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Ecology, status and conservation of short-beaked common dolphins *Delphinus delphis* in the Mediterranean Sea

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ABSTRACT

1. The recent decline in the Mediterranean population of short-beaked common dolphins *Delphinus delphis* has been the subject of scientific controversy and political indifference. Research on these animals has been very limited and there has been no large-scale, systematic effort to assess and monitor their abundance and distribution. The consequent lack of data has prevented a good understanding of historical and ongoing trends.

2. Nonetheless, literature and osteological collections confirm that common dolphins were widespread and abundant in much of the Mediterranean Sea until the late 1960s and that their decline occurred relatively quickly. Today, common dolphins remain relatively abundant only in the westernmost portion of the basin (Alboràn Sea), with sparse records off Algeria and Tunisia, concentrations around the Maltese islands and in parts of the Aegean Sea, and relict groups in the south-eastern Tyrrhenian and eastern Ionian Seas. Otherwise, these dolphins are rare in, or completely absent from, Mediterranean areas where information is available.

3. Circumstantial evidence and qualitative judgements by the authors suggest that the following factors may have contributed to the decline of common dolphins: reduced availability of prey caused by overfishing and habitat degradation; contamination by xenobiotic chemicals resulting in immunosuppression and reproductive impairment; environmental changes such as increased water temperatures affecting ecosystem dynamics; and incidental mortality in fishing gear, especially gillnets. The cumulative importance of these factors is poorly understood, and as a result, few conservation measures have been implemented.

4. This paper reviews current knowledge and suggests priorities for action aimed at identifying and mitigating the main threats to common dolphins in the Mediterranean, with the ultimate goal of restoring the species' favourable conservation status in the region.

Keywords: cetaceans, conservation, gill-netting, marine mammals

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INTRODUCTION

The short-beaked common dolphin *Delphinus delphis* (Fig. 1) is a small cetacean species with a wide distribution. Like most other cetaceans, however, it is not panmictic and occurs as a series of geographically separate populations (Heyning & Perrin, 1994; Perrin & Brownell, 1994; Jefferson & Van Waerebeek, 2002). On a global scale, the systematics and zoogeography of the genus *Delphinus* are subjects of ongoing investigation (e.g. Jefferson & Van Waerebeek, 2002). At present, two species are recognized unanimously – the short-beaked common dolphin *D. delphis* and the long-beaked common dolphin *D. capensis* (Heyning & Perrin,

Fig. 1. Two short-beaked common dolphins photographed in the eastern Ionian Sea show the characteristic morphology of the species: short beak, narrow dark flipper stripe, occasional white patch in dorsal fin. Photo by G. Bearzi.

1994; Rosel, Dizon & Heyning, 1994). Only short-beaked common dolphins inhabit the Mediterranean Sea (Fig. 2) and adjacent water bodies, and therefore throughout this paper references to 'common dolphins' can be understood to mean this species.

The short-beaked common dolphin was listed as lower risk 'conservation dependent' in the 1996 IUCN Red List of Threatened Animals (Baillie & Groombridge, 1996). This designation reflected that although some populations had declined from historical levels, the aggregate world population remained in the low millions (e.g. Yukhov, Petukhov & Korkhov, 1986; Gaskin, 1992; Wade & Gerrodette, 1993; LeDuc, 2002). Therefore, the species as a whole did not appear to fit the Red List classification criteria for vulnerable or endangered. The 'conservation dependent' caveat was included as a way of acknowledging the importance of maintaining conservation measures to minimize incidental mortality of dolphins in the eastern tropical Pacific tuna fishery (see Gosliner, 1999), as well as other measures taken in national waters to limit the numbers taken deliberately and incidentally.

By contrast, in the Mediterranean Sea, conservation problems for the species have been recognized since the 1970s. The UNEP Mediterranean Action Plan (Barcelona, 1975) recommended strong conservation measures to protect the species but without specifying what these should be. Determining the conservation status of Mediterranean common dolphins was cited as a priority in past cetacean action plans of the IUCN Species Survival Commission (Perrin, 1988; Reeves & Leatherwood, 1994) and the latest such plan notes that they have declined dramatically in the central and eastern Mediterranean and that conservation action is urgently needed to prevent extirpation in this portion of the species' range (Reeves *et al*., 2003). In 2003 the Mediterranean common dolphin 'subpopulation' was listed as endangered in the IUCN Red List of Threatened Animals, based on criterion A2, which refers to a 50% decline in abundance over the last three generations, the causes of which 'may not have ceased *or* may not be understood *or* may not be reversible' (http://www.redlist.org).

Although both public and institutional awareness of the importance of protecting the natural environment has increased in several Mediterranean countries during the last few

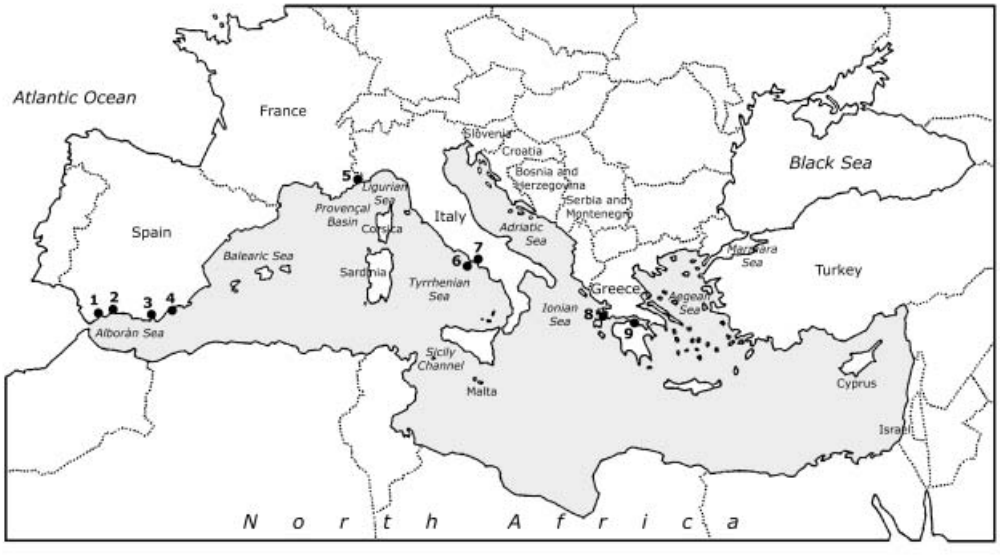

Fig. 2. Map of the Mediterranean Sea showing the locations cited in the text. Numbers indicate the following localities: (1) Estepona; (2) Málaga; (3) Almería; (4) Gulf of Vera; (5) Principality of Monaco; (6) island of Ischia and Campanian Archipelago; (7) Naples; (8) island of Kalamos; (9) Gulf of Corinth.

decades, little progress has been made towards understanding the causes of the common dolphin's regional decline. Perhaps at least partly because of this dearth of understanding, no specific conservation measures have been taken to address the problem (Notarbartolo di Sciara & Demma, 1997). The *Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area* (ACCOBAMS), which came into effect in 2001, has proposed that the status of common dolphins in the Mediterranean be evaluated in a comprehensive manner, with the goals of estimating distribution and abundance throughout the basin, identifying critical habitat and characterizing threats. Such an evaluation would entail a series of localized surveys to locate any concentrations of animals that might remain, with a priority in the eastern Mediterranean (ACCOBAMS, 2002).

A major hindrance to determining the status of common dolphins in the Mediterranean is the fragmentary character of the literature, which is composed almost exclusively of unpublished reports, academic theses or dissertations, conference proceedings and other non-refereed publications. Although some of these studies are of high scientific quality and have been long running, only a small proportion of the relevant available data has been published in peer-reviewed scientific journals. This situation makes it difficult to evaluate what is known even for many of the areas where focused research on the species has been carried out. Questions about the past and present occurrence of common dolphins in Mediterranean areas where no cetacean surveys have been conducted (particularly along much of the north African coasts and in far-eastern portions of the basin) remain completely open, and nothing is known about current abundance and trends in those areas.

