (< 150-m depth).

Similar high discard levels have been reported for other Mediterranean trawl fisheries. Total annual discards in Sicily during the 1980s were estimated at around 70 000 t, accounting for an average of 44–72% of catches (Charbonnier, 1990). The monitoring of fleets operating in three major Greek fishing grounds (Ionian Sea, Cyclades Islands and Thracian Sea) during 1988–1997 yielded discard estimations of 40%, 55% and 25% of the total catch of fish, crustaceans and cephalopods, respectively (Machias *et al*., 1999). Field studies carried out in 1995 showed that the fraction discarded by the trawl fleet operating in the Cyclades area, in the Aegean Sea, amounted to 59% of the total catch in bottoms less than 150 m deep, 63% in bottoms 150–200 m deep, and 37% in grounds deeper than 300 m (Vassilopoulou and Papaconstantinou, 1998). On the whole, discards in the Hellenic commercial trawl fishery are estimated to account for 45% of total catch (Stergiou *et al*., 1998). The “rapido” beam trawler fleet (56 units) based in Chioggia in the Adriatic Sea produces qualitatively heterogeneous discards depending on the species target. Whilst pectinid fishing involves the exploitation of sandy bottoms offshore and discards consist of echinoderms (32% in weight), crustaceans (26%), molluscs (23%) and porifers (15%), flatfish fishing is carried out on muddy coastal areas, where molluscs and crustaceans account for the bulk of discards (60% and 30%, respectively).

High discard levels are also common in the case of Mediterranean deep sea trawling fisheries. Discards by the trawling fleet operating on the upper slope (230–611 m) off Alacant (south-east Spain) have been estimated at 34.6% of the total catch (Soriano and Sánchez-Lizaso, 2000). The low selectivity of trawling is highlighted by data from this fishery showing that up to 95 species are taken; only 12 of these account for nearly 89% of the total, and 89 of them are discarded. The analysis of discards in the Norway lobster (*Nephrops norvegicus*) and red shimp (*Aristeus antennatus*) fisheries at 280–720 m in the Balearic Islands (western Mediterranean), estimated at an average of 42% of the total catch, led the authors to conclude that “an important fraction of the catch of the two deep-sea decapod crustacean fisheries of the Western Mediterranean is discarded” (Moranta, Massutí and Morales-Nin, 2000). Longer tows, to compensate for the reduced biomass, seem to result in lower selectivity by the mesh and higher discard rates.

Discarding can also involve important commercial species, especially smallest size classes. Discards of commercial species in Greek waters are reported to range from 0% for red mullet (*Mullus surmuletus*) to 10% for hake (*Merluccius merluccius*) and shrimp *Parapenaeus longirostris* (Machias *et al*., 1999). The bulk of discards (66%) in the Balearic deep sea crustacean fisheries at a depth of 300 m referred to above correspond to undersized marketable species. The study of hake discards (*Merluccius merluccius*), forkbeard (*Phycis blenoides*) and poor cod (*Trisopterus minutus capelanus*) in the trawl fishery of the northern Tyrrhenian Sea revealed that they can reach high levels, depending on the species, the season and the depth exploited (Sartor *et al*., 1999). Maximum estimates of discards were 34.1% of total catch (in weight) for hake, 41% for forkbeard and 39% for poor cod, whereas total annual mean discards in the traditional trawl fishery amounted to 39%, 65% and 57% respectively in numbers of individuals. All individuals under 10 cm are discarded in all three species.

Although a proportion of discards in Mediterranean trawling fisheries may survive, few helpful data on which to base quantitative estimates exist. Observations derived from experiments on aquaria carried out on board point to the low mortality of crustaceans caught as a bycatch in Catalan trawl fisheries, whereas survival rates of fish are highly heterogeneous and vary strongly according to the species (i.e. 0% for *Trachurus* spp. and 100% in *Scyliorhinus canicula*) (Sánchez, 2000). Another study of bycatch survival in the “rapido” fleet operating in the northern Adriatic showed low mortality in all taxa examined during the three to four hours following capture (Pranovi *et al*., 1999).

3.1.5 Impact of discards on demersal ecosystems

The impact of discards goes far beyond single-species demographic effects, since discarded biomass can alter ecosystem structure by favouring scavengers (Moranta, Massutí and Morales-Nin, 2000). The consequences of the fishing-driven increase in food supply stemming from have seldom been addressed by specific studies.

