Cetaceans of the Mediterranean and Black Seas: State of Knowledge and Conservation Strategies

SECTION 9

Interactions between Cetaceans and Fisheries in the Mediterranean Sea

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Overview

Interactions between cetaceans and fisheries in the Mediterranean Sea are probably as old as the first human attempts to catch fish with a net. Countless reports and artefacts from the former Tethys Ocean tell the story of dolphins interacting with fishermen. The earliest reports describe idyllic relationships between dolphins and people, but things changed as fisheries developed. As early as in 1587 a Papal Decree was issued "anathematising the vermin" in response to concerns in France about the effect of dolphins on fisheries (Smith 1995). Eighteenth century reports describe fishermen attempts to keep dolphins away from their nets, by means including loud noises, dynamite, weapons, modifications of fishing techniques and schedules, and large-mesh nets surrounding the fishing nets to protect them from dolphin incursions. The animals were claimed to be "consistently seeking a parasitic life at the poor fishermen's expenses" and requests were repeatedly submitted by fishermen to governmental bodies to reduce dolphin numbers through culling (Barone 1895, Smith 1995).

In some Mediterranean areas, direct killings and bounties for dolphins represented the first human attempts to solve the problem of net depredation[1], a strategy that was supported by several governments for at least one century (Smith 1995). In the 1950s, retaliation measures were still encouraged by State money rewards, resulting in hundreds of dolphins being killed annually in the Adriatic Sea (Holcer 1994).

Although bounties are no longer issued, the overall impact of world fisheries on cetaceans remains extremely high (Reeves *et al.*, In press). Together with deliberate kills, incidental catches of cetaceans in fishing gear also increased with the worldwide development of fisheries. However, it was only in the last few decades that bycatch became one of the major threats to the very survival of several cetacean populations. In the Mediterranean, where most data are sparse or difficult to evaluate, this impact has never been comprehensively assessed. Nevertheless, unsustainable bycatch rates have been reported for several fisheries, and the combined effect of intentional killings, bycatch, reduction of prey resources and fishery-related habitat loss represent a source of concern in many Mediterranean areas.

While it is known that cetaceans have been facing serious problems owing to fisheries in the last half-century (Reeves and Leatherwood 1994), there is no clear evidence that depredation may have risen in recent times. Therefore, it is unclear why the issue appears to be increasingly perceived by Mediterranean fishermen to be causing economic hardship, particularly as far as small-scale, coastal fisheries are concerned. One of the reasons may be that small-scale fisheries in many parts of the Mediterranean have become economically marginal, whether due to the depletion of fish stocks, over-capitalisation, market changes or socio-cultural factors (Reeves *et al.* 2001). Therefore, even relatively small losses to dolphin depredation can now have a proportionally large impact on a fisherman's livelihood. The resulting economic distress may be prompting fishermen to complain about the depredations by dolphins and to perceive these animals as competitors. Moreover, fishermen have learned of new opportunities to gain compensation and have therefore become more vocal about the importance of dolphin interactions in recent times (Reeves *et al.* 2001).

Although approaches to marine mammal control such as culling or harassment have become illegal in most Mediterranean countries, and are no longer viewed as appropriate by most fishing organisations, direct killings are occasionally enacted by individual fishermen. Nevertheless, many fishermen are becoming aware that blaming the dolphins for the ongoing changes within the ecosystem does not represent sensible behaviour. If solutions to the problems of cetacean-fisheries interactions are to be found, these must be based on the comprehension of ecosystem dynamics.

Impact of cetaceans on fisheries. Interactions between cetaceans and coastal fisheries may negatively affect the fisheries through:

- damage to fishing gear in the form of holes torn in the nets as the dolphins attempt to remove fish, or other forms of gear damage caused by cetaceans;
- reduction in the amount or value of the catch as the dolphins mutilate or remove caught fish from nets or longlines;
- reduction in the size or quality of the catch as the dolphins' presence causes fish to flee from the vicinity of the nets;

[1] Referring to "predators taking, or attempting to take, prey that are confined in pens or that have been - or are about to be - caught in fishing gear" (Reeves *et al.* In press).

- time, money, or gear loss by fishermen due to cetaceans interacting with fishing operations, or getting caught in nets;
- a real or perceived ecological competition with cetaceans, based on the conviction that depredation – particularly by dolphins - reduces the amount of fish available to fisheries (Reeves *et al.* 2001).

Beneficial effects may also occur. These may involve dolphins "co-operating" in fishing operations, or otherwise increasing the chances of success of a fishery (*e.g*., Pryor *et al.* 1990). Indirect beneficial effects may include cetaceans making an area more attractive to tourists, thus providing economic advantages (*e.g*., increased request for seafood) that may positively impact local fisheries. More importantly, marine mammals are essential components of healthy ecosystems, and their ecological importance (*e.g.,* Estes *et al.* 1998) is an issue that has been given little consideration until the present day.

The main types of fishing gear used in coastal Mediterranean waters where conflict with dolphins has been reported are bottom-set trammel nets and gillnets. Dolphins also interact with trawl nets, and occasionally with small purse seines targeting pelagic schooling fish (Reeves *et al.* 2001). Although perceived conflict is being reported from a number of Mediterranean areas, there have been few studies aimed at defining the extent of the conflict, and estimating the actual costs to fisheries.

Studies specifically focusing on fishery-dolphin interactions have been initiated in a few Mediterranean areas. In Italy's Asinara Island National Park, north-western Sardinia, an attempt has been made to quantify the impact of dolphin depredation in the trammel net fishery for red mullet (*Mullus surmuletus*) (Cannas *et al.* 1994, Lauriano *et al.,* In press). In two areas of Sicily (Catania and Favignana) a European Commission-sponsored study (project ADEPTs) has been initiated to test the feasibility and efficacy of using pingers to reduce dolphin depredation in trammel and gill net fisheries (Quero *et al.* 2000). Studies conducted by the University of Barcelona in the Balearic Islands from 1992-95 indicated that about 30 bottlenose dolphins were dying annually as a result of entanglement or direct killing by fishermen, in retaliation for depredation on trammel nets and shore-anchored gill nets set for red mullet and cuttlefish (*Sepia officinalis*) (Silvani *et al.* 1992, Gazo *et al.,* In press). Finally, research is underway to evaluate the dynamics of trawl fisheries / bottlenose dolphin interactions off the Israeli coast (Goffman *et al.* 1995, 2001).