In this article, we review and summarize information on common dolphins in the Mediterranean, with particular emphasis on their conservation. We discuss potential threats, both 'natural' and anthropogenic, and attempt to define the most urgent research and management needs for the species in this region.

KEY AREAS OF DISTRIBUTION

There is no basin-wide estimate of abundance for common dolphins in the Mediterranean Sea. Line transect ship surveys of the Alboràn Sea in 1991–92 produced an estimate of 14 736 (CV = 0.38; 95% CI = 6923–31 366), with a density of 0.16 dolphins/km^2, but no estimates were made for this species elsewhere in the western Mediterranean due to the low number of sightings (Forcada & Hammond, 1998). Vella (1998, in press) combined data from ship and aerial strip-transect surveys conducted 1997–2002, and obtained a density estimate of 0.135 dolphins/km^2 (CV = 0.28; 95% CI = 0.066–0.290) in the area around the Maltese islands. Apart from these studies, the presence of common dolphins, and in some instances a qualitative assessment of their relative abundance, can be inferred for other portions of the basin on the basis of evidence from more general cetacean surveys and a few longitudinal investigations.

Groups containing several hundred individuals are occasionally observed in the Alboràn Sea and in the Gulf of Vera (southern Spain), in contrast with the smaller groups recorded elsewhere in the Mediterranean (Cañadas, Sagarminaga & García-Tiscar, 2002). There are sparse records off the coast of Algeria and Tunisia where, however, survey coverage has been limited (Boutiba, 1994; Boutiba & Abdelghani, 1995; Zanardelli, Panigada & Bearzi, in press). Possibly isolated groups are present around Sardinia and Corsica, particularly off their western coasts (Notarbartolo di Sciara *et al.*, 1993; Gannier, 1995; Lauriano & Notarbartolo di Sciara, 1995; Forcada, 1998; A. Gannier, personal communication). Common dolphins are seen in the early summer in the south-eastern Tyrrhenian Sea off the island of Ischia (Mussi, Miragliuolo & Bearzi, in press a). The species is also present in the Sicily Channel

(Cavalloni, 1988; Arcangeli *et al*., 2001; Zanardelli *et al*., in press), with larger groups being observed around Malta (Vella, 1998, 1999, in press). Common dolphins can be found in portions of the eastern Ionian Sea, particularly around the island of Kalamos (Politi, 1998; Politi & Bearzi, in press), and in the Gulf of Corinth (Frantzis & Herzing, 2002). Sighting and stranding data indicate a regular presence of common dolphins in the Aegean Sea, particularly in the Thracian Sea, Northern Sporades, the southern Evvoikos Gulf, the Saronic Gulf and the Dodekanese (Frantzis, 1996; Öztürk & Öztürk, 1998; Carpentieri, Corsini & Marini, 1999; Casale, Milani & Kallianiotis, 1999; Zafiropoulos, Verriopoulos & Merlini, 1999; Frantzis *et al*., in press). Apart from the eastern Ionian Sea and Aegean Sea, no reliable data exist for most of the eastern Mediterranean basin, except for a rare occurrence of common dolphins off the Israeli coastline (Goffman *et al*., 2000; Scheinin, 2003). Figure 3 attempts to outline the approximate species' distribution and relative density in the Mediterranean, based on a review of recent literature.

Coastal groups in western Greece seem to exhibit relatively high levels of site fidelity (Politi, 1998), but little is known about the movements and ranging patterns of animals living offshore. The case for regarding Mediterranean common dolphins as a distinct population is not perfect, and admittedly rests upon a somewhat complicated chain of inference. Genetic studies indicate a significant level of divergence between Mediterranean and Atlantic populations (Natoli *et al*., in press). Differences in contaminant levels between dolphins from the Alboràn Sea and Atlantic Ocean also suggest a certain degree of isolation. Organochlorine concentrations in Alboràn Sea dolphins were about double those typical of dolphins in neighbouring North Atlantic waters and showed a completely different profile [proportions between polychlorinated biphenyl (PCB) congeners, the DDE/tDDT ratio, etc.] (Borrell *et al*., 2001). Genetic exchange between common dolphins from the Mediterranean Sea and Atlantic Ocean, to the extent that it occurs, appears to involve only animals from the Alboràn Sea (Natoli *et al*., in press), possibly due to oceanographic features such as the Almería-Orán thermohaline front (Tintoré *et al*., 1988) that has been shown to function as an ecological

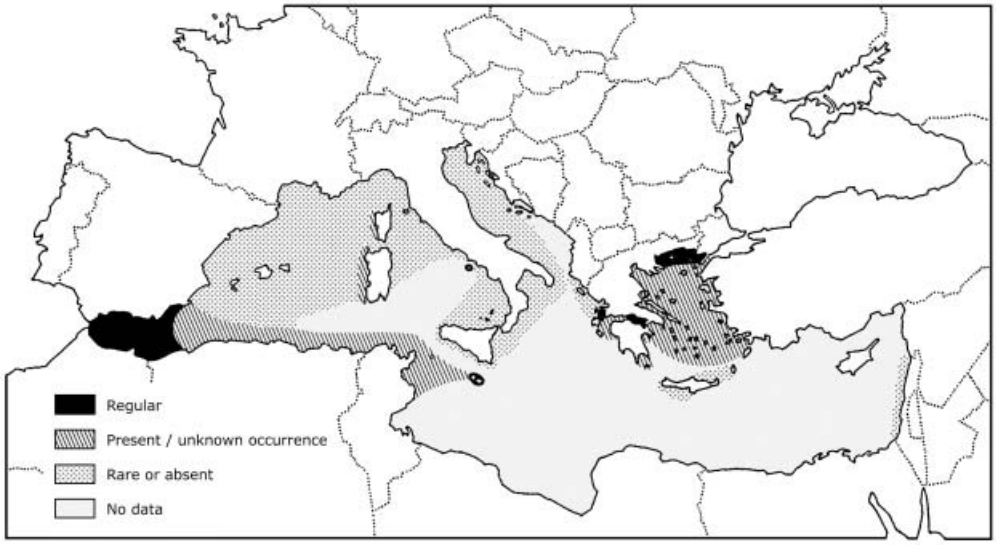

Fig. 3. Approximate distribution and relative density map of short-beaked common dolphins in the Mediterranean Sea. Atlantic Ocean, Marmara Sea and Black Sea have not been considered. Drawing by Massimo Demma.

barrier for some species (Sanjuan, Zapata & Alvarez, 1994). There is little indication of movement by common dolphins through the narrow Dardanelles Strait between the Aegean and the Marmara and Black Seas. Intrusions or migrations to and from the Aegean Sea cannot be excluded, since common dolphins are known to occur in the western part of the Marmara Sea (Topaloglu, Öztürk & Colak, 1990; Öztürk & Öztürk, 1997). Therefore, genetic mixing may occur between Aegean Sea and Black Sea common dolphins due to movements through the Turkish Straits System (Barabasch, 1935; Kleinenberg, 1956). Black Sea common dolphins are considered by some Russian investigators to constitute an endemic subspecies, *D. delphis ponticus* (Barabasch, 1935; Tomilin, 1957; Heptner *et al*., 1996). A preliminary study of skull morphometrics (Amaha, 1994) suggested differences between Black Sea and Mediterranean common dolphins. In contrast, a genetic comparison of relatively small samples (eight Black Sea, 20 central Mediterranean) revealed no significant differences between them ($P > 0.05$; Natoli *et al.*, in press). Clearly, further work based on larger samples is needed to characterize the relationship between Black Sea and Mediterranean common dolphins. It is acknowledged that some genetic exchange might occur in portions of the Aegean Sea where favourable habitat still exists (e.g. in the Thracian Sea; Frantzis *et al.*, in press). However, what remains between the Aegean and Alboràn sectors of the Mediterranean seems to be only isolated, remnant groups (possibly indicative of further population substructure).