The only work dealing with this issue in the Mediterranean is based on photographic surveys carried out off the Catalan coast in the northwestern Mediterranean, and focuses on the estimation of the consumption rate of fishery discards by scavengers (Bozzano and Sardà, 2002). The study used a baited camera, which was set on the sea floor at a depth of 100 and 300 m in two areas subjected to trawling with continual discards. Eight fish and nine crustacean species were recorded feeding on the baits, and the benthic snake eel *Ophichthus rufus* was the main scavenger species, followed by isopods (i.e. *Cyrolana borealis*) and amphipods (i.e. *Schopelocheirus hopei*). Sporadic scavenging behaviour was even reported for common fish species such as *Spicara* spp. and *Trachurus* spp. Discarded material seems to enter demersal food webs quite quickly, as suggested by the high consumption rates recorded. In all cases baits were fully consumed within 24 hours, and consumption rates reached maximum levels in deep bottoms at night. The authors concluded that the prevalence of *O. rufus* indicated an environment dominated by a monospecific scavenger guild, whose competitors and predators have probably been eliminated by fishing activity. This conclusion is particularly interesting since it highlights the multiple effects of fishing on complex systems such are communities and ecosystems: fishing can favour a single species within the demersal ecosystem by both removing its competitors and independently increasing its food availability through discards.

3.1.6 Conclusions

There is compelling evidence that discards by Mediterranean unselective trawling fleets are significant. The effect on marine communities is twofold: at a single-species level, the population dynamics of a species are altered, and at the ecosystem level profound changes occur because of the disruption of food webs. Ecosystem modifications are triggered by the change in the biomass and demographic structure of the different species as well as by the increasing food supply for scavenger and opportunistic species. It is worth noting that the latter can result in the trophic connection of separate sub-systems (i.e. pelagic and benthic), making ecosystem consequences even more dramatic.

Although bottom trawling is inherently rather unselective, bycatches and discards can be minimized. Trawling can be limited and technical measures can be introduced to improve selectivity. Trawl selectivity within an area depends on many factors, ranging from the depth exploited or the kind of bottom, to the season. Most impacting scenarios could be avoided by restricting trawling both spatially and temporally. In this context, current provisions banning trawling in coastal waters less than 50 m deep or three miles offshore should be enforced effectively. Trawling gears could be made more selective by using higher mesh sizes or incorporating special excluding devices, such as those based on rigid grids. The former solution may be difficult to apply in Mediterranean waters for social and political reasons, but the development and compulsory use of excluding devices increasing selectivity (such as those in use in some North Atlantic waters) deserve attention. Alternatively, the use of a square mesh can also improve selectivity. It is convenient to mention here that shorter trawling hauls are known to reduce discard rates (Stergiou *et al*., 1998, Moranta, Massutí and Morales-Nin, 2000).

Partial solutions and technical improvements notwithstanding, the banning of bottom trawling in large marine protected areas throughout the Mediterranean Basin appears to be the only way of maintaining a sample set of demersal ecosystems free of the damage caused by this widespread fishing practice. These areas would moreover be very useful as a basic reference guide to healthy bottom communities in the context of a future ecosystem-based management of Mediterranean fisheries.

3.2 The impact of longlining on large pelagic populations

3.2.1 Introduction

Pelagic longlining in Mediterranean waters inflicts considerable mortality on elasmobranchs, marine turtles and seabirds taken as bycatch or even (in the case of the former) target species. It is obvious, however, that large pelagics, the objective of this fishery, is the group most impacted by this gear. The main species targeted in the Mediterranean are swordfish (*Xiphias gladius*), bluefin tuna (*Thunnus thynnus*) and to a lesser extent, albacore (*Thunnus alalunga*). Bluefin tuna and swordfish are exceptional in the Mediterranean context for being the only species whose populations are subjected to an international TAC-based management regime. The overall issue of the sustainable management of their populations is beyond the scope of this report, and the discussion below focuses instead on the selectivity of surface longline fisheries operating in Mediterranean waters as it affects the immature, small-sized fraction of their dwindling populations and the degree of compliance with current international legislation.

3.2.2 Overview. Brief summary of the main fleets and fishing grounds

A variety of medium-scale and industrial pelagic longlining fleets operate in Mediterranean waters, ranging from local coastal state fleets to large industrial foreign fleets, whether Japanese, flag of convenience (FoC), or even unflagged "pirate" fleets. FoC and pirate fleets are estimated at about 100 units (GFCM, 1997). Surface longline gears, including those used by local Mediterranean fleets, are deployed in large areas since line lengths of 50–60 km (bearing several thousand hooks) are not rare. Longline fleets in quest of their highly migratory target fish species, even local ones, are highly mobile, covering virtually the whole Mediterranean basin. A significant share of catches is taken in international waters, more than 12 miles offshore.

