

# ***The role of historical dolphin takes and habitat degradation in shaping the present status of northern Adriatic cetaceans***

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## ABSTRACT

1. Nine cetacean species have been reliably reported to occur in the shallow northern Adriatic Sea since the 17th century. However, only two species were considered regular there until the 1970s: the short-beaked common dolphin (*Delphinus delphis*) and the common bottlenose dolphin (*Tursiops truncatus*).

2. Short-beaked common dolphins have progressively disappeared from the northern Adriatic and are now rare in the region. The systematic culling campaigns and other takes that occurred between the second half of the 18th century and the 1960s, and habitat degradation in subsequent years are the most likely causes of their decline.

3. Today, common bottlenose dolphins are the only regular component of the northern Adriatic cetacean fauna; however, they now occur at low densities, and their fragmented groups are facing significant anthropogenic threats.

4. The future of northern Adriatic dolphins will depend on precautionary action to prevent further decline and on intensified research effort aimed at identifying the most effective mitigation strategies. Copyright © 2004 John Wiley & Sons, Ltd.

KEY WORDS: cetaceans; Adriatic Sea; *Delphinus delphis*; *Tursiops truncatus*; anthropogenic impact; historical takes; habitat degradation

## INTRODUCTION

Until the late 1980s, little effort was invested in documenting the occurrence and distribution of cetaceans frequenting or occasionally occurring in the northern Adriatic Sea. Most information from previous years originated from strandings and opportunistic sighting reports. Concern about the status of cetaceans in the region was first raised in the late 1970s, when it was suggested that short-beaked common dolphins, *Delphinus delphis* (hereafter 'common dolphin'), may have been declining in the Adriatic Sea (Pilleri and Gahr, 1977). However, it was only in the late 1980s that data on Adriatic cetaceans started to be collected

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through dedicated surveys at sea (Notarbartolo di Sciara *et al.*, 1993). In a preliminary assessment of cetacean status in the northern Adriatic, Notarbartolo di Sciara and Bearzi (1992) noted that the common dolphin (a species that was previously regarded as regular in the area) had almost completely disappeared by the late 1980s. The common bottlenose dolphin, *Tursiops truncatus* (hereafter 'bottlenose dolphin'), is the only cetacean species regularly reported in the area at the present time. This species survives at low population densities and in small groups, but faces challenges that range from prey depletion to contamination by xenobiotic pollutants (Notarbartolo di Sciara *et al.*, 2002). This paper contributes to the understanding of present cetacean conservation status and trends in the northern Adriatic through a review of historical data (17th century to the 1960s) and recent information (1970–2002). By documenting the extent and the impact of dolphin deliberate takes and culling campaigns lasting for almost a century, and of the generalized habitat degradation and prey depletion occurring in subsequent years, we conclude that the combined impact of these threats likely promoted the disappearance of common dolphins and the decline of bottlenose dolphins in the region.

### CETACEAN SPECIES RECORDS FOR THE NORTHERN ADRIATIC

Several cetacean species that are regularly present in the Mediterranean basin (see Notarbartolo di Sciara and Demma (1997)) have been reported in the northern Adriatic. These include the fin whale *Balaenoptera physalus*, the sperm whale *Physeter macrocephalus*, the long-finned pilot whale *Globicephala melas*, Risso's dolphin *Grampus griseus*, the bottlenose dolphin, the common dolphin, and the striped dolphin *Stenella coeruleoalba*. Cuvier's beaked whale *Ziphius cavirostris* is the only cetacean species known to be regular in the Mediterranean Sea that has never been recorded in the northern Adriatic, although a few stranding reports exist further south in the Adriatic basin (Holcer *et al.*, 2003).