In addition to these areas, some information exists on conflicts between cetaceans and fisheries in several Mediterranean areas, including the Thracian Sea (Mitra *et al.,* In press), the Amvrakikos Gulf, Greece (I. Siori and E. Hatzidimitriou, pers. comm.), the Ionian Sea (Tringali *et al.*, In press), the sea area off Tunisia (Lofti 2000), the Tyrrhenian Sea (Consiglio *et al.* 1992, Mussi *et al.* 1998), and the Gibraltar Strait (De Stephanis *et al.* 2000, Pèrez Gimeno *et al.*, In press). In the past, there have also been recorded interactions between false killer whales, *Pseudorca crassidens*, and tuna fisheries in the Messina Strait, Italy (Scordìa 1939).

Overall, most information on the economic effects of dolphin interactions with Mediterranean fisheries is qualitative and inadequately documented. Although it is certain that in some areas fishermen suffer from either gear damage, reduced catch, or time/money loss, no attempt has ever been made to evaluate trends, nor to quantify the costs of such interactions (Reeves *et al.* 2001).

Most interactions having a negative impact on Mediterranean fisheries have involved the common bottlenose dolphin and the short-beaked common dolphin, which are the most abundant coastal cetaceans in the Mediterranean (Notarbartolo di Sciara and Demma 1994). However, it must be considered that Mediterranean common bottlenose and short-beaked common dolphin populations, which are thought to be geographically isolated from those in the Atlantic Ocean (A. Natoli and R. Hoelzel, pers. comm.), have now declined considerably and their numbers are certainly not as high as they used to be only 50 years ago.

Today, the common bottlenose dolphin – that in the basin is typically found on the continental shelf - remains the species involved in most cases of interactions with coastal fisheries, although its populations appear to be increasingly scattered and fragmented into small units.

Interactions with Mediterranean fisheries have also involved the short-beaked common dolphin, but the current extent of such interactions is limited by the fact that the species has faced a dramatic decline in numbers over the past few decades. The forthcoming revised IUCN/SSC action plan recognises that short-beaked common dolphins in the central and eastern Mediterranean have declined precipitously and that conservation action is urgently needed to prevent their extirpation in this region (Reeves *et al.*, In press) . Relic common dolphin sub-populations are still reportedly involved in fishery depredations in coastal portions of the Mediterranean, including Tunisia and Cyprus (UNEP 1998*b*, Reeves *et al.* 2001).

The striped dolphin - by far the most abundant cetacean in the Mediterranean - has a pelagic distribution and largely feeds on non-commercial prey species (Notarbartolo di Sciara and Demma 1994). Therefore, it rarely represents a problem to coastal fisheries, apart from gear damage or time loss for fishermen when the animals get entrapped in fishing gear.

Impact of fisheries on cetaceans. Fisheries can affect cetaceans both directly and indirectly. Effects on the animals may include:

1. bycatch in fishing gear;
2. injury or mortality from retaliatory measures taken by fishermen who may perceive the animals as competitors, or blame them for gear damage or catch reduction;
3. unintentional disturbance by fishery-related operations;
4. reduction of food prey availability or changes in food prey composition/distribution caused by overfishing;
5. habitat loss and/or degradation (*e.g.*, from bottom trawling);
6. short- to long-term modifications in cetacean behaviour leading to emigration, dispersion or reduced reproductive rates as a consequence of direct or indirect interactions with fisheries.

The part that follows specifically focuses on the potential or known impact on Mediterranean cetaceans of the threats listed above, with the exception of item listed as n. 2 ("injury or mortality from retaliatory measures …"), which was dealt with elsewhere in this Report (Notarbartolo di Sciara and Bearzi 2002).

Fishery interactions involving unintentional takes (bycatch)

Before the mid to late 1960s, there was no place in the world where the magnitude of bycatch was considered great enough to threaten a population of cetaceans (Reeves and Leatherwood 1994). We are now only a few decades ahead, but cetacean deaths in various fishing gear occur virtually everywhere, and are often among the main causes of human-related mortality for a number of cetacean species. Incidental captures in fishing gear – the impact of which is often underestimated - certainly represent a serious threat to the survival of many cetacean populations around the world, and in some areas have brought cetacean species or populations close to extinction (IWC 1994, Reeves and Leatherwood 1994, Read 1996).

In the Mediterranean, the problem of incidental mortality in fishing gear has caught the attention of both scientists and the general public due to high-seas driftnet fishing by vessels flying Italian and other flags. A recent European Union ban of driftnetting may result in decreased bycatch rates in portions of the basin, however the problems remains in unregulated waters and in areas where illegal use of driftnets is an issue.

In the Italian seas alone, where an effective cetacean stranding network exists, it has been calculated that 83% of the stranding events occurred between 1986-90, for which the cause of death could be established, resulted from bycatch in driftnets (Cagnolaro and Notarbartolo di Sciara 1992). Although bycatch has been reported for most Mediterranean species, incidental captures in fishing gear have mostly affected sperm whales, common dolphins, bottlenose dolphins, and striped dolphins (Perrin 1988, Di Natale and Notarbartolo di Sciara 1994, Northridge and Hofman 1999).

Entrapment in pelagic driftnets. Pelagic driftnets are long, non-selective nets with strong, loose nylon mesh that can virtually entrap all kinds of large marine animals. Worldwide, these nets have been depleting a number of cetacean populations, including species of all sizes (Read 1996). Driftnet fisheries around the world that have shown to be highly detrimental to cetacean populations include the Japanese North Pacific driftnet fishery for salmon (Ohsumi 1975), the Taiwanese driftnet fishery for shark, tuna, and mackerel off northern Australia (Harwood and Hembree 1987), the French tuna driftnet fishery in the north-eastern Atlantic (Goujon *et al.* 1993), and several others (Northridge and Hofman 1999).

In the Mediterranean, pelagic driftnets are used by the drift gillnet fishery for small pelagic fish, and by the drift gillnet fishery for swordfish and albacore (IWC 1994). The latter involves the use of the most threatening fishing gear used in Mediterranean waters, where the fishery has dramatically impacted several cetacean populations. Multifilament nylon nets for swordfish have 36-52 cm mesh and are 2-40 km long, with a typical length of 12-15 km. Similar nets are used for albacore, with a mesh size of 16-20 cm and a total length of 9-15 km (IWC 1994).

Mediterranean countries with driftnetting fleets reportedly included Algeria, Morocco, Spain, France, Italy, Malta, Greece, and Turkey (Di Natale and Notarbartolo di Sciara 1994, Silvani *et al.* 1999). The number of vessels rapidly increased to over 1,000 by 1990 (IWC 1994). For instance, the Italian driftnet fleet – reported as being the largest in the Mediterranean - had increased by 57% between 1987-90, totalling 700 boats carrying nets up to 22.5 km long. After management measures taken in 1990, the Italian fleet was reduced to 120 units (Di Natale and Notarbartolo di Sciara 1994). Based on fishermen interviews conducted in the southern Tyrrhenian Sea, about 90% of the bycatch was composed of "dolphins", while sperm whales represented the remaining 10%; up to 15 dolphins were reported to die in fishing gear deployed overnight by a single boat in the area (B. Mussi and A. Miragliuolo, pers. comm.)