The Spanish longline fleet operates from the Strait of Gibraltar (5ºW) to 7ºE near Sardinia, and from 42ºN to the Algerian coast (Camiñas and De la Serna, 1995). In the early 1990s a Spanish fleet of 30 longlines operated throughout the year in the southwestern Mediterranean. In the summer months, when the swordfish fishery peaks, the number of Spanish boats rose to 60–80. This local fishing effort was complemented by about 30 Japanese and 30 FoG longliners (Aguilar, Mas and Pastor, 1992). Overall, some 145 Spanish longliners target swordfish in Mediterranean waters and a further 100 artisanal boats operate in coastal waters during the summer. Seventy percent of total yearly effort in this fishery is concentrated in the summer and autumn. Bycatch, excluding turtles, accounts for 10% of total landings in weight (Camiñas and De la Serna, 1995).

Italian longlining fleets targeting swordfish and albacore are based mostly in Sicily, Puglia, Sardinia, Campania and Liguria, and comprise more than 1 500 boats operating mainly in the Gulf of Taranto, the south Adriatic and the Aegean Sea (Camiñas and De la Serna, 1995). About 27 longline units operated in 1997 in the vicinity of the Santuario dei Cetaceii, in the Western Central Ligurian Sea, where driftnets have been banned since 1992. These fleets, however, are able to reach much more distant grounds. In 1992, the Sicilian fleet operated from Crete and Cyprus in waters close to Egypt and the rest of the north African coast (Cavallaro and Luca, 1996). Italian longline fleets are also known to reach Iberian waters during the autumn. In the central southern Tyrrhenian Sea, swordfish have historically been fished with driftnets ("spadara") but an important longline fishery has recently been established at Mazzara del Vallo in the Strait of Sicily (Di Natale *et al*., 1996).

The Greek National Statistic Service includes longlining in the broad category of "coastal fisheries" and although no specific figures are available, it is estimated that the swordfish fishery accounts for more than 50% of the total professional fishing effort by Greek fleets in western Greece (Panou *et al*., 1999). A total of 47 longline boats were known to be based in the Ionian Islands and the Epirus coastal region alone in the mid-1980s. Camiñas and De la Serna (1995) gave a total figure of 400 boats from 70 ports being involved in the Greek swordfish fishery in 1991. The main fleets, concentrating 50% of total Greek production, are based in Kalymos (south-east Aegean) and Chania (Crete). Of the total annual catch, 70% is taken at the peak of the season, from May to September, in an area covering the Aegean Sea, the Ionian Sea and even the Levant Sea. About 180 vessels are involved in albacore fishing in the central and northern Adriatic.

3.2.3 Size selectivity of surface longlining regarding the target species

Seasonal differences in the size of swordfish caught by the Spanish longline fleet operating in the Mediterranean have been reported, suggesting that different age groups are targeted in different seasons (Camiñas and De la Serna, 1995). Smaller specimens are caught during the autumn months, when fishing is carried out in more coastal areas, peninsular and insular (for the Balearic Is.). The Italian longline fleet is also known to operate near the coast in the Strait of Sicily during the autumn (Di Natale *et al*., 1996). In Greek waters, however, the fishing of swordfish is prohibited by law from October to January (Panou *et al*., 1999).

The selectivity of longline fishing in the Mediterranean with respect to ICCAT's minimum legal sizes for swordfish and bluefin tuna are a matter of concern. The percentage of legally undersized swordfish with respect to current EU legislation (< 120 cm LJFL) caught by Spanish longliners in the Mediterranean was 81–83% in 1992–1994 (Anonymous, 1995, cited in Raymakers and Lynham, 1999). A recent study commissioned by TRAFFIC and WWF confirmed the previous figures, and demonstrated the Spanish longline fleets' non-compliance with its international and EU legal obligations (Raymakers and Lynham, 1999). The study, based on observers at the main Mediterranean Spanish ports from June to September 1998, showed that 86% of a sample of 2 097 swordfish landed from 171 vessels had been illegally fished (<120 cm., and probably <25 kg). This sample represented about 7.5% of the 1991–1995 annual average of swordfish caught by Spanish fleets in the Mediterranean. As for bluefin tuna, 210 out of a sample of 254 individuals (or 83% of the total) landed by ten longline vessels were below the minimum legal size of 6.4 kg. The monitoring of swordfish catches by the Italian longlining fleet operating in the central and southern Tyrrhenian Sea and the Strait of Sicily also pointed to the predominance of immature, small-sized individuals in this fishery (Di Natale *et al*., 1996). The mean weights of individuals caught in the southern and central Tyrrhenian Sea were 16.8 kg and 12 kg respectively, and 17.5 kg in Sicily. These values contrast sharply with the current minimum weight of 25 kg recommended by ICCAT.