ECOLOGY AND BEHAVIOUR

The short-beaked common dolphin is a poorly known species. Outside the Mediterranean, it has been studied in a few areas, mostly in the context of abundance and distribution studies (Evans, 1971, 1975; Hui, 1979, 1985, 1994; Dohl, Bonnell & Ford, 1986; Selzer & Payne, 1988; Holt & Sexton, 1990; Reilly, 1990; Scott & Perryman, 1991; Gaskin, 1992; Perryman & Lynn, 1993; Wade & Gerrodette, 1993; Chivers & DeMaster, 1994; Dizon, Perrin, & Akin, 1994; Fiedler & Reilly, 1994; Ferrero & Walker, 1995; Gowans & Whitehead, 1995; Forney & Barlow, 1998; Brereton, Williams & Williams, 1999; M. Bearzi, 2001; Neumann, 2001a,b; Neumann, Leitenberger & Orams, 2002). Relatively little is known about groups living near or on the continental shelf edge, and the ecology and behaviour of offshore populations remain largely unknown (Evans, 1994).

In the Mediterranean, common dolphins are found in both pelagic and neritic environments (Notarbartolo di Sciara *et al*., 1993; Notarbartolo di Sciara & Demma, 1997; Cañadas *et al*., 2002), occasionally sharing the former with striped dolphins *Stenella coeruleoalba* (Viale, 1985; Fabbri & Lauriano, 1992; Forcada *et al*., 1994; Sagarminaga & Cañadas, 1995; Mussi *et al*., 1998; Airoldi *et al*., 1999) and the latter with common bottlenose dolphins *Tursiops truncatus* (Politi, Airoldi & Notarbartolo di Sciara, 1994; Bearzi & Notarbartolo di Sciara, 1995; Cañadas *et al*., 2002). Mixed-species groups of common, striped and Risso's dolphins *Grampus griseus* have been consistently observed in the pelagic waters of the Gulf of Corinth, Greece (Frantzis & Herzing, 2002). Frequent associations with striped dolphins also have been recorded in the Alboràn Sea (García-Tiscar *et al*., 2000) and near the Campanian Archipelago (Mussi *et al*., in press a) while occasional associations with bottlenose dolphins have been observed in the Sicily Channel (Cavalloni, 1988; Pace, Pulcini & Triossi, 1998) and north-eastern Adriatic Sea (Bearzi, 1996). Frantzis & Herzing (2002) compared the occurrence of mixed groups in three Mediterranean Sea areas where common and striped dolphins are sympatric, and noticed that the incidence of mixed-species sightings increased as the relative abundance of common dolphins decreased. Determining why common dolphins have different patterns of association with other cetacean species in different Mediterranean areas will require further investigation.

Mediterranean common dolphins are typically found in groups of 50–70 animals, with aggregations of 100–600 animals occasionally recorded (Notarbartolo di Sciara *et al*., 1993; Mussi *et al*., in press a; Vella, in press; Cañadas *et al*., 2002). In the eastern Ionian Sea coastal waters, however, groups rarely include more than 15 individuals, and groups greater than 40 were never observed (Politi & Bearzi, in press).

The sparse information available on the foraging ecology of common dolphins in the Mediterranean indicates relatively flexible feeding habits, with a preference for epipelagic and mesopelagic fish, similar to what has been observed outside the basin (e.g. Evans, 1975; Collet, 1981; Overholtz & Waring, 1991; Berrow & Rogan, 1995; Silva & Sequeira, 1996; Ohizumi *et al*., 1998; Birkun, 2002). The stomach contents of stranded individuals from the Ligurian Sea and western Mediterranean indicate a diet based primarily on shoaling fish such as European anchovy *Engraulis encrasicolus*, European pilchard *Sardina pilchardus*, round sardinella *Sardinella aurita* and garpike *Belone belone*, but also on eurybathic cephalopod and crustacean species (Orsi Relini & Relini, 1993; Boutiba & Abdelghani, 1995; Cañadas & Sagarminaga, 1996). In coastal waters of the eastern Ionian Sea, shoaling fish including anchovies and sardines are key prey (Bearzi, 2000; Agazzi, Bearzi & Politi, in press).

Recent evidence of direct interactions between common dolphins and fishing operations in the Mediterranean is scarce, possibly reflecting the species' low current abundance. However, such interactions were said to have been frequent in the early 20th century (e.g. Brunelli, 1932), when common dolphins – reportedly present in very large numbers – were regarded by fishermen either as vermin or as useful indicators of fish schools around which the nets could be set. Barone (1895) reported severe, frequent depredation and gear damage suffered by Ligurian fishermen who targeted anchovies with gillnets set during the night. In the Gulf of Naples, interactions between common dolphins and fishermen have been reported both historically and recently. Local fishermen claim that cooperative fishing occurs, with the fishermen taking advantage of fish aggregations actively chased towards the surface by common dolphins. In the past, fish rewards were reportedly offered to the dolphins in reciprocation (Mussi & Miragliuolo, in press). These kinds of interactions between common dolphins and local fisheries in the Gulf of Naples have been reported since the beginning of the 20th century (Brunelli, 1932; Police, 1932). Near Málaga and Estepona, Spain, common dolphins follow purse-seine boats at night, surround the net when it is set and feed from outside the net on small pelagic fish that escape from the net or protrude from the mesh (Abad *et al*., in press; X. Valeiras, personal communication) As a result of these interactions, some fishermen from Estepona consider common dolphins as a 'plague', while in the area of Málaga fishermen also consider the benefits of having the dolphins concentrate prey.

Most of the information concerning the ecology and behaviour of common dolphins in the Mediterranean comes from longitudinal studies conducted in and around the Alboràn Sea, Sicily Channel, south-eastern Tyrrhenian Sea and eastern Ionian Sea. In the Alboràn Sea, where this species has been studied since 1992, the average group size is very large (mean = 68.4, SD = 102.39, $n = 534$, range 1–600) while in the Gulf of Vera (situated further north-east on the Spanish coast), it is much smaller (mean = 47.5, SD = 50.17, $n = 123$, range 1–300; Universidad Autónoma de Madrid & Alnitak, 2002). Sighting frequencies for common dolphins are higher in the Alboràn Sea (0.023 groups/km, or 1.74 dolphins/km) than in the Gulf of Vera (0.007 groups/km, or 0.36 dolphins/km). Common dolphins are sighted mostly in and near the Bay of Almería and around Málaga and Estepona, areas known to contain high concentrations of sardines (Gil, 1992). Data collected during the past decade suggest that the Alboràn Sea is an important feeding and breeding ground for common dolphins. In this area, surface feeding was observed during 11.2% of all sightings, and 46.4%

of all groups included calves. Calves were seen year round but especially between April and July (Universidad Autónoma de Madrid & Alnitak, 2002).

In the waters around Malta, where research started in 1997 (Vella, 1998), common dolphin groups average 26 individuals (SD = 33, $n = 85$). Larger groups were observed in September and October, when 75% of common dolphin sightings in Malta's territorial waters ranged between 150 and 250 individuals (A. Vella, personal communication). In this area, common dolphins reportedly associate with bluefin tuna *Thunnus thynnus* between May and July (35% of sightings), and with dorado *Coryphaena hippurus* between August and January (40% of sightings; Vella, in press).

In the south-eastern Tyrrhenian Sea, the presence of common dolphins off the northern coast of the island of Ischia, Italy, has been consistently documented since 1997 (Mussi *et al*., in press a). The animals are sighted mostly in the summer over the submarine canyon of Cuma, a highly productive marine area characterized by high pelagic biodiversity and multi-species associations (Mussi *et al*., in press b). Based on preliminary photo-identification data, common dolphins may be using the area on a seasonal basis. Groups observed around Ischia are relatively large (mean = 65.5, SD = 23.94, $n = 41$, range 35–100 individuals) and often observed in association with striped dolphins, particularly during surface feeding targeting shoaling prey. Surface feeding occurs frequently and the Atlantic saury *Scomberesox saurus* (a seasonal fish that is highly valued on local markets) is a typical prey of common dolphins (Mussi *et al*., in press a).