Due to recent regional legislation, the situation is changing in European Union countries, where driftnets have been be banned starting from 1 January 2002; meanwhile, a decommissioning process of the Italian driftnet fleet is in process. However, the unregulated use of pelagic driftnets by non EU countries (possibly including both Mediterranean and non-Mediterranean nations) represents a source of concern. Moreover, illegal driftnetting is still an issue in some EU countries (*e.g.*, in Italy, Miragliuolo *et al.* 2002). Owing to lack of enforcement measures, in most Mediterranean countries cetacean bycatch in driftnets and deliberate killing of cetaceans caught alive in these nets occur irrespective of national regulations that prohibit the taking of marine mammals (Di Natale and Notarbartolo di Sciara 1994).

It was estimated that in the '90s thousands of Mediterranean cetaceans have died in pelagic driftnets every year, at rates deemed unsustainable (Di Natale 1990, Notarbartolo di Sciara 1990, Cagnolaro and Notarbartolo di Sciara 1992, Di Natale and Notarbartolo di Sciara 1994, IWC 1994, UNEP/IUCN 1994, Forcada and Hammond 1998, Silvani *et al.* 1999). Remarkably, the majority of strandings along the Italian coasts between 1986-90, the cause of which could be related to fishing gear, were caused by driftnets (Cagnolaro and Notarbartolo di Sciara 1992). Sperm whale and striped dolphin populations were reportedly the most impacted, but bycatch also involved Cuvier's beaked whales, long-finned pilot whales, Risso's dolphins, common bottlenose dolphins and short-beaked common dolphins (IWC 1994). Although fin whales may at times be capable of breaking the nets after entanglement and find their way out (Di Natale 1992), even Mediterranean mysticetes may die in pelagic driftnets (Centro Studi Cetacei 1992, IWC 1994).

When driftnet fisheries reached their peak, a total annual bycatch of over 8,000 cetacean specimens (mostly striped dolphins, but including at least 30 sperm whales) was estimated for the Italian Seas alone (Di Natale and Notarbartolo di Sciara 1994), and perhaps up to 10,000 cetacean specimens died annually in the whole Mediterranean (IWC 1994). The current annual toll that cetaceans have to pay to driftnets fisheries is unknown, but remains potentially unsustainable in some areas (*e.g.*, in the Tyrrhenian Sea, Miragliuolo *et al.* 2002). Between 1993-98, it has been reported that 15 of 24 sperm whale strandings in the Balearic Islands where caused by bycatch in driftnets (Làzaro and Martìn 1999).

Entrapment in bottom gillnets. Bottom gillnets have been known to cause incidental entrapment and death of thousands of cetaceans worldwide (Jefferson *et al.* 1992, IWC 1994, Read 1996, Reeves *et al.*, In press). This fishing gear is used in coastal waters up to 200 m deep, and usually targets demersal and bentho-pelagic prey.

Bycatch in bottom gillnets largely affects small coastal cetaceans such as harbour porpoises, bottlenose dolphins (*Tursiops* sp.), humpbacked dolphins (*Sousa* sp.), common dolphins (*Delphinus* sp.), and virtually all riverine cetaceans (IWC 1994, Reeves and Leatherwood 1994, Read 1996). Mortality in gillnets is considered as the main threat to the survival of the vaquita, *Phocoena sinus* (Vidal 1995, D'Agrosa *et al.* 1995) and the Hector's dolphin, *Cephalorhynchus commersoni* (Dawson and Slooten 1993). Conversely, incidental takes of large cetaceans in bottom gillnets are a rare occurrence (Reeves and Leatherwood 1994). Factors that may contribute to the entrapment of cetaceans in gillnets include (Jefferson *et al.* 1992, Lien 1994, Tregenza *et al.*

1997): 1) presence in the nets or in their proximity of organisms representing potential cetacean prey; 2) water turbidity making the fishing gear less visible; 3) ambient noise in the marine environment that may mask or confuse the echoes produced by fishing gear, thus reducing their detectability for echolocating cetaceans; 4) location and three-dimensional position of fishing gear; and 5) cetacean capability to detect the net filaments by means of echolocation. Moreover, lack of experience by juvenile or immature individuals, together with their bent for playful and/or scouting behaviour, may make them more vulnerable to entrapment in gillnets (Mann *et al.* 1995, da Silva 1996, Fertl and Leatherwood 1997).

Bottom gillnet fisheries are very common throughout the Mediterranean basin, with around 50,000-100,000 boats reportedly involved (IWC 1994). Target species are largely represented by demersal and bentho-pelagic fish and crustaceans. Although few entrapments in bottom gillnets have been documented in the Mediterranean, this may be in part due to under-reporting (Di Natale and Notarbartolo di Sciara 1994). Being so widespread throughout the Mediterranean coastline, this fishery may actually result in occasional mortality of coastal species. Incidental catches of short-beaked common dolphins and common bottlenose dolphins in gillnets reportedly occurred in Italy and Turkey, and are suspected to occur in several other Mediterranean countries (Di Natale and Notarbartolo di Sciara 1994, UNEP 1998*a*).

Bycaught cetaceans are usually removed from the nets dead or alive - either by disentangling/cutting the net or by amputation of cetacean fins or flukes. Occasionally, small cetaceans may be brought to the port for human consumption. The proportion of live/dead bycatch is unknown, and remarkably few studies have been conducted to evaluate mortality trends in bottom gillnet fisheries. Scientific data are scarce and for most Mediterranean countries only anecdotal reports exist, making it difficult to assess the current impact of this threat to coastal cetaceans. The 1994 IWC report estimated “likely annual ranges of marine mammal mortality” of 1-10 Risso’s dolphins, 0-5 short-beaked common dolphins, 50-200 common bottlenose dolphins, 1-20 striped dolphins and low numbers of other cetacean species in coastal set gillnet fisheries (IWC 1994). However, the incidence of accidental captures in gillnets is reportedly significant in some Mediterranean areas, and it is very likely that the existing estimates are lower than the actual toll (Silvani *et al.* 1992, UNEP/IUCN 1994).

Entrapment in trawl nets. Trawl nets are towed horizontally or obliquely, and consist of a cone-shaped net with a cod-end or bag for collecting fish or other target species. Trawling nets target demersal and bentho-pelagic stocks, as well as mid-water species. Typical target species may include species such as hake, pollock and other groundfish, shrimp, prawn, and a variety of squid (Read 1996).