Albacore longlining also has negative consequences on swordfish and bluefin tuna populations. Di Natale *et al*. (1996) report small-hooked surface longlines targeting albacore in western Italian waters catching very small swordfish, weighing less than 3 kg. De Metrio *et al*. (1997) investigated the catches of the albacore longline fleets operating in 1995 in the Gulf of Taranto (north Ionian Sea), the eastern coast of Sicily (south Ionian) and the north Sicilian coast (south Tyrrhenian), an area fished by a fleet of nearly 150 vessels. Comparisons of landings at ports and catches on board revealed that most swordfish catches were not reported at the ports. Catches of young (class 0) swordfish and bluefin tuna were estimated at 53.2% and 10.1%, respectively, of the total catch in number of individuals, which point to high absolute catches.

3.2.4 Conclusions

Apart from harming important groups taken as bycatch, pelagic longlining in Mediterranean waters is clearly unselective with respect to non-target undersized fractions of the populations that are the object of the fishery. Some data even point to immature large pelagic fish being the bulk of surface longline fisheries. This applies mainly to swordfish and, to a lesser extent, bluefin tuna. Regardless of whether small specimens are caught because of the intrinsic action of the gears or merely reflect overfishing of populations, known to be at low levels, action could be undertaken to minimize the negative impact of present longline practices. The creation of no-fishing zones in strategic areas and seasons, for example spawning and nursery grounds or coastal areas in autumn, could be considered as recommended also by the authors of the TRAFFIC-WWF study. The extension of the Spanish fisheries jurisdiction to a vast region in the western Mediterranean (Royal Decree 1315/1997) provides an opportunity to enforce EU Regulations (derived from ICCAT Recommendations) and implement other new measures in these former international waters.

This section does not set out to deal with the issue of the monospecific management of large pelagic populations, but it is clear that pelagic longlining in the Mediterranean induces high levels of mortality in several ecologically valuable and biologically vulnerable species as well as in non-target, legally protected fractions of swordfish and tuna populations, to the extent that the fishery might just as well be targeting this latter group. Large pelagic species are apex predators and key players in Mediterranean pelagic ecosystems and their conservation appears to be essential to keep ecosystems healthy. Overfishing of pelagic apex predators (bonito and mackerel) in the Black Sea may have triggered a trophic cascade effect working down to lower trophic levels, making the system less resilient to external changes (Daskalov, 1999). The well-known *Mnemiopsis* invasion led to the collapse of fisheries in the late 1980s. All the evidence strongly suggests that current policies should be revised in favour of an ecosystem-based management of large pelagic fisheries and the related surface longlining fishing practices.

3.3 The ecosystem impact of artisanal gears

3.3.1 Introduction

The diversity and economic importance of artisanal gears in small-scale fisheries are essential features of Mediterranean fishing. Stergiou, Petrakis and Politou (1996) consider that small-scale fishing is socioeconomically more important than trawling and purse seining in Greece since it occupies 87.5% of all boats, 57.5% of total fishing power (in HP) and produces near half of the total wholesale value of catch. The heterogeneity of gears and target species makes it difficult to reach any general conclusions as to the impact of these small-scale practices on the ecosystem. Factors such as the season of the year, the characteristics of the area exploited (depth, type of bottom, etc.) further complicate the picture. Some trends emerge nonetheless, such as the higher selectivity of some gears and the negative effects of other artisanal practices. Ghost fishing by abandoned or discarded small-scale gears is another issue of potential importance in the Mediterranean. These points are discussed below, excluding the specific effect of some small-scale fisheries on the populations of endangered species such as monk seals or turtles addressed in previous sections.