Around the island of Kalamos, in the eastern Ionian Sea, a community (*sensu* Wells, Scott & Irvine, 1987) of approximately 100 common dolphins has exhibited a high degree of site fidelity since studies began in 1993 (Politi, 1998). Common dolphin groups were observed a total of 882 times in the springs and summers 1993–2002. Group sizes decreased significantly after 1996 (Student's $t = 9.66$, $P < 0.001$). The mean group size was 12 in 1993–96 (median = 9, SD = 9.08, $n = 157$, range 1–40) and dropped to seven in 1997–2002 (median = 6, SD = 4.42, $n = 725$, range 1–32). In the years 1993–2000, the mean sighting frequency was 0.016 groups/km (or 0.11 dolphins/km), but in 2001–02, there was a significant decrease in the sighting frequency, that dropped to 0.007 groups/km (or 0.04 dolphins/km; Student's $t = 4.88$, $P < 0.001$). The number of individuals encountered in the study area has decreased continually, and many individuals that used to be seen regularly until 1996 have disappeared (Politi & Bearzi, in press; Tethys Research Institute, unpublished data). Common dolphins are often seen feeding on shoaling prey near the surface and have never been observed to interact with sympatric bottlenose dolphins, that seem to focus on demersal prey (Ferretti, Bearzi & Politi, 1998). Common dolphins around Kalamos exhibit a highly fluid fission-fusion social system, and it has been suggested that this flexibility may enable the animals to adapt to environmental shifts and fluctuating prey availability (Bruno, 2001; Bruno, Politi & Bearzi, in press).

PAST AND PRESENT TRENDS IN ABUNDANCE

Delphinus delphis may have been one of the most abundant cetacean species in the Mediterranean basin until at least the early 20th century. Although a certain number of misidentifications exist in past accounts (e.g. Richard, 1936, plates VI.1, VII.4; Tortonese, 1965, p. 183), in which striped dolphins were mistakenly labelled as common dolphins (Poggi, 1982), literature, photographic records and osteological collections unambiguously indicate that common dolphins used to be abundant in many parts of the Mediterranean where they are now absent or extremely rare (Giglioli, 1880; Barone, 1895; Arbocco, 1969; Pilleri, 1970; Duguy & Cyrus, 1973; Casinos & Vericad, 1976; Pilleri & Gihr, 1977; Casinos, 1982; Cagnolaro, Di Natale & Notarbartolo di Sciara, 1983; Pilleri & Pilleri, 1982, 1983; Poggi, 1986; Cagnolaro,

1996). Brunelli (1928, 1932) reported *D. delphis* to be a common species in Mediterranean waters off Spain, France, Italy, former Yugoslavia (Slovenia, Croatia, Bosnia and Herzegovina, and Montenegro), and Turkey. Of the dolphins killed as a result of conflicts with fishermen off Liguria and Sardinia, Italy, 1914–17, and ending up in osteological collections, 29 (64.4%) were positively identified as *D. delphis* and 16 (35.6%) as *T. truncatus*, whereas none were *S. coeruleoalba* (Poggi, 1986). Bompar (2000), reviewing historical information and quoting literature published between 1863 and 1929 to document the presence of common dolphins along the coasts of France, concluded that the species used to be abundant from the region of Roussillon to the islands of Hyères, and that bycatch of common dolphins in fishing gear was a common occurrence. The same author also provided evidence that, at least in some of the quoted sources, common dolphins were not confused with other cetacean species. A popular book by Cousteau & Diolé (1975) included photographs of large schools of common dolphins, reportedly taken in the years 1957–58 off the Mediterranean coasts of France and the Principality of Monaco, where the species apparently was common. Strandings data provide unambiguous evidence for declines of common dolphins in various Mediterranean areas, e.g. along the Spanish (Grau *et al*., 1986; Borrell *et al*., 2000) and French Mediterranean coasts (data from Duguy & Budker, 1972; Duguy, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989a,b, 1990, 1992; Van Canneyt, Dabin & Collet, 1998; Van Canneyt *et al*., 1999; Van Canneyt, Leniere & Collet, 1999; Van Canneyt, Heintz & Poncelet, 2000; Van Canneyt, 2001, 2002; Fig. 4). The decline in the French sector has been matched by a concurrent increase of striped dolphins, with the trajectories of the two species crossing in the early 1970s (Fig. 4). However, the most compelling evidence of such a shift is provided by a comprehensive review of acquisitions of cetacean specimens by museums and zoological collections in Italy, 1601– 1993 (Cagnolaro, 1996). In that review, the trends in acquisitions of *D. delphis* ($n = 56$), *T. truncatus* ($n = 109$) and *S. coeruleoalba* ($n = 243$) from 1851 to 1993 show a steep decline of common dolphins, in stark contrast with an equally steep, simultaneous increase of striped dolphins (Fig. 5).

Even though quantitative documentation of trends rests on indirect indicators, such as stranding data and museum acquisitions, many authors concur that the aggregate population of common dolphins in the Mediterranean has declined dramatically during the past three decades (Casinos & Filella, 1977; Casinos, 1982; Duguy *et al*., 1983; Viale, 1985; Aguilar,

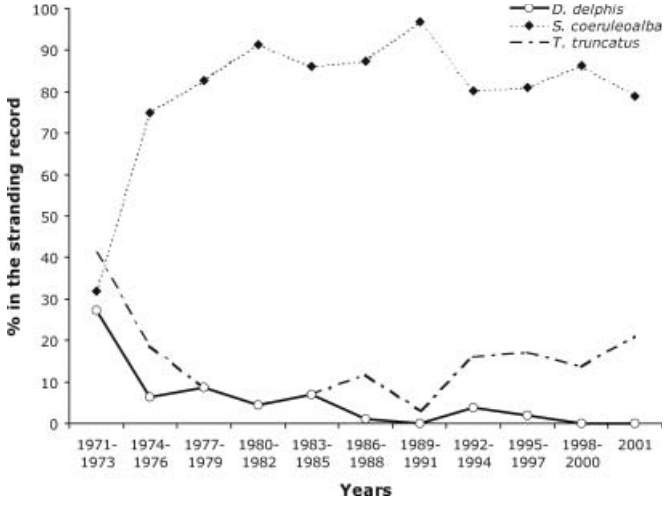

Fig. 4. Strandings of dolphins along the Mediterranean coasts of France between 1971 and 2001 (see text for references). *Delphinus delphis* ($n = 25$), *Stenella coeruleoalba* ($n = 700$), *Tursiops truncatus* ($n = 96$).

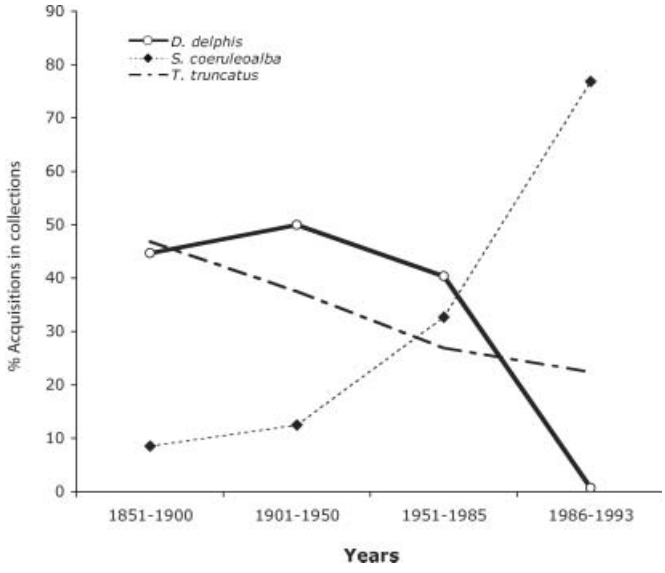

Fig. 5. Acquisitions of cetacean specimens by museums and zoological collections in Italy between 1851 and 1993, based on Cagnolaro (1996). *Delphinus delphis* ($n = 56$), *Stenella coeruleoalba* ($n = 243$), *Tursiops truncatus* ($n = 109$).