The significance of cetacean mortality in trawl nets has only recently begun to be recognised (*e.g.*, Jefferson *et al.* 1992, Crespo *et al.* 1994, Couperus 1997, Crespo *et al.* 1997, Dans *et al.* 1997, Fertl and Leatherwood 1997, Crespo *et al.* 2000). Incidental takes of cetaceans exist in most areas where trawling occurs (Fertl and Leatherwood 1997), and several cetacean species are known to become incidentally caught in the nets. A preliminary review of global data indicates that 25 cetacean species (two mysticetes, 23 odontocetes) have died in working trawls or discarded trawling gear (Fertl and Leatherwood 1997). In extra-Mediterranean areas, bycatch in trawl nets may affect species including *Tursiops*, *Delphinus*, *Stenella*, *Lagenorhynchus*, and *Globicephala* (Jefferson *et al.* 1992, Waring *et al.* 1990, Kuiken *et al.* 1994, Read 1996, Tregenza and Collet 1998, Morizur *et al.* 1999). Recent mass strandings of small odontocetes - particularly short-beaked common dolphins and Atlantic white-sided dolphins - on the western and northern coasts of Europe have been related to pelagic trawl fishing, and the potential of these mortality events at the population level has been probably underestimated (Kuiken *et al.* 1994, Berrow and Rogan 1997, Couperus 1997, Tregenza and Collet 1998, Morizur *et al.* 1999). In the U.S. waters of the Mid-Atlantic Bight, *Globicephala* and *Delphinus* have been heavily bycaught by mid-water trawl fisheries for mackerel (*Scomber scombrus*) in the 1980s and early 1990s (Waring *et al.* 1990).

It has been suggested that cetaceans bycaught in trawl nets are probably aware of the net and the boat’s activity (Fertl and Leatherwood 1997). In many areas around the world, cetaceans have learned to follow bottom trawlers to take advantage of fish caught by the net, stirred up by the net, attracted by the net, or discarded from the nets after trawling (*e.g.*, Leatherwood 1975, Corkeron *et al.* 1990, Waring *et al.* 1990, Morizur *et al.* 1999, Goffman *et al.* 2001). While these nets may provide a concentrated food source that may be easy to exploit, cetaceans may become entangled in operating nets and this opportunistic feeding behaviour is likely to be responsible for most cetacean captures in trawl nets (Overholtz and Waring 1991, Read 1996). However, there is little systematic knowledge of the behavioural processes that cause cetaceans to be vulnerable to incidental takes in trawls (Fertl and Leatherwood 1997).

Mid-water trawling seems to represent the main threat, because it may target species that represent typical components of cetacean diet. Moreover, these nets are usually dragged at relatively high speeds, with irregular and unpredictable changes of route that increase the chances of entanglement (Fertl and Leatherwood 1997). In both European and U.S. waters the recent development of near-surface trawling (in particular when nets are dragged by two fishing boats) has further increased the risk of incidental captures of cetaceans (Crespo *et al.* 1995, Couperus 1997, Morizur *et al.* 1999).

In the Mediterranean, interactions between trawlers and several cetacean species reportedly occur, the main species involved being the common bottlenose dolphin (Northridge 1984, Consiglio *et al.* 1992, Silvani *et al.* 1992, Gannier 1995, Goffman *et al.* 1995, Marini *et al.* 1995, Casale 1996, Mussi *et al.* 1998, Pace *et al.* 1998, Bearzi *et al.* 1999, Mazzanti, In press). Based on the available data, bycatch in trawling nets appears to be a relatively uncommon occurrence in most Mediterranean areas. However, high mortality rates in bottom trawl nets have been reported from the Mediterranean coast of Israel. Of 67 common bottlenose dolphins found dead stranded or adrift, 26 (39%) were incidentally bycaught in trawl nets (Goffman *et al.* 2001). Contrary to what has been suggested from other areas (Fertl and Leatherwood 1997), bycatch off Israel affects animals regardless of gender and age classes (Goffman *et al.* 1995, 2001).

Goffman *et al.* (2001) make the following observations for common bottlenose dolphins following bottom trawlers off the Mediterranean coast of Israel:

"Foraging is done by a unique method, a learned behaviour, of cutting out segments of fish that protrude from the outer side of the net. The reason may be the change of modern nets from cotton to nylon, which makes them resistant to tear, either by yanking whole fish or by forcing an entry in and/or out of the net. In the past, the dolphins used to badly damage the nets in order to reach the fish, to the point of being shot at by the fishermen. During the last few years, the dolphins have learned (or forced to revert) to feed without damaging the net, however, they apparently also venture into the net and incidental captures still occur (Kerem 2001). Some of the bycaught animals are brought up inside the net and some (about 1/3) are found entangled in the free-floating lazy-line the purpose of which is to secure the net in case the main towing lines break."

Apart from the remarkable incidence of bycatch off the Israeli coast, and possibly in other Mediterranean areas for which data are lacking, the main impact of trawl fisheries on Mediterranean cetaceans – particularly on coastal species feeding on demersal prey such as the common bottlenose dolphin – may be due to direct or indirect food-web interactions and habitat loss rather than bycatch (see in following pages, "Competitive interactions between cetaceans and fisheries").

Entrapment in purse seines. Purse seines are widely used in the world's industrialised fisheries to capture a variety of pelagic species, from tuna to anchovies and sardines. The most dramatic case of interaction between purse seines and cetaceans has occurred – and to some extent still occurs - in the eastern tropical Pacific, where strong affiliation between yellowfin tuna (*Thunnus albacares*) and dolphins has led to extremely high mortality rates - with perhaps as many as seven millions dolphins killed since the late 1950s (Gosliner 1999). In this fishery, the association between tuna and dolphins is used to assist in the location and capture of tuna schools. As dolphins are more easily seen from vessels than tuna, fishermen search for schools of dolphins and, after determining that they are associated with tuna, encircle the entire aggregation with large purse seines. Dolphins may die if they become entangled or trapped in billows of the net. Following regulations to prevent dolphin bycatch, fishermen in the Pacific have been forced to release alive the dolphins that were encircled by the net, but dolphin mortality could still occur when efforts to release them failed, whether due to unpredictable dolphin behaviour, human error, or unfavourable conditions of weather, current speed, or lighting (Gosliner 1999, Reeves *et al.*, In press) Following strict regulations to reduce bycatch, dolphin mortality in Pacific tuna nets has substantially decreased in recent years. However, the past and present impact may be significantly underestimated because of unobserved deaths of nursing calves due to separation from their mothers during fishing (Archer *et al.* 2001).