3.3.2 Overview

Static nets are usually highly selective, catching larger fish than, in most cases, trained nets. Different types of nets can, in turn, also differ deeply as to intra- and interspecific selectivity. A comparative study of catches in eight types of net gear (both beach seines and static gill and trammel nets) in the Aegean Sea revealed that large meshed trammel nets yielded the biggest commercial catches as a proportion of total catches (Stergiou, Petrakis and Politou, 1996). In another study, the relative selectivity of trawlnets, bottom longlines and gillnets operating on slope bottoms (between 200–700 m) in the Southern Adriatic Sea was analysed with respect to three demersal species: blackmouth catshark (*Galeus melastomus*), rockfish (*Helicolenus dactylopterus*) and blue whiting (*Micromesistius poutassou*) (Ungaro *et al*., 1999). The results showed that gillnets ("rete ad imbrocco") were always the most positive selective gear for size of individuals caught. The modal length of blackmouth catshark caught by gillnets, for instance, was 54 cm, contrasting sharply with only 16 cm reported for trawlnets. Sbrana *et al*. (1999) carried out a comparative study of interspecific selectivity with three kinds of static nets: monofilament gillnets, trammel nets with a monofilament inner panel and entirely multifilament trammel nets, and also tested the effect of different mesh sizes. The study concluded that whereas the number of species caught was negatively correlated with mesh size of a given gear type, inter-specific selectivity decreased from gillnets to trammel nets; the trammel nets with three multifilament nets were the least selective of all. However, the target species in the Sardinian cuttlefish (*Seppia officinalis*) fishery using trammel nets constituted up to 78% of the total catch weight (Cuccu *et al*., 1999).

Beach seines, deployed in very shallow grounds to catch small fish, are common in some Mediterranean waters and are relatively unselective. They are used in Italy, where they are known as "sciabica", and other countries to catch small sardine fry ("biancheto"), transparent goby (*Aphia minuta*) ("rosetto") and sand eel (*Gymnammodytes cicerellus*) ("cicerello"). The beach seine fleet in Crotone (northwestern Ionian Sea) operates on bottoms less than 9 m deep (Carbonara *et al*., 1999). A different kind of beach seine ("sonsera") is used to catch sand eel in a limited area off the coast of northern Catalonia (northwestern Mediterranean). Fine-meshed trawling gears are employed in Adriatic waters mainly in the Gulf of Manfredonia (Casavola, De Ruggieri and Lo Caputo, 1999). The transparent goby fishery is allowed to operate there from January to March, and catches mainly *Aphia minuta* (53.7%) and small sardine (39.7%), together with other fish (including juvenile anchovy) and benthic invertebrates (Casavola *et al*., 1999). The Sardinian squid (*Loligo vulgaris*) fishery works with beach seines on shallow bottoms ranging from 25 m deep almost to the shore. Whereas squid catches consist of adult individuals, contrasting with the local trawlnet catches, *Loligo vulgaris* accounts for only 20% of the total catch in weight and salema (*Sarpa salpa*) makes up the bulk of the catch (72%) (Cuccu *et al*., 1999). A comparative study of small-scale gears used in the south Euboikos Gulf (Greece) during 1992 and 1993 revealed that beach seines were very effective in catching younger and smaller specimens, leading the authors to conclude that "banning of beach seines is essential for the conservation of demersal and inshore diversity" (Stergiou, Petrakis and Politou, 1996). It is worth mentioning that the minimum legal beach seine cod-end mesh size in Greek waters is only 8-mm bar length.

Game fishing is a growing leisure activity in many Mediterranean waters, and probably has a significant impact on some species, for example bluefin tuna and swordfish, whose low age classes suffer particularly. As many as 380 000 juvenile swordfish are estimated to be caught annually by non-commercial fishermen in Calabria (De Metrio *et al*., 1997). The impact of this activity on marine populations and ecosystems in the Mediterranean remains to be adequately addressed.

The massive use of fixed nets (and other artisanal gears such as traps) in many small-scale Mediterranean fisheries, makes ghost fishing by abandoned or discarded gears a potentially important problem in Mediterranean waters but has attracted scant attention. Erzini *et al*. (1997) carried out an experimental study of gillnet and trammel net ghost fishing in shallow (15–18 m) rocky bottoms in the Atlantic waters off the coast of the Algarve in southern Portugal. The results of the study indicated that abandoned gillnets yielded more catches than trammel nets as measured by the mean number of fish caught by 100 m-length pieces of nets after 120 days of deployment on the bottom (gillnets: 344 fish specimens entangled; trammel nets: 221 fishes entrapped). Whilst catches decreased gradually over time, nets continued to catch fish four months after the experiments had started. Osteichthyes were the most numerous group among the 39 species recorded, accounting for 88.8% of the total specimens in number. The other groups included molluscs, gastropods and crustaceans. Sparidae species, however, made up about 33% of total catches in numbers. There is evidence suggesting that nets lost in deep water may have an even longer effective fishing life span, running to years. This is matter of concern since some deep gillnet fisheries (such as the Italian "rete ad imbrocco" in the southern Adriatic) operate in Mediterranean waters.