1986; Cagnolaro & Notarbartolo di Sciara, 1992; Notarbartolo di Sciara *et al*., 1993; UNEP/IUCN, 1994; Gannier, 1995; Notarbartolo di Sciara & Demma, 1997; Notarbartolo di Sciara & Gordon, 1997; Forcada & Hammond, 1998; Borrell *et al*., 2001). Areas where the decline has been confirmed by extensive cruises, where common dolphins were sighted only sporadically, include the Balearic Sea, Provençal Basin and Ligurian Sea (Forcada, Notarbartolo & Fabbri, 1995; Forcada & Hammond, 1998; Notarbartolo di Sciara *et al*., 1993).

The northern Adriatic Sea represents an interesting case study. In that area, the regular presence of common dolphins until the 1970s was well documented (Kolombatovic, 1882; Brusina, 1889; Trois, 1894; Ninni, 1901, 1904; Brunelli, 1932; Vatova, 1932; cf. Dathe, 1934 and Dathe, 1972; Pilleri & Gihr, 1977; Pilleri & Pilleri, 1982, 1983). For unknown reasons, in the last three decades, they have declined and almost completely disappeared there (Notarbartolo di Sciara & Bearzi, 1992; Notarbartolo di Sciara *et al*., 1993; Azzali, Casini & Lamberti, 1994; Bearzi & Notarbartolo di Sciara, 1995; Stanzani, Bonomi & Bortolotto, 1997; Gomercic *et al*., 1998; Francese *et al*., 1999; Bearzi *et al*., 2000). It is now very difficult to conduct meaningful studies on the species in the northern Adriatic because only rare, scattered individuals remain (Bearzi & Notarbartolo di Sciara, 1995; Bearzi, 1996). During the last 30 years, the food webs in the northern Adriatic Sea have suffered from severe contamination by noxious manmade compounds, dramatic shifts of biotic communities, persistent eutrophication phenomena, anoxia, and sea-floor degradation (Degobbis, 1989; De Walle, Nikolopoulou-Tamvakli & Heinen, 1993; Corsolini *et al*., 1995; Nasci *et al*., 1999; Dulcic & Grbec, 2000). Trends in commercial fish stocks in the last 25 years imply acute shifts in dolphin prey type and density, probably the result of large-scale environmental changes that were both natural and man-induced (Bombace, 1992; Solic *et al*., 1997; Degobbis *et al*., 2000). Most significantly, given the well-known importance of small epipelagic fishes to common dolphins, the biomass of anchovies and sardines reportedly has fluctuated widely, and the Adriatic anchovy stock collapsed in 1987 (Bombace, 1992; Cingolani, Giannetti & Arneri, 1996; Santojanni *et al*., 2001). Demersal fish catches have also declined dramatically (Bombace, 1992). The northern Adriatic Sea has become a difficult environment for the survival of any marine mammal species, as demonstrated by the current condition of bottle-

nose dolphins in that area. Although some groups of *T. truncatus* survive in the northern Adriatic, their numbers are now rather low (mean sighting frequency between 0.003 and 0.014 sightings/km of survey depending upon subarea; Bearzi, Notarbartolo di Sciara & Politi, 1997; Tethys Research Institute, unpublished data). Contaminant levels in their tissues are high (Corsolini *et al*., 1995), and prey depletion has been suggested as a factor to explain the unusually high percentage (i.e. around 80%) of the dolphins' time budget being devoted to food search and foraging (Bearzi, Politi & Notarbartolo di Sciara, 1999). Both dolphin species in the Adriatic were intensively culled during the 1950s (Holcer, 1994), and this likely started the decline of common dolphins in the area. However, there is no evidence of significant levels of direct takes or bycatch of common dolphins in the northern Adriatic Sea that would account for the decline observed since the 1970s. It therefore seems reasonable to propose as a working hypothesis that the virtual disappearance of this species in the last 30 years is related to large-scale changes in habitat quality and/or prey availability, possibly adding to the problems caused by deliberate culling in the past. The marine environment in the area has changed during the last decades from highly productive and relatively pristine to degraded and overfished (Grubisic, 1974; Bombace, 1992; Nasci *et al*., 1999).

In the Alboràn Sea, as opposed to other Mediterranean areas, historical and recent data suggest a quite constant presence of common dolphins, the most frequently sighted cetaceans in the area based on both sighting and stranding data (Casinos, 1982; Grau *et al*., 1986; Bayed & Beaubrun, 1987; Duguy *et al*., 1988; Boutiba, 1989; Laurent, 1991; Boutiba, 1994; Universitat de Barcelona, 1994; Bayed, 1996; Forcada & Hammond, 1998; Cañadas *et al*., 2002; Universidad Autónoma de Madrid & Alnitak, 2002). The abundance of common dolphins (and several other cetacean species) in the Alboràn Sea has been attributed to the area's biogeographical and oceanographic characteristics, which enhance primary productivity and in turn provide ample prey for cetaceans, and to the area's less degraded state when compared to most other parts of the Mediterranean (Casinos, 1982; Universidad Autónoma de Madrid & Alnitak, 2002).

FACTORS IMPLICATED IN THE SPECIES' DECLINE

A number of interacting factors may have played a role in the decline of common dolphins in the Mediterranean, ranging from natural fluctuations to the impact of human activities. In this section, we discuss some of the human-induced threats that – based on the available evidence – are most likely to be implicated in the species' decline. These include factors as diverse as prey depletion, contamination by xenobiotics, direct killing, fishery bycatch and global climate change.

Other potential threats to Mediterranean common dolphins include disturbance by recreational vessel traffic, noise from shipping, mineral prospecting (seismic) and military sonar (Notarbartolo di Sciara & Gordon, 1997; Gisiner, 1998; Jasny, 1999), and oil pollution (Geraci & St. Aubin, 1990; Engelhardt, 1987; Würsig, 1990). Although potentially pervasive, these threats remain poorly characterized or have yet to be linked with specific effects on common dolphins in the Mediterranean or elsewhere (Notarbartolo di Sciara *et al*., 2002).

Environmental fluctuations and global changes

It has been speculated that striped dolphins – that have apparently increased in numbers in the western Mediterranean in recent decades (Aguilar, 2000) – progressively occupied the niche of the common dolphin (Viale, 1985). Genetic studies of Mediterranean striped dolphins indicate differences from north-eastern Atlantic striped dolphins (Archer, 1996; García-Martinez, Raga & Latorre, 1997), thus dispelling the hypothesis that common dol-

phins declined in the Mediterranean as a result of a recent invasion of striped dolphins from the Atlantic Ocean. Competition with the striped dolphin has been listed among the possible causes of the common dolphin's decline in the Mediterranean (Casinos, 1982; Viale, 1985; Di Natale, 1987; Perrin, 1988; Cagnolaro & Notarbartolo di Sciara, 1992; Gannier, 1995; Sagarminaga & Cañadas, 1995; Notarbartolo di Sciara & Demma, 1997), but this would be difficult to corroborate with scientific evidence, as is true of most claims concerning interspecies competition for prey resources (e.g. see Clapham & Brownell, 1996). Although the two species share a common habitat in portions of their range (Sagarminaga & Cañadas, 1995; Forcada & Hammond, 1998; Frantzis & Herzing, 2002), no evidence exists that striped dolphins are competing with common dolphins, e.g. for food. It must be noted that the diet of the striped dolphin – a species that feeds predominantly on mesopelagic cephalopods and fishes (Casinos, 1982; Wurtz & Marrale, 1991; Perrin, Wilson & Archer, 1994) – overlaps only slightly with the diet of common dolphins. In any event, competition would not be an issue in areas such as the northern Adriatic Sea, where the common dolphin has disappeared while the striped dolphin rarely occurs.