Fishing with purse seines aimed at tuna appears to be scarcely practiced in the Mediterranean, where purse seining appears to be mostly targeted to small epipelagic schooling fish. In the Italian seas, Di Natale and Notarbartolo di Sciara (1994) reported only ten tuna nets being used, for a total of 1,000 fishermen involved and a fishing period of 60 days per year. Bycatch in purse seines would mainly affect small odontocetes such as striped dolphins, bottlenose dolphins and common dolphins (Di Natale 1983*a*, 1983*b*, 1990, UNEP/IUCN 1994). Rare reports exist of cetaceans bycaught in tuna purse-seine in the Mediterranean (*e.g.*, Magnaghi and Podestà 1987). Overall, the impact of these nets on Mediterranean cetaceans is commonly considered to be negligible (Di Natale and Notarbartolo di Sciara 1994). However, reliable information is completely lacking, and thus an accurate assessment of the impact of tuna purse seine fishing on cetaceans in the Mediterranean is presently impossible.

Entrapment in longlines. Longlines consist of a series of baited hooks attached to a long, horizontal line by short connecting lines. This type of fishing gear can be configured to take a wide variety of fish, from small, bottom-dwelling species to large pelagic species such as swordfish, tuna and sharks. The use of different hook sizes and fishing depths allows fishermen considerable flexibility in their choice of target species. In many areas longlines are important components of coastal and pelagic fisheries (Read 1996).

Cetaceans may get entangled in the line filaments or in other parts of the gear, or get hooked (Green *et al.* 1991, Read 1996). In some areas around the world, mortality related to longline fisheries may be significant (Crespo *et al.* 1997, Reeves *et al.*, in prep.). For instance, in the southern U.S., short-finned pilot whales can get entangled in longline fisheries for swordfish and tuna; most entangled animals are released alive, but it is not known what effects the hooks and/or entanglement may have on their survival after release (Read 1996). In the Yangtze River, China, a bottom longline fishery called 'rolling hooks' kills every year unsustainable numbers of endangered baiji (Perrin *et al.* 1989).

Longlines are commonly used in the Mediterranean for catching tuna, albacore, swordfish and a number of other fish (Di Natale 1990). Although a few cases of incidental catches of cetaceans have been reported, clear evidence is often missing because cetaceans can be released alive at sea by fishermen. Reports of cetaceans caught by longlines include a few striped dolphins, common bottlenose dolphins, Risso's dolphins, false killer whales and sperm whales taken in Italy and Spain (Di Natale and Mangano 1983, Di Natale 1990, Mussi *et al.* 1998). In all these cases, the gear was a surface drifting longline for swordfish.

In the Italian seas, most reports of entanglement in longlines have involved small Odontocetes, particularly striped dolphins, but documented cases exist for Risso’s dolphins (Cataldini and Bello 1987), common bottlenose dolphins, long-finned pilot whales, sperm whales, and a young fin whale (Di Natale 1990, UNEP/IUCN 1994, Centro Studi Cetacei 1987÷1998, Mussi *et al.* 1998). Some individuals (striped dolphins, Risso’s dolphins and common bottlenose dolphins), have been found stranded with hooks in their mouths, or with fishing lines in their larynx, suggesting that in some cases these animals may try to feed on bait or hooked fish. Mussi *et al.* (1998) reported interactions with fisheries using illuminated handlines for squids. These involved small groups of striped dolphins, Risso's dolphins, and long-finned pilot whales waiting near the fishing boats until the light had attracted a great number of squids. Cetaceans would then take profit of the higher prey density and forage near the fishing boats. However, no cetacean bycatch was reported during these interactions.

Comprehensive studies on the potential impact of longlines on cetaceans in the Mediterranean have never been conducted. However, this seems likely to represent a minor threat in the basin.

Entrapment in discarded or abandoned nets. Nets that remain entangled on the sea floor, or that are damaged or worn out, may be discarded or abandoned by fishermen at sea. Gillnets, driftnets or other fishing gear may also be broken or dispersed by storms. These nets can then continue to catch and kill cetaceans and other marine animals for decades, until the net filaments composing the web are degraded (Jefferson *et al.* 1992).

Entanglement in discarded gear is an often overlooked, but potentially important problem. For instance, when proportions of litter were studied on south-eastern Alaska beaches, 76-85% by weight consisted of trawl-web fragments, indicating surprisingly high quantities of nets discarded at sea. Net fragments of all kinds may act as “ghost nets”, and may entrap cetaceans and other marine life while they are simply swimming by, or when they are trying to catch food that is entangled or in the proximity of the net. Some of the fragments may have food organisms growing on them, or entrapped by them, and may occasionally be regarded as food by individual cetaceans (Fertl and Leatherwood 1997).

Several reports exist of marine mammals entangled in net fragments or other discarded fishing gear (O’Hara *et al.* 1986, Fertl and Leatherwood 1997). The available data for the Mediterranean do not allow to evaluate the relative importance of this threat, as compared to bycatch in operating fishing gear. However, it is clear that the practice of discarding nets at sea should be prohibited, and measures should be taken to reduce the occurrence of nets and other fishing gear abandoned or lost at sea (*e.g.*, by active removal from the marine environment whenever possible).

Entrapment in tuna traps. Traditional tuna traps were largely used in Italy in the past, and could entrap coastal cetaceans such as common bottlenose dolphins. The animals, taken alive and rarely reported by fishermen, were usually killed together with tuna in the "death chamber". However, this fishing method is becoming increasingly rare in the Mediterranean, and the current impact of these traps on cetaceans is negligible (Di Natale and Notarbartolo di Sciara 1994).

Cetacean interactions with aquaculture facilities. Interactions between dolphins and aquaculture facilities in the Mediterranean appear to be occurring with increasing frequency, possibly owing to: 1) the rapid expansion of fish farming in coastal waters, and 2) opportunistic behaviour shown by the dolphins possibly as a result of decreasing food resources (Reeves *et al.* 2001, Bearzi *et al.*, In press).

In Cyprus, fishermen claim that dolphins have increased spectacularly as a result of the development of aquaculture, which has been rapidly expanding since 1990. Fishermen blame the fish farms for the large numbers of dolphins staying in Cyprus waters throughout the year, and claim that the dolphins are attracted primarily by the large shoals of fish, mainly boque (*Boops boops*), that have appeared in the vicinity of fish farms (UNEP 1998*b*).

Bearzi *et al.* (In press) noted a relative increase in time spent by bottlenose dolphins around coastal fish farms in eastern Ionian Greece after 1999, and observed that increased nutrient levels, complex substrate and provision of food bait in the proximity of the cages may create a favourable environment and attract potential bottlenose dolphin food prey. In 1981-2000 the aquaculture production of marine fish in Greece increased by 300%, largely due to the development of cage technologies in inshore waters (Anonymous 2000, EEA/UNEP 2000).

In north-eastern Sardinia the construction of a floating fish farm has been linked to increased bottlenose dolphin abundance, and dolphin behavioural changes were recorded possibly as a result of high fish density around the farming area (Diaz Lopez *et al.*, In press).