The results of the study mentioned above also implicated ghost fishing in disturbing demersal food-webs in a similar way to that reported for trawl discards. The authors described considerable scavenging pressure on entrapped fish by octopuses, cuttlefish, conger eels, moray eels and wrasses (*Coris julis*), which could have led to an underestimate for the actual fishing capacity of discarded nets.

3.3.3 Conclusions

The high diversity of artisanal gears (and species targeted) and the importance of small-scale fisheries in many Mediterranean coastal waters introduce considerable additional complexity to the overall issue of the ecosystem-based management of Mediterranean fisheries. In this context, Stergiou, Petrakis and Politou (1996), referring to Greek small-scale fisheries, stated that "management strategies based on single species calculations will be of limited value", and advocated the promising alternative approach of a management regime based on marine harvest refuges. This holistic approach overcomes, in part, the problems related to the variable intraspecific and interspecific selectivity of different gears and other variable factors such as bottom type, depth of setting, seasons and the phenomenon of ghost fishing.

There is enough scientific consensus to support the total banning of some artisanal gears in Mediterranean waters. Beach seines should be eradicated from EU Mediterranean waters from January 2002. All fishing with coastal seines will also be prohibited by 2001 in Turkish Aegean waters, as long demanded by many local artisanal fishermen (Anonymous, 1999b). Game fishing is a superfluous non-commercial practice and must be prevented from inflicting any additional damage on vulnerable species such as swordfish and bluefin tuna.

In general terms, and leaving managerial issues aside, many artisanal fisheries (such as static or bottom longlines) are probably more selective than trawling practices, and therefore a preferable, much less ecosystem-impacting alternative, provided that discarding gears at sea can be stopped.

3.4 The case of Mediterranean driftnet fisheries

3.4.1 Introduction

The outstanding impact of bycatches by surface swordfish driftnets fleets on many vulnerable groups inhabiting Mediterranean waters, as reported in some detail in previous sections, makes a summary of the present status of these fleets desirable. Details of technical aspects of gears and specific fleets are not included here, since the controversial issue of driftnets has been extensively discussed and an extensive literature is already available (see Paul, 1994, for a global, world-wide account of this issue).

3.4.2 State of the art

The Italian Mediterranean driftnet fleet of at least 650 vessels in 1996, using nets measuring on average 10–12 km long, has long been at the centre of the debate, though it is not the only one operating in Mediterranean waters. Driftnet fleets continue their activities despite successive international initiatives banning or limiting this low selective fishing practice (swordfish represented only 18% of the Italian driftnet catch in numbers, but nearly 50% in weight; Di Natale, 1996). Resolutions 44/225 and 46/215 adopted in 1989 and 1991 by the General Assembly of the United Nations recommended the imposition of a moratorium on all large-scale pelagic driftnet fishing by 30 June 1992. European Regulation (EC) No 345/92 prohibited driftnet fishing in the Mediterranean with nets more than 2.5 km in length, as did the General Fisheries Commission for the Mediterranean (GFCM) in 1997 under Resolution 97/1, a binding recommendation. Effective moves to restructure the Italian driftnet fleet have been made since the adoption of European Regulation (EC) No 1239/98 and later regulations totally banning the use of driftnets by Community fishing vessels within and outside Community waters from 1 January 2002. Finally, in November 2003 ICCAT laid down a binding Recommendation (03–04) completely banning the use of driftnets for fisheries of large pelagics in the Mediterranean.

Some fleets indeed limited driftnet fishing in Mediterranean waters during this long political process, whilst others grew rapidly. The Spanish Mediterranean swordfish driftnet fleet is an example of the former. In 1993–1994, 27 boats illegally deployed nets 3–5 km long on the Mediterranean side of the Gibraltar Straits (Silvani, Gazo and Aguilar, 1999). This fishery was particularly unselective, with swordfish catches accounting for only 5–7% of total catch in numbers, which was mostly sunfish (*Mola mola*) (71–93%) and other species such as dolphins and turtles (see the respective sections above). After 1994, these boats stopped using large-scale driftnets and changed target species. Other fleets, on the contrary, have continued to expand, in some cases taking advantage of gears supplied from reconverted fleets. This is the case of North African countries and Turkey, despite national legislation banning large-scale swordfish driftnetting in most of them. Italian and Greek fishermen are known to sell their equipment to Turkish fishermen (A.C. Gücü, pers. comm.). According to Tudela *et al*. (2005) at least 177 Moroccan vessels carry out large-scale driftnet activities in the Alboran Sea and Straits of Gibraltar areas (357 according to Moroccan sources; document ICCAT SCRS/2002/139). In addition to this important North African fleet, the other major fleets involved are Italian (about 90–100 vessels still exist), Turkish (45–110 vessels; Akyol *et al*., 2003, SCRS/ICCAT, 2001) and French (46–75; SGFEN/STECF, 2001). Many evidences point to other countries like Algeria as being also likely driftnetters, though confirmed official information is not available.