Several cases of faunal change have been documented in North America over the last few decades that could be instructive. Reciprocal increases and decreases in the relative abundance and distribution of pairs of small cetaceans have occurred off the north-eastern USA (white-beaked dolphins *Lagenorhynchus albirostris* and Atlantic white-sided dolphins *L. acutus*; Katona, Rough & Richardson, 1993; Kenney *et al*., 1996), in the southern California bight (short-finned pilot whales *Globicephala macrorhynchus* and Risso's dolphins; Shane, 1994) and possibly in the Gulf of Mexico (again, short-finned pilot whales and Risso's dolphins; Jefferson & Schiro, 1997). The dramatic switch between the two species of *Lagenorhynchus* dolphins was thought to have been related to changes in prey abundance and distribution (e.g. sand lance *Ammodytes* sp., and Atlantic herring *Clupea harengus*), which in turn may have been driven by large-scale changes in water temperature (Palka, Read & Potter, 1997). Similarly, shifts in squid species dominance have been linked to the switch between short-finned pilot whales and Risso's dolphins in California (Shane, 1994). Episodic shifts in the inshore occurrence of Pacific white-sided dolphins *L. obliquidens* in British Columbia (western Canada) have been correlated with changes in sea temperature as well as major fluctuations in the local abundance of capelin *Mallotus villosus*, South American pilchard *Sardinops sagax* and Californian anchovy *Engraulis mordax* (Morton, 2000). Caldwell & Caldwell (1978) reported that common dolphins were once common along the north-eastern coast of Florida, but disappeared from these waters since 1960. Based on the absence of known interactions with fisheries or other human-caused mortality events involving the species, the authors concluded that its disappearance was probably the result of natural fluctuations in numbers or distribution, probably associated with oceanographic changes. The possibility that similar processes occurred in the Mediterranean, with conditions improving for striped dolphins while deteriorating for common dolphins, is something that cannot be ruled out (e.g. see Aguilar, 2000).

Mediterranean biodiversity is undergoing rapid alteration under the combined pressure of human impact and climate change (Bianchi & Morri, 2000). Sanford (1999) showed that small changes in climate may generate large changes in marine communities through regulation of keystone predation, and Petchey *et al*. (1999) demonstrated that environmental warming alters food-web structure and function of aquatic ecosystems. There is increasing evidence of change in Mediterranean biodiversity patterns related to increasing seawater temperature (Francour *et al*., 1994). According to Bethoux & Gentili (1995), temperature and salinity changes in the deep and intermediate waters of the western basin signify changes in heat and/

or water budgets at the surface. The warming trend in western Mediterranean deep waters was assumed by Béthoux *et al*. (1990) to represent some of the earliest evidence of the greenhouse effect (Graham, 1995).

It must be stressed that while the distribution of common dolphins may be related to shifting environmental conditions such as sea temperature (Gaskin, 1968; Neumann, 2001a), these kinds of 'fluctuations' affect dolphin distribution and/or abundance primarily by influencing the distribution of their prey. In other words, factors that concentrate or disperse prey may secondarily affect the distribution and abundance of cetaceans (Selzer & Payne, 1988). Therefore, it may be difficult to discriminate between the effects of environmental shifts due to climate change, whether 'natural' or a result of the greenhouse effect, and other factors affecting the availability of dolphin prey, such as overfishing and habitat degradation.

In conclusion, it cannot be excluded that recent temperature changes in Mediterranean waters may have had a negative impact on common dolphins, largely through their effects on food-web dynamics. However, environmental fluctuations (whether 'natural' or related to the greenhouse effect) are not the best candidates to explain the rapid decline of these top predators. Rather, such a rapid decline would appear to be the result of pervasive habitat degradation caused by overfishing, pollution, or a combination of both, which have become increasingly serious problems in the Mediterranean concurrently with the decline in common dolphin abundance.

Prey depletion

Jackson *et al*. (2001) argued that 'ecological extinction caused by overfishing precedes all other pervasive human disturbance to coastal ecosystems, including pollution, degradation of water quality and anthropogenic climate change'. This lesson likely also applies to the Mediterranean, where fisheries have had major direct and indirect impacts on ecosystem dynamics (e.g. Briand, 2000; FAO, 2000). However difficult it may be to establish a clear, mechanistic link between fisheries and the decline of common dolphins, such a link provides one of the most plausible contending hypotheses.

As stressed by Chapman & Reiss (1999) 'the lack of sufficient food to maximize reproductive potential may be the most important regulator of population size in animals'. Overfishing and habitat degradation may have contributed to the decline of common dolphins by affecting the availability of key prey. Although Mediterranean fisheries statistics are incomplete and unreliable, and there is an acute lack of historical data (Briand, 2000), the available evidence indicates that unsustainable harvesting has led to the decline of many fish stocks (Caddy & Griffiths, 1990; De Walle *et al*., 1993; Stanners & Bourdeau, 1995; Briand, 2000; FAO, 2000), with potentially serious ecological consequences (cf. Dayton *et al*., 1995; Jackson *et al*., 2001). The mean trophic level of Mediterranean catches has declined significantly and quite steadily since the late 1950s, although aggregate fishery landings have increased (e.g. Pauly & Palomares, 2000; Stergiou & Koulouris, 2000). Such a pervasive and large-scale 'fishing down' impact on food-web dynamics (*sensu* Pauly *et al*., 1998) is likely to have a profound impact on ecosystem dynamics, ultimately affecting top predators.

The eastern Ionian Sea is one of the Mediterranean areas where a potential for 'exploitative competition' (Keddy, 1989) exists between common dolphins and local mid-water fisheries targeting sardines and anchovies. Much of the fish fauna of the area is reduced because of overfishing. Decreased total landings were reported (Papaconstantinou, Mytilineou & Panos, 1988; Papaconstantinou & Stergiou, 1995; Stergiou *et al*., 1997), and the area has been subjected to intensive trawling (Papaconstantinou, Caragitsou & Panos, 1985; Papaconstantinou, Stergiou & Petrakis, 1985). As a result of the 'fishing down' phenomenon, Stergiou &

Koulouris (2000) report decreased mean trophic levels along the Greek Ionian coasts. Top predators such as bottlenose dolphins, which are locally sympatric with common dolphins in the eastern Ionian Sea, exhibit obvious signs of malnutrition (around 40% of photo-identified individuals described as emaciated; Politi, Bearzi & Airoldi, 2000). Although common dolphins, unlike bottlenose dolphins, feed mostly on small epipelagic schooling fish, they can be affected by overfishing when it causes a disruption of the interrelationships among the many components of marine ecosystems. The complexity of marine food webs makes it difficult to provide quantitative evidence that overfishing represents a threat to common dolphins. However, photo-identification and survey data showed that the total number of common dolphins using the study area has decreased since 1996, and reduced prey availability remains the most likely proximate cause to account for the observed trends (Politi & Bearzi, in press).

In all Mediterranean areas where common dolphins have been studied consistently, exploitative competition with fisheries represents a source of concern. In the south-eastern Tyrrhenian Sea, fishermen claim that the fleet targeting Atlantic saury *Scomberesox saurus* (locally a key prey species for common dolphins) has decreased by an order of magnitude due to the decline in fish stocks (Mussi *et al*., in press a). Moreover, purse seiners reportedly do not comply with the regulations intended to prevent overfishing (Mussi & Miragliuolo, in press). In the Alboràn Sea, purse seining targeting small pelagic fishes has increased dramatically in recent years, casting doubts on the extant common dolphin population's ability to persist at current levels of abundance. Until recently, fishermen targeted only anchovies and sardines, but depletion of these stocks and increased demand for low-value small pelagic fish (e.g. round sardinella *Sardinella aurita* and garpike *Belone belone*) by the growing aquaculture industry has led to the intensive commercial exploitation of most of the common dolphin's prey species (Universidad Autónoma de Madrid & Alnitak, 2002). The impacts of such trends in fisheries on the local groups of common dolphins are unknown, but are unlikely to be beneficial.