So far, there is no published evidence that cetaceans may cause direct damage or indirect impact (*e.g.*, by inducing stress in farmed fish) to Mediterranean aquaculture facilities, but it must be considered that the possibility that coastal dolphins may one day learn to exploit this relatively new food source (*e.g.*, by jumping into the cages or damaging them to gain access to the farmed fish) represents a source of concern (Bearzi *et al.* In press). Bottlenose dolphins are known for their behavioural flexibility and their capacity to learn new feeding strategies (Shane *et al.* 1986). If dolphins ever learn ways of gaining access to the farmed fish, hostile reactions by fishermen can be expected (Würsig, In press).

Competitive interactions between cetaceans and fisheries

During the last century, and particularly in the last 50 years, overfishing practices have so impoverished the marine environment that present and future generations of cetaceans (and fishermen) are in trouble (Pauly *et al.* 2000). In studying the effects of fishing and trying to manage fisheries, man has apparently ignored changes in food web dynamics, or has not paid enough attention to complex cause-effect relationships. Only the often overwhelming direct effect of reducing the target species has occasionally been studied; indirect effects have been largely neglected (Smith 1995). Complex ecosystem dynamics and/or lack of research may hide cause-effect links, thus leaving room for continued overexploitation. However, the unwise management of resources has impacted the marine environment to the point that, today, everybody acknowledges the need for preservation of the remaining stocks (Kemp 1996).

Fishery trends and the depletion of fish stocks, worldwide. Global totals of the amount of fish caught during the past half-century provide a misleadingly reassuring view of the state of the world's fisheries (Pauly *et al.* 2000). Most scientists now agree that the overall increase in the world fishery production should not be misunderstood for a healthy status of the marine resources. The *growth rate* of the landings has actually declined steadily since 1950, and reached a plateau at the beginning of the 1990's (FAO 1994, 1997*a*, 1998).

It has been pointed out that "aggregate landings from various stocks which are the subject of a fishery-complex may continue to increase despite local overfishing situations, as long as the process of increase through expansion to new areas and resource elements overshadows the process of decrease through overfishing" (FAO 1997*a*). For instance, the increasing catch of small pelagic species has masked the stagnation or impoverishment in take of demersal fish (FAO 1997*a*, Pauly *et al.* 2000), and it has been stressed that "the world fish supply is increasingly relying on low value species, characterised by large fluctuations in year-to-year productivity, hiding the slow but steady degradation of the demersal high value resources" (Garcia and Newton 1994).

Despite increased fishing effort, landings of some of the most important demersal fish (including *Gadus* sp., *Merluccius* sp., *Melanogrammus* sp.) decreased from 5 million tonnes in 1970 to 1.6 million tonnes in 1993, forcing the fishing industry to target other pelagic species on a lower trophic level, such as *Trachurus capensis* and *Engraulis encrasicholus* (FAO 1994). At a global level, the phenomenon has been described as "fishing down marine food webs", which refers to "a gradual transition in landings from long-lived, high trophic level, piscivorous bottom fish toward short-lived, low trophic level invertebrates and planktivorous pelagic fish" (Pauly *et al.* 1998*a*). According to Pauly *et al.* (1998*a*), this leads at first to increasing catches, then to a phase of transition associated with stagnating or declining catches.

A striking intensification of world fisheries has been recorded since 1950, which corresponded to an increase in the proportion of resources subject to declines in productivity (FAO 1997*a*). Recent reviews confirm that, worldwide, an estimated 44% of the major fish stocks are fully exploited and are, therefore, producing catches that have reached their maximum limit. About 16% of fish stocks are overfished, and there is an increasing likelihood that catches might decrease if remedial action is not undertaken to reduce or suppress overfishing. Another 6% appear to be depleted, and only 3% seem to be recovering slowly (FAO 1998). A global production model showed that the demersal high-value species were overfished and that a reduction of at least 30% of fishing effort was required to rebuild the resources. Given that few countries have established effective control of fishing capacity, around 60% of the major world fish resources are considered in urgent need of management action (FAO 1994, 1997*a*). Such a picture is worsened by the fact that evaluating the impact of fishing activities on the marine environment is a difficult issue, as fishing trends are routinely based on landing data (*i.e.*, the catch brought to the fish market). Unfortunately, these data are largely unreliable, as they are affected by biases that cannot be estimated (Earle 1996). For instance, the biomass of discarded fish – that can account for a very high percentage of the catch[2] – is simply ignored.

In conclusion, the available data on world fishery trends show that marine resources have been exploited beyond reasonable limits and to levels deemed unsustainable in most areas (Earle 1996, Kemp 1996, Caddy *et al.* 1998, Christensen and Pauly 1998, Pauly *et al.* 1998*a*, Pauly *et al.* 2000). In a recent article on Science - co-authored by 19 scientists - it was concluded that "ecological extinction caused by overfishing pre-

[2] A global assessment of fisheries bycatch and discards accounted for 33% (range 22-47%) of the total landings (Alverson *et al.* 1994), and it has been pointed out that the sum of fishery-related mortalities occurring as a result of harvesting often involves a significant number of fish in addition to catch and discard, fishing mortality being the aggregate of all catch mortalities including discard, illegal fishing and misreporting (Alverson and Hughes 1996). For accounts of bycatch rates and discards in Mediterranean trawling fisheries see for instance Carbonell *et al.* (1998), Stergiou *et al.* (1998), Vassilopoulou and Papaconstantinou (1998).

cedes all other pervasive human disturbance to coastal ecosystems, including pollution, degradation of water quality, and anthropogenic climate change" and that the "historical abundances of large consumer species were fantastically large in comparison with recent observations" (Jackson *et al.* 2001).

Fishery trends and the state of Mediterranean fish stocks. Trends similar to those observed at a global scale can be observed in the Mediterranean, where fisheries resources are in a state of over-exploitation driven by rising prices and demand in the past decades. Overfishing and fishing practices largely account for the impact on natural stocks and habitats (EEA/UNEP 2000). According to FAO, the Mediterranean fish stocks have been "fully exploited", with fisheries operating at or close to an optimal yield level, and no expected room for further expansion.