Solid legal instruments already exist to tackle the issue of driftnet fishing in the Mediterranean, especially after the recent total ban issued by ICCAT. Their enforcement should be a priority for the different coastal states and the concerned Regional Fisheries Organizations (GFCM and ICCAT).

4. GENERAL DISCUSSION AND CONCLUSIONS: THE ECOSYSTEM EFFECTS OF FISHING IN THE MEDITERRANEAN AND THEIR REMEDY FROM A SYSTEMIC PERSPECTIVE

Most of the major effects of fishing recorded around the world occur in Mediterranean ecosystems too. They vary from local effects on the sea bottom caused by damaging trawler gears to large-scale impacts on cetacean populations arising from the entanglement of the animals in long driftnets. This variety is due to three principle factors: the huge diversity of fishing gears and practices (most of them artisanal), the very high intensity of fishing, and an important biological diversity. The latter is demonstrated by the Mediterranean presence of a vast array of vulnerable species, including emblematic seals, whales, turtles and sharks.

The case by case approach adopted in this document notwithstanding, it should be emphasized that the impact of fishing goes far beyond the mere effects caused on single populations of target and bycatch species, or the degradation of the physical support system. Fishing profoundly affects the complex structure of ecosystems, altering their internal functioning. A measure of human appropriation of marine biological production, the percentage of the primary production required to sustain a given fishery (%PPR), has been estimated on a global basis by Pauly and Christensen (1995). The results obtained indicated a much higher ecological footprint for fishing than expected: up to 35.3% in the case of world non-tropical shelves. Another ecological index, the average trophic level of the fishery (TL), indicates fishing impact on the structure of marine food webs over time. Pauly *et al*. (1998) described the existence of a global "fishing down marine food webs effect" (FDMFW) based on the steadily decreasing trend of TL values of catches recorded for the period 1950–1994, also verified in the Mediterranean. The lack of correspondence between the harvesting on lower TLs and the expected increase of catches points to the disruption of major energy pathways and the subsequent decrease in yields, resulting from the structural and functional degradation of the ecosystem. Well-structured ecosystems maintain healthy predator population levels, tend to be energetically more efficient and more resilient to external perturbations, and are the bases for sustainable fisheries.

Some recent attempts to evaluate the overall ecosystem effect of fishing in specific areas of the Mediterranean appear to arrive at the same conclusions as those above. Claims concerning the role of the increase in biological production due to the anthropic nutrient enrichment of waters add some uncertainty to the interpretations.

Tudela (2000) estimated a %PPR for the mixed pelagic/demersal fishery operating off the central Catalan coast (northeastern Spain) on the shelf and the slope down to 1 000 m as slightly more than 40% of the total primary production. This figure takes both discards and misreporting of catches into account. Such a huge level of human appropriation, one of the highest ever recorded, together with the stagnation of landings despite the growth of fishing capacity and the fact that the fishery works at moderately low trophic levels implies the full, and ecologically unsustainable, exploitation of the ecosystem. The author warned about the possible loss of ecosystem resilience in these conditions. A further assessment by Tudela, Coll and Palomera, (2004) of the overall pressure on the Mediterranean ecosystem due to fisheries demonstrates that the threshold for ecosystem overfishing (as defined by ecological indicators on ecosystem structure and functioning) has already been exceeded. Stergiou and Koulouris (2000), using official landing statistics in the eastern Mediterranean basin, studied the evolution of mean TLs of catches during the last 30 years, looking for a local FDMFW effect. The results showed that at least in the main part of the Aegean Sea the mean trophic level has decreased in recent years, and the authors concluded that the present pattern of harvesting in not sustainable. In any case, such a high level of ecosystem exploitation is liable to disrupt food-webs, and prevent the ecosystem from supporting healthy populations of apex predator species. This phenomenon may underlie many of the conflicts reported in previous sections and point to the need for combining both conservation policies for specific threatened species (i.e. monk seal) and sustainable fishery policies, allowing ecosystems to rebuild themselves.

This reduction of the mean TL of an exploited community may be intentional from the start, as exemplified by fishermen in southern Sicily: they customarily “clean the sea” by repeatedly trawling a new fishing ground to eliminate sharks and other undesirable species (Badalamenti, pers. comm.). Conversely, the creation of marine protected areas (MPA) in which fishing is banned has proved useful for rebuilding the diversity of exploited communities: the mean TL of fish assemblages in seagrass beds has risen following protection along the French Mediterranean coast (Harmelin-Vivien, pers. comm.).