Prey depletion may represent a subtle and scarcely noticeable threat, and the impacts may go unnoticed owing to inadequate research effort (e.g. monitoring changes in reproductive success or survival rates). When mass mortality events occur, prey depletion and xenobiotic contamination are often mentioned as potentially contributing factors. For example, inadequate nutrition may have compromised animal health and made Mediterranean striped dolphins more susceptible to the epizootic that caused a large die-off in 1990–92 (Aguilar & Raga, 1993; Aguilar, 2000).

In the Black Sea, reduced prey availability has been cited as a factor affecting the abundance of common dolphins and harbour porpoises *Phocoena phocoena* (Bushuyev, 2000). Of two mass mortality events involving Black Sea common dolphins in 1990 and 1994 (Krivokhizhin & Birkun, 1999), only one was recognized as being the result of a morbillivirus epizootic (Birkun *et al*., 1999). Most stranded animals (dead and alive) examined during both die-offs were emaciated (A. Birkun, personal communication). Although such emaciation could be a result of the disease, both die-offs coincided with steep declines of European anchovy *Engraulis encrasicolus* and European sprat *Sprattus sprattus* stocks, the main prey of Black Sea common dolphins (Birkun, 2002). Overfishing, combined with the consequences of eutrophication (e.g. water hypoxia) and the concurrent irruption of the introduced ctenophore *Mnemiopsis leidyi*, has been blamed for the rapid decline in anchovy and sprat stocks (Zaitsev & Mamaev, 1997). The total commercial catch of anchovies experienced a 12-fold decline (from an absolute maximum of 468 800 tonnes in the 1987–88 fishing season to 39 100 tonnes in 1990–91), while landings of sprat fell by a factor of nearly eight (from 105 200 tonnes in 1989 to 13 800 tonnes in 1993; Prodanov *et al*., 1997). This suggests a close

relationship between large die-offs of Black Sea common dolphins and prey scarcity (A. Birkun, personal communication).

Xenobiotic contamination

The role of xenobiotic contamination is controversial, but likely significant. High levels of PCBs in Mediterranean dolphins, compared to levels in dolphins from other areas (Fossi *et al*., 2000, in press; Aguilar, Borrell & Reijnders, 2002), represent a major concern, as toxic contaminants such as PCBs, that accumulate in dolphin tissues through food-chain biomagnification, are known to cause immunosuppression and reproductive impairment in mammals. PCB levels in common dolphins from the Mediterranean Sea are close to the range at which adverse effects could be expected (Borrell *et al*., 2001; Fossi *et al*., in press). Fossi *et al*. (in press) found a significant correlation between benzo(a)pyrene monooxygenase activity and organochlorine levels in common dolphin skin biopsies, indicative of potential toxicological stress in this species, even though total organochlorine levels were lower than those found in striped dolphins and common bottlenose dolphins.

In the Mediterranean, epizootics and reproductive disorders related to high contaminant loads appear to have affected striped dolphins primarily (Aguilar & Raga, 1993; Van Bressem *et al*., 1993; Aguilar & Borrell, 1994; Munson *et al*., 1998), but common dolphins could also be at risk (Fossi *et al*., 2000, in press). In fact, as noted above, Birkun *et al*. (1999) suspected a possible role of xenobiotic contamination in a mass die-off of common dolphins in the Black Sea, although an epizootic outbreak appeared to be the proximate cause.

The Alboràn Sea is less contaminated than the rest of the western Mediterranean (UNEP, 1984). This is consistent with the results presented by Borrell *et al*. (2001), who found relatively low organochlorine levels in common dolphins from the Atlantic and westernmost Mediterranean waters off Spain. It is unclear, however, if relatively low contaminant levels can be related directly to the species' abundance in the far western Mediterranean. Comparisons among toxicological information obtained from common dolphins sampled in different Mediterranean areas may show whether contaminant levels are higher in those areas where the species has declined.

Direct takes and bycatch

Through the 1950s, the deliberate catching or killing of dolphins occurred in several Mediterranean areas, and still occurs in portions of the basin. In the past, common dolphins were culled because of their reputation as competitors with fisheries, and because their flesh was valued for human consumption or for use as bait (Notarbartolo di Sciara & Bearzi, 2002). Research methods were occasionally lethal (e.g. Richard & Neuville, 1897; Richard, 1936; Pilleri & Knuckey, 1969; Cousteau & Diolé, 1975), reflecting the prevailing ethics of an earlier time when Western societies had a different view of dolphins than today (cf. Lavigne, Scheffer & Kellert, 1999). Past exploitation may have had an impact on coastal dolphin populations, but it is unclear whether *Delphinus* would have been more affected than *Tursiops*. In fact, in most areas where 'predator control' killing occurred, bottlenose dolphins were viewed as greater threats to fisheries than common dolphins. The latter were often considered beneficial to various fisheries (e.g. Brunelli, 1932; Police, 1932), although in some areas common dolphins were definitely regarded as vermin (e.g. Brusina, 1889; Barone, 1895).

Fishery bycatch is a major threat to many cetacean populations, and it could well have played a role in the decline of common dolphins in at least some Mediterranean areas (Di Natale & Notarbartolo di Sciara, 1994; IWC, 1994; UNEP/IUCN, 1994; Aguilar & Silvani, 1995; Forcada & Hammond, 1998; Silvani, Gazo & Aguilar, 1999). In the Alboràn Sea, for

example, it was estimated that Spanish drift gillnets caught a couple of hundred common dolphins per year during the early 1990s. No account was taken in this estimate for the catches by Moroccan and Italian vessels, the former four times more numerous but smaller than the Spanish boats and the latter of unknown number but working with substantially larger nets (Silvani *et al*., 1999). The Spanish fishery finally stopped in 1994 (Aguilar, 2000), but it operated for many years and undoubtedly had some impact on the population. If driftnets were taking common dolphins in the Alboràn Sea, it is reasonable to assume that they were (and are) doing so in other parts of the Mediterranean where driftnet fishing and common dolphin occurrence overlap. The lack of quantitative bycatch estimates must not be interpreted as evidence of insignificant impact. Pelagic driftnets were banned by the European Union (EU) starting from 2002. Nevertheless, driftnet fishing by non-EU Mediterranean fleets, as well as the illegal continuation of driftnet fishing within EU waters (e.g. in the south-eastern Tyrrhenian Sea; Miragliuolo, Mussi & Bearzi, in press a), represent potentially important ongoing threats to common dolphins.

Although fishery bycatch may threaten common dolphins in some Mediterranean areas, it remains unclear to what extent their decline in the basin overall is related to past or present levels of bycatch. There is no scientific evidence to suggest that bycatch has selectively reduced common dolphins. In the aforementioned Spanish study (Silvani *et al*., 1999), it was noted that roughly similar numbers of common and striped dolphins were being caught, and that the abundance of these two species in the Alboràn Sea was similar. The number of striped dolphins was 'greatly reduced' by an epizootic in 1990–92, yet this species remains widespread and relatively abundant throughout its Mediterranean range (Aguilar, 2000). We conclude that although bycatch may have played a significant role in some areas in the past, it is unlikely to be the factor most responsible for the decline of common dolphins in the Mediterranean region. Unfortunately, however, there is no prospect of obtaining reliable or complete retrospective data on cetacean bycatch in most Mediterranean driftnet fisheries and, as a result, we will probably never be able to achieve a satisfactory resolution of this issue.

PRIORITIES FOR ACTION

The relative importance and interplay of the potential threats listed above are not well understood, so designing and implementing appropriate measures to counteract negative trends is a daunting task. Continued inaction, however, is unacceptable if there is to be any hope of preserving viable numbers of common dolphins throughout much of their historic range in the Mediterranean basin. The following recommendations are proposed as a basis for addressing scientific uncertainty while moving forward with precautionary management efforts without delay. In some areas, it may already be too late to prevent these dolphins' disappearance from the local marine fauna, so the goals in such locations should be to understand the causes of decline and facilitate immigration from adjacent waters, hopefully leading to recovery. In other areas, the fate of remaining animals will likely depend upon precautionary action and the adoption of precise conservation and management measures to prevent further decline. The ACCOBAMS and the *Barcelona Convention Protocol on Specially Protected Areas and Mediterranean Biodiversity*, which have both recently come into force, provide an ideal framework to coordinate research efforts and design appropriate conservation strategies for cetaceans in the region (Notarbartolo di Sciara *et al*., 2003).