Although Mediterranean fisheries statistics are scarce and unreliable (Stanners and Bourdeau 1995, Earle 1996, FAO 1997*a*), and there is an acute lack of general and historical data (Briand 2000), evidence exists that overfishing and unsustainable harvesting has led to the decline of many fish stocks[3] (Caddy and Griffiths 1990, De Walle *et al.* 1993, Stanners and Bourdeau 1995, FAO 1998, Briand 2000). One of the most pervasive ecological consequences may be the "fishing down marine food webs" phenomenon (Pauly, *et al.* 1998*a*), and it has been recently demonstrated that the mean trophic level of Mediterranean catches has declined significantly and quite steadily since the late 1950s, although fishery landings increased (*e.g.*, Pauly and Palomares 2000, Stergiou and Koulouris 2000). The declining or flattening catch trends in Mediterranean areas are consistent with the observation that these areas have the highest incidence of fully-exploited fish stocks and of stocks that are either overexploited, depleted, or recovering after having been depleted (FAO 1997*a*, 1998). The European Environment Agency also reported that unsustainable harvesting of Mediterranean fish stocks has led to the decline of many, and that demersal fish stocks are usually fully exploited, if not over-exploited, with a general trend towards smaller individual sizes (Stanners and Bourdeau 1995, EEA/UNEP 2000). Small pelagic fish stocks remain highly variable in abundance, depending on environmental conditions (EEA/UNEP 2000).

The effect of this kind of systematic impoverishment of marine food prey resources on cetacean populations is largely unknown (see "Impact of reduced prey availability on cetaceans").

Competition for resources. Human fisheries have the potential to reduce prey availability and affect cetacean food resources (Dayton *et al.* 1995). Such competitive interactions may be both direct, when target prey for cetaceans and fishermen overlap, and indirect, through the human exploitation of resources that may influence the availability of cetacean food prey ("food web competition"; Earle 1996, Trites *et al.* 1997). A case of possible competition between fisheries and marine mammals has been studied in the Pacific Ocean, where it has been suggested that the excessive growth and capitalisation of fishing fleets inevitably result in over-exploitation of the available resources, thus representing a threat to marine mammals. The availability of resources that are important to marine mammals would therefore decrease with an increased exploitation of fish stocks for human consumption (Trites *et al.* 1997).

Cetaceans, in turn, can rely on resources of economic interest and may affect fisheries through direct and "food-web" competition (Earle 1996). The claim that cetaceans compete with fisheries has been used to support economic incentives for commercial hunting, and it was observed that recent initiatives to quantify the impacts of cetaceans on world fisheries have been intended to help build a case in favour of expanded commercial whaling (Reeves *et al.*, In press). However, whilst the deleterious impact of overfishing on several marine ecosystems has been well documented, it is still unclear whether cetacean removal – including the intentional killing of cetaceans charged of net depredation - would eventually benefit the fisheries.

Output obtained from ecosystem models (*e.g.*, Christensen and Pauly 1992) and long-term observations (*e.g.* Estes *et al.* 1998) suggested that removing natural predators from an ecosystem may have unpredictable effects, *i.e.* not those that could be expected based on simplistic predator-prey models. The available data actually indicate

[3] Decreasing catches due to overfishing have been recorded in several Mediterranean subareas, particularly as far as demersal fish are concerned (*e.g.*, Jardas 1985, Papaconstantinou *et al.* 1985*a*, Azzali and Luna 1988, Levi and Andreoli 1989, Bombace 1990, Andreoli *et al.* 1995, Jardas *et al.* 1997, Stergiou *et al.* 1997, Ardizzone *et al.* 1994, Cau *et al.* 1994, De Ranieri *et al.* 1994, Levi 1994).

that fish may be far more important predators of other fish than are marine mammals (Trites 1997, Trites *et al.* 1997, Mangel and Hofman 1999, Trites *et al.* 1999). The ultimate effect of removing natural top predators would be a loss of diversity, physical complexity, productivity and resilience (Naeem *et al.* 1994, Trites 1997).

The understanding of predator-prey interactions and ecosystem functioning therefore represents an essential conservation means, which may allow to evaluate the potential effects of food-web interactions between marine mammals and man (Mohn and Bowen 1996, Estes *et al.* 1998, Pauly *et al.* 1998*b*, Croxall *et al.* 1999). Ecosystem modelling has been proposed in recent years as a viable tool for understanding the complex ecological interactions between cetaceans, fisheries and other ecosystem components (*e.g.*, Smith 1995, Earle 1996). As reported by Reeves *et al.*, (2001), "modelling might elucidate counter-intuitive trends which in turn could help explain why dolphin depredations occur in some areas and not in others".

For instance, a combination of burgeoning fisheries, increased ocean temperature and depletion of marine mammals have been reportedly triggering the collapse of the kelp forest ecosystem in western Alaska (Estes *et al.* 1998). A chain of ecological interactions beginning with reduced or altered fish stocks in the oceanic environment sent pinniped populations to decline; pinniped numbers became so reduced that some of the killer whales who once fed on them expanded their diet to include sea otters (*Enhydra lutris*); this shift in killer whale foraging behaviour prompted the collapse of the sea otter population, which caused a sea urchin population overgrowth; unregulated urchin populations increased rapidly and overgrazed the kelp forests, thus setting into motion a host of effects in the coastal ecosystem. This chain of interactions was probably initiated by anthropogenic changes in the offshore oceanic ecosystem (Estes *et al.* 1998). This remarkable study highlights a number of key points about the way ecosystems work, including the unappreciated importance that uncommon or transient species of top carnivores can have in controlling community structure, and the need for large-scale approaches to ecological research.

Although the idea of multi-species or ecosystem management may be appealing, it has been argued that this level of management is extremely difficult to conceive and implement due to data needs, inherent complexity and dynamism of natural systems, and inadequacy of knowledge about functional relationships (Mangel and Hofman 1999, Reeves *et al.*, In press). As stressed by Okey and Pauly (1999) "just as real-world food webs contain complex interactions among species, so too must scientists and others interact to describe food webs in realistic ways". In the capacity to interact and collaborate in ways that are both multidisciplinary and inspired by a genuine search for truth reside the chances of success of this "ecosystem approach". If given proper development and implementation, software tools such as "Ecopath-Ecosim" (Christensen and Pauly 1992) may greatly benefit future large-scale management.

Today, the lack of comprehensive and reliable fish stock assessments and longitudinal studies aimed at describing and quantifying Mediterranean ecosystem components remains one of the main problems to be addressed by scientists and managers willing to adopt an ecosystem approach. As long as this situation doesn't change "dolphins may often serve as scapegoats for unsustainable fishing practices" (Reeves *et al.* 2001).

Impact of reduced prey availability on cetaceans

Over the last decade, the reduction of food prey resources has been considered by several authors as a threat of primary importance that may have contributed to the decline of some cetacean populations in the Mediterranean (Perrin 1988, Reeves and Leatherwood 1994, UNEP/IUCN 1994, Reeves *et al.*, In press). It is therefore surprising that the issue has been given so little consideration.