It has been suggested that the increase in primary production in the northwestern Mediterranean in recent years may have been having positive effects on fisheries production in the region (Caddy, 1997; 2000). This hypothesis, if confirmed, could provide a mechanism to counter the reduction in fishery production due to ecosystem overexploitation, as explained above. In the Mediterranean, the relationship between the overall increase in fishery production and the decrease in the mean TL of catches would be compatible with such a bottom-up effect, as demonstrated by the upward trend of the FIB index relating both parameters, although there are alternative explanations (Pauly, pers. comm.). However, meta-analyses of data from mesocosm-based experiments and natural marine ecosystems from all over the world show a general weak coupling of N loading and phytoplankton productivity with higher trophic levels, implying that anthropogenic nutrient loading is unlikely to result in increased fish biomass, regardless of local conditions and the magnitude of nutrient enrichment (Micheli, 1999). In the absence of a specific study, these conclusions seem to challenge the validity of the former hypothesis.

It could be inferred from the evidence presented above that the effects of fishing in the Mediterranean go far beyond the isolated impacts on overfished target species, vulnerable non-commercial groups or sensitive habitats. The ecosystem effects of fishing in the Mediterranean are also conspicuous at the systemic level, as highlighted by the massive ecological footprint of fishing or the marked effects on the food-web structure. A holistic approach should therefore be adopted if the overall changes to the structure and the functioning of marine ecosystems caused by fishing are to be remedied. These changes directly affect important ecosystem properties such as its resilience to human interference.

There is growing consensus on the potential use of marine reserves or marine protected areas (MPAs) as a precautionary tool for the systemic management of fisheries (Roberts, 1997; Hall, 1998; Lauck *et al*., 1998; Hastings and Botsford, 1999). The use of this approach in the Mediterranean appears to be promising, given the preliminary results of some limited experiments with marine reserves (see above). The idea of rebuilding degraded ecosystems, mostly through MPAs is gaining support in the scientific community (Pitcher and Pauly, 1998). These authors think the goal should consist not of the conservation of ecosystems in their current states, but rather be to reconstruct past, healthier states that existed prior to their extensive modification by man. This approach would be of particular interest in the Mediterranean given the profound transformation of the marine ecosystems due to centuries of intense human exploitation. As suggested in the respective sections of this document, these precautionary ecosystem-based measures should be accompanied by general improvements in both intra- and interspecific selectivity of gears and fishing practices, the minimization of the physical damage they cause to the supporting environment, and parallel educational programmes for fishermen. Public subsidies diverted to these measures, which in some cases would involve the eradication or tight restrictions on especially harmful fishing practices, would probably result in the improvement of fisheries and their related ecosystems.

In conclusion, a reductionist approach alone may not prove sufficient to tackle the issue of the conservation of Mediterranean ecosystems and their biological diversity satisfactorily. Furthermore, conservation policies targeting vulnerable species or habitats shouldn't be separated from fisheries management policies, given that they have essentially the same goal. From the cases reported in this document it becomes clear that apart from the issues linked to technical aspects, such as those concerning harmful gears or fishing practices, overfishing is a central problem underlying many of the other problems. Many instances have been reported of how intensive fishing exacerbates interactions between vulnerable groups and fisheries. The development and enforcement of integrated precautionary policies appears to be highly necessary, which appeals to the need to develop an operational framework aligned with a truly ecosystem-based fisheries management in the Mediterranean.

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Most of the major impacts of fishing on the ecosystems recorded around the world occur in the Mediterranean. This variety of interactions is due to four main interrelated factors: the wide range of fishing gear and practices; very intensive fishing; a high diversity of exploited habitats, ranging from shallow waters to the deep-sea and oceanic domain; and high biological diversity. Populations of elasmobranchs (mainly rays and pelagic sharks), seabirds, marine turtles and marine mammals (including the monk seal) are heavily impacted by poorly selective fishing gears and practices, as well as by other fishing-related effects, such as reduced trophic availability. High bycatch figures resulting from the continued use of illegal, high-impact gears such as driftnets are of special concern. Benthic communities are also subject to high impact from towed gears and other aggressive practices. Recent studies show that the ecosystem effects of fishing in the Mediterranean are also conspicuous at the systemic level, as highlighted by the massive ecological footprint of fishing or the marked effects on the overall food web structure.

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