Research recommendations

Below, we provide a series of research initiatives that should be implemented to increase understanding of the species' past and ongoing trends. We believe that it is important that

work be initiated without further delay, and that results be conveyed to managers and incorporated into the design of conservation actions as quickly and efficiently as possible.

1. Field surveys are clearly needed to determine the current distribution and abundance of common dolphins in the Mediterranean, particularly along the entire northern African coastline, in the Aegean Sea (especially in its northern part, the Thracian Sea) and in far eastern Mediterranean areas where little information exists. Such surveys should be designed to identify hot spots of occurrence that can be accorded priority for intensive research and management. Standard methods such as vessel-based and/or aerial line transect surveys should be used so that results can be compared over time and from one region to another.

2. A better understanding is needed of the genetic characteristics of Mediterranean common dolphins. The risks of local or regional extinction from stochastic processes might be reduced by preserving as much genetic diversity as possible (cf. Shaffer, 1987; Lande, 1988). Ongoing genetic studies may provide some insight concerning rates of gene flow between what appear to be 'isolated' groups of dolphins (e.g. Universidad Autónoma de Madrid & Alnitak, 2002; A. Natoli, personal communication). However, more genetic material is needed from groups living in different portions of the region. In addition, further comparisons should be made between Mediterranean groups and groups from adjacent basins (i.e. Black Sea, Atlantic Ocean). Biopsies should be collected for genetic and other analyses with minimal intrusiveness (e.g. Harlin *et al*., 1999), while recognizing that the darting is not without risk to free-ranging dolphins (Bearzi, 2000). Samples should be archived in a central repository (e.g. Aguilar & Borrell, in press; Anfuso *et al*., in press). Similarly, collaborative photo-identification studies (e.g. see http://www.europhlukes.net) should be initiated to better understand habitat use, the relationship between coastal and pelagic groups, and long-range movement patterns.

3. Contaminants analyses should be conducted to identify regional differences in exposure, and relate them to population abundance and trends. In addition, comparative analyses of contaminant loads and evaluation of interspecies susceptibility to organic pollutants (e.g. Fossi *et al*., 2000, in press) may shed light on the relative impact of xenobiotic contamination on common dolphins as compared to other cetacean species living in the Mediterranean.

4. Sighting surveys, stranding networks and related activities will require collaboration among individual scientists, government agencies and non-governmental organizations from the various range states. For instance, rigorous investigations should be conducted to assess the scale of bycatch and intentional killings of common dolphins, with a focus on areas where evidence of conflict between dolphins and fisheries exists. This will require improved communication and exchange of information at the regional level. Common dolphin conservation workshops would provide opportunities for experts to discuss available evidence with one another and with experts from different disciplines, local stakeholders and managers. The goal of these efforts should be to develop and modify, on an adaptive basis, a comprehensive programme for the assessment and monitoring of the status of Mediterranean common dolphins, closely coupled with the implementation of measures for their conservation.

5. Comprehensive analyses of existing datasets assembled by several independent research groups over the last decade should be promoted and supported. Such analyses, together with the publication of results, have often been delayed because of insufficient funding and other resources, including expertise (e.g. in the field of statistics), to deal with massive datasets. Comparative analyses among different Mediterranean habitats would provide further insight on why common dolphins have persisted in some areas but disappeared in others. The far-western Mediterranean – where common dolphins are still relatively abundant – might be regarded as a 'control' area for such comparisons. It may also be informative to compare

features of the central and eastern Mediterranean with those of non-Mediterranean areas where common dolphins are thought to have declined.

6. Elucidation of ecosystem dynamics, and specifically the possible role of prey depletion and regime shifts as factors contributing to the decline of common dolphins in the Mediterranean, is an important, but challenging, area of research. Investigations of the spatial and temporal variability in Mediterranean fish stocks, when correlated with common dolphin abundance and movements, could be informative, as could output obtained from ecosystem models (e.g. Christensen & Pauly, 1992) and analyses of food-web dynamics.

Recommended conservation measures

A large marine sanctuary for cetaceans in the Corso-Ligurian Basin has been declared by the Governments of Italy, France and Monaco (Notarbartolo di Sciara, in press). Other smaller marine protected areas exist or have been proposed throughout the Mediterranean Sea (e.g. Fayos, Cañadas & Sagarminaga, in press; Raga *et al*., in press). In 1999, the Spanish Ministry for the Environment included the common dolphin in its National Endangered Species Act as 'vulnerable'. The following year, a programme was initiated to identify important areas for the conservation of cetaceans in the Spanish Mediterranean with the aim of implementing the EU's 'Habitats' Directive, the Barcelona Convention and the Bonn Convention (Convention on Migratory Species, or CMS) through the creation of marine protected areas (Universidad Autónoma de Madrid & Alnitak, 2002). A follow-up of this project started in the year 2002 to develop the management schemes required for these areas. Based on the presence of a relict group of common dolphins, the eastern Ionian area around the island of Kalamos has been included by the Greek Ministry of the Environment in the Natura 2000 network ('Site of Community Importance') under the 9243 EEC 'Habitats' Directive (Frantzis, 1996). The area around the island of Kalamos has also been identified by the ACCOBAMS (2002) as one where pilot conservation and management actions should be developed and implemented immediately to preserve critical habitat for common dolphins. In the waters around Ischia, south-eastern Tyrrhenian Sea, the creation of a marine reserve dedicated to the rich cetacean fauna was proposed recently by the Italian Ministry of the Environment, which – if finalized – may lead to mitigation of at least some obvious threats such as harassment by pleasure boaters (e.g. Miragliuolo, Mussi & Bearzi, in press b) and uncontrolled fishing. However, few specific measures have been adopted that would directly benefit common dolphin conservation in any of those areas. In fact, the 9243 EEC 'Habitats' Directive includes only the bottlenose dolphin and the harbour porpoise in its Annex II ('Animal and plant species of Community interest whose conservation requires the designation of special areas of conservation'), and although the Convention on the Conservation of Migratory Species includes the Mediterranean common dolphin in its Appendix 2 ('Migratory species that have an unfavourable conservation status or would benefit significantly from international cooperation'), that status is inexplicably limited to a 'western population'. We find it distressing that so little has been accomplished towards the goal of conserving Mediterranean common dolphins, and that so little success has been realized in conveying the message about this species' decline in the region to policy makers and, apparently, the general public.

Although the creation of an internationally coordinated network of marine protected areas may represent an important step (e.g. Agardy, 1997; Bianchi & Morri, 2000), this is unlikely to be sufficient for conserving the species unless specific precautionary measures are taken to prevent further decline and, hopefully, facilitate population recovery. These measures should be aimed primarily at reducing overfishing and habitat degradation in areas where relict groups of common dolphins are known to reside, particularly in the central and eastern

Mediterranean Sea. At the same time, habitats where the species is still abundant should be granted special conservation status, and actions should be taken to mitigate the existing threats if common dolphins are to persist beyond the next few decades in the central and eastern Mediterranean Sea.

The authors recognize that the forces causing climate change and chemical contamination are unlikely to be influenced in a major way by concern for common dolphins in the Mediterranean. Lifestyle choices, entrenched patterns of overconsumption, human overpopulation and political gamesmanship militate strongly against the types of changes needed to reverse what are essentially global trends. However, in a moment in which the stark evidence of wide-scale overfishing and the consequent need for immediate and decisive measures to reduce fishing pressure is finally capturing the attention of European decision makers, the goal of conserving common dolphins may converge with, and in fact add to, the momentum building in the direction of improved ecological conditions for the benefit of both humans and wildlife. In this context, the decline of common dolphins provides a further signal that our collective actions can have large-scale, unforeseen, unintended and intractable consequences.

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