As noted in the previous paragraph, one of the reasons that may have discouraged research in this field is that ecosystem dynamics are exceedingly complex, and their investigation requires sophisticated tools, extensive background information, and a multidisciplinary approach. Whilst powerful software tools and analytical approaches have become available in the last several years, research is hampered largely because 1) appropriate datasets are rarely obtainable, 2) expertise in this field is still lacking, and 3) collaboration among scientists from different disciplines (*e.g.*, fishery scientists, fish biologists, marine mammalogists, oceanographers etc.) is not the rule in Mediterranean countries. Perhaps for these and other reasons, most cetacean scientists have been focusing their attention on threats that are less complex and relatively easier to document.

Although complex food-web dynamics are difficult to study, it is clear that reduced prey availability caused by overfishing of Mediterranean fish stocks and other causes, may impact cetaceans in a number of ways. Several Mediterranean cetaceans - particularly coastal species such as short-beaked common dolphins and common bottlenose dolphins - compete for prey species of commercial interest that have been heavily exploited by human fisheries during the last decades. Dolphins, as top predators, can be affected due to a decreased prey biomass or to a reduced mean size or nutritional value of individual prey items.

Moreover, fish distribution may become more scattered, and seasonal and yearly trends of abundance may show wider fluctuations due to the combined effects of overfishing, pollution and environmental variables (FAO 1997*b*, Bombace 1990, Stergiou *et al.* 1997, Degobbis *et al.* 2000). Marine mammals with widespread distributions may react to worsening habitat conditions by leaving their core areas either permanently or temporarily, as changes in the distribution of key prey represent primary factors determining dolphin movements and habitat preferences (Evans 1971, Wells *et al.* 1990, Hanson and Defran 1993, Maze and Würsig 1999). As cetacean feeding preferences are related to prey ecology and availability in their own habitat, diet modifications may occur as a response to fishery exploitation (Northridge 1984, Estes *et al.* 1998). The long-term, population-level, impact of changes in distribution and feeding habits due to reduced prey availability is largely unknown, and deserves further investigation.

Behaviourally flexible cetacean populations affected by a temporarily lower prey abundance, or by shifts in food prey availability, may react in part by devoting more time to foraging or by displaying a wider range of feeding strategies (*e.g.*, Shane 1990, Bräger 1993). The capability of some cetacean species to adapt to fluctuations in the abundance of some prey by feeding on other prey is clearly an important requisite to withstand seasonal and yearly variations in food supply (Northridge 1984). A consistently lower prey availability, however, implies higher energetic costs for the dolphins to secure their daily food intake. This has the potential to affect population fitness by reducing the range of behavioural flexibility that is necessary to react with appropriate strategies to other environmental fluctuations, or to a further worsening of conditions (*e.g.*, further prey reduction, increased human disturbance, etc.).

As stressed by Chapman and Reiss (1999) "the lack of sufficient food to maximise reproductive potential may be the most important regulator of population size in animals". As a general rule, increased time spent searching for food and feeding reduces the time that can be devoted to social and reproductive activities, including mating, weaning, and caring for the offspring, with negative repercussions on reproductive success (Wilson 1979, Valiela 1995). More dramatic effects may be recorded in the long-term, if access to prey resources is consistently impaired by human competition, habitat degradation, or both. This may ultimately result in: 1) increased levels of stress, 2) loss of weight and physical strength accounting for emaciation (*e.g.*, in common bottlenose dolphins: Politi *et al.* 2000) or starvation, 3) reduced reproductive rates, due to behavioural modifications and negative feedback mechanisms, 4) behavioural responses leading to dispersion or emigration towards areas with higher food availability, 5) increased inter- and intra-specific competition and aggressive behaviour (*e.g.*, in common bottlenose dolphins: Ross and Wilson 1996, Patterson *et al.* 1998), 6) increased susceptibility to disease due to reduced immune responses (*e.g.*, in striped dolphins: Aguilar and Raga 1993), and 7) higher mortality rates (Baker 1978, Sinclair 1983, Swingland 1983, Fowler 1987, Apanius 1998, Hofer and East 1998, von Holst 1998).

In addition, reduced food prey availability may increase or exasperate the extent of interactions between cetaceans and fishermen, and expose the former to higher risks of intentional takes and harassment (Northridge 1984, UNEP/IUCN 1994, Fertl and Leatherwood 1997). Unfortunately, no clear evidence is currently available to address this issue. It has been noted (Reeves *et al.* 2001) that conflict occurs in certain areas where target fish stocks are relatively abundant (*e.g.*, in the Asinara Island, Italy) whilst in some other areas where target fish stocks are depleted there is little or no conflict between dolphins and fisheries (*e.g.*, in the Kvarneric, Croatia). The complexity of ecosystem dynamics may be responsible for the lack of simple cause-effect evidence.

Reduced prey availability and nutritional stress may be an issue in the reduced dolphin abundance or mass mortality events observed in several Mediterranean areas. For instance, an unusually high effort devoted to food search has been recorded for Mediterranean common bottlenose dolphin population units that have been consistently studied during the last decade (Politi 1998, Bearzi *et al.* 1999). Approximately 40% of "resident" common bottlenose dolphins in the eastern Ionian Sea, where demersal fish resources have been over-fished (Papaconstantinou *et al.* 1985*a,b*) were reportedly emaciated (Politi *et al.* 2000). In the same area, a decline in short-beaked common dolphin numbers was consistent with the hypothesis of reduced prey availability or increased prey patchiness (Politi and Bearzi, In press). In Mediterranean striped dolphins, inadequate nutrition has been cited possibly having played a role in an epizootic outbreak (Aguilar and Raga 1993) and to be responsible for their extremely elevated age at sexual maturation observed in this region as compared to other conspecific populations inhabiting waters were food resources were more abundant (Calzada *et al.* 1996, Aguilar 2000).

Risky synergies. Several factors other than overfishing may contribute to a reduced prey availability, or induce changes that can affect the marine food webs. For instance, global environmental changes (MacGarvin and Simmonds 1996) may combine with overfishing and habitat contamination to jeopardise ecosystem dynamics. Moreover, the build-up of man-made toxic contaminants may reduce the reproductive success or depress the immune-responses of top predators, including both fish and marine mammals (*e.g.*, Fossi *et al.*, In press).

The impact of man-made toxic compounds on biologic communities is a major source of concern. Many organochlorine compounds, for instance, are responsible for endocrine dysfunctions in a number of organisms, including cetacean preys. By affecting the reproductive success and the sex ratio of a species, contamination may negatively affect fish stocks (Focardi *et al.* 1998, Johnson *et al.* 1988, IEH 1995, Janssen *et al.* 1997, Arcand-Hoy and Benson 1998), with cascade effects on both cetaceans and fisheries.

Finally, it must be observed that contamination and food scarcity may act synergistically, as malnutrition may prompt mobilisation of lipophilic contaminants that are "stored" in the blubber of cetacean species as food reservoir, thus making them more exposed to their toxic effects at a time when they are already debilitated by food scarcity.

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