The literature for the Adriatic Sea also includes reports of cetacean species that were likely misidentified (Holcer *et al.*, in press). For the northern Adriatic, these include the blue whale *Balaenoptera musculus*, the white-beaked dolphin *Lagenorhynchus albirostris*, and the harbour porpoise *Phocoena phocoena*. The blue whale does not occur in the Mediterranean. Reports of *B. musculus*, often called 'Mediterranean rorqual' in the old literature, have been the result of confused nomenclature and taxonomy rather than actual misidentifications (Brusina, 1889; Kolombatovic, 1894; Parona, 1896; Ninni, 1901; Dulic and Tortic, 1960; Dulic and Miric, 1967; see Notarbartolo di Sciara *et al.* (2003)). The white-beaked dolphin record (Dathe, 1934) was corrected by Dathe (1972) himself, who re-identified the animal as a common dolphin. Reports of harbour porpoises in the region (e.g. Nardo, 1853) are very doubtful. A skull of *P. phocoena* collected in 1822 and preserved in the comparative anatomy museum of the University of Bologna is the only specimen known to date that may have originated from the Adriatic (Alessandrini, 1852; Cagnolaro, 1996). Considering the total lack of confirmed records of that species from the Mediterranean (with the exception of the western Alborán and northern Aegean Seas), reports in the old literature most likely represent either confused nomenclature/taxonomy, as suggested by Brusina (1889), or misidentifications (see Frantzis *et al.* (2001)).

Although historical and recent reports may suggest that the northern Adriatic supports a diverse cetacean fauna, most of the recorded species are incidental in the region (Notarbartolo di Sciara and Bearzi, 1992), and only two species, the bottlenose and common dolphin, can be regarded as regular since historical times. Considering that the northern Adriatic is part of a rather shallow continental shelf, it is not surprising that the pelagic cetacean fauna is notably reduced compared with the Mediterranean as a whole. A review of the existing information on the cetacean species having occurred in the region on an occasional basis is provided below; common dolphins and bottlenose dolphins are treated separately.

Occurrences of fin whales have been reported in the northern Adriatic since the early 18th century (Notarbartolo di Sciara *et al.*, 2003). In past catalogues of the fauna of 'Former Yugoslavia' *B. physalus* was listed as accidental or occasional (Dulic and Tortic, 1960; Dulic and Miric, 1967). Sightings and strandings of fin whales have also been recorded in recent times (Pilleri and Gahr, 1977; Rallo, 1979; Benvenuti *et al.*, 1991; Krystufek and Lipej, 1993; Stanzani *et al.*, 1997; Affronte, 2000a; Bearzi *et al.*, 2000; Podestà and Bortolotto, 2001; Gomercic *et al.*, 2002), suggesting that the species still occurs occasionally in the northern Adriatic.

A 10 m long humpback whale *Megaptera novaeangliae* was reported off Senigallia, Italy, in August 2002 (Affronte *et al.*, 2003). Frantzis *et al.* (in press b) suggested that it may have been the same individual that was sighted about 2 weeks earlier in the eastern Ionian Sea. Humpback whales are rare in the Mediterranean, and this is the first and only report from the Adriatic (Affronte *et al.*, 2003).

A possible northern Adriatic record exists of a minke whale *Balaenoptera acutorostrata*, a species rarely found in the Mediterranean (Van Waerebeek *et al.*, 1999). The record is represented by the cranium of a young specimen, collected in 1771 in the fish market of Bologna, and still preserved in the Comparative Anatomy Museum of that city (Capellini, 1877).

Reviews of sperm whale occurrences in the Adriatic Sea have been provided by Nardo (1853), De Marchesetti (1882), Trois (1894), Parona (1896) and especially by Brusina (1889), who reported several strandings, sightings, and captures recorded between 1713 and 1885. Based on previous literature, rather than original data, Dulic and Tortic (1960) listed the species as occasional. Affronte *et al.* (1999) stressed the relatively high occurrence of sperm whale reports in the past literature. In recent times, a single northern Adriatic record exists of a sperm whale that entered an inland channel near Trieste in 1995 (<http://www.riservamarinamiramare.it>). The northern Adriatic does not offer suitable habitat for this deep-diving species, and all reports in this region probably refer to stray individuals.

False killer whales *Pseudorca crassidens* are rarely found in the Mediterranean Sea (Notarbartolo di Sciara and Demma, 1997), and even more rarely in the Adriatic. Hirtz (1937) reported a specimen captured near the island of Korčula, in the central Adriatic. Three individuals from a pod of 30–40 false killer whales were reportedly captured in northern Adriatic waters off Ravenna, Italy, between 1959 and 1961 (Stanzani and Piermarocchi, 1992).

There is only one report of long-finned pilot whales in the northern Adriatic, concerning two individuals caught in a tuna trap off the island of Rab, Croatia (Hirtz, 1921, 1922). This is one of the very rare known occurrences of long-finned pilot whales in Mediterranean waters east of Italy (Frantzis *et al.*, in press a).

The first accounts of Risso's dolphin in the northern Adriatic date back to the 1860s (Giglioli, 1880; Brusina, 1889). Records, however, are relatively few, and most authors have concurred that *G. griseus* has always been accidental in the Adriatic Sea (Trois, 1874, 1883, 1894; Ninni, 1890, 1901; Valle, 1900; Brunelli, 1932; Dulic and Miric, 1967). Between 1860 and 1900, four Risso's dolphins were reportedly captured in the Italian Veneto region, one in Istria and four near Zadar, Croatia (Trois, 1894; Valle, 1900). A few recent strandings and sightings indicate that the species presently occurs in the area on an occasional basis (Stanzani *et al.*, 1997; Francese *et al.*, 1999; Affronte, 2000c; Podestà and Bortolotto, 2001; Gomercic *et al.*, 2002; Picciulin *et al.*, in press; D. Holcer, unpublished data). All recent records relate to lone individuals, except for three animals observed together in 1993 in inland channels and lagoons near the Gulf of Trieste (Francese *et al.*, 1999).

The striped dolphin is the commonest pelagic cetacean throughout the Mediterranean (Notarbartolo di Sciara and Demma, 1997). However, the species has always been rare in the northern Adriatic. It is possible that, in the past, striped dolphins may have been occasionally confused with the once abundant common dolphin (see Bearzi *et al.* (2003)), because these two species could be reported together as 'common' dolphins in second-hand reports (e.g. see Pilleri and Pilleri (1987)). However, an analysis of museum collections has confirmed that, in the past, striped dolphins were rare along the coasts of Italy (Cagnolaro, 1996; Bearzi *et al.*, 2003). A limited number of specimens ( $N=26$ ; Cagnolaro, 1996), in large part recent

acquisitions, have been included in collections along the southern Adriatic coast of Italy. In addition, *S. coeruleoalba* specimens were never included in Croatian collections (Gomercic *et al.*, 1994, 1998). Today, striped dolphins may occasionally wander into the northern Adriatic, as indicated by a few recent stranding and sighting reports (Lapini *et al.*, 1995; Stanzani *et al.*, 1997; Bearzi *et al.*, 1998; Pribanic *et al.*, 1999; Podestà and Bortolotto, 2001; D. Holcer, unpublished data). The species is rare in the Gulf of Venice and off the entire Croatian coastline (Bearzi *et al.*, 2000; Gomercic *et al.*, 2002; Lucic, 2002) but appears to be more frequent in the Gulf of Trieste. However, most reports are of only one or two individuals (Francese *et al.*, 1999; Picciulin *et al.*, in press). Given that striped dolphins are typically gregarious (Notarbartolo di Sciarra and Demma, 1997), sightings of single specimens are indicative of unnatural conditions of those individuals. This pelagic, deep-water species is relatively abundant towards the southern portion of the Adriatic Sea (Azzali *et al.*, 1994). The number of striped dolphins stranded along the Italian coasts between 1986 and 1996 was 148 in the southern Adriatic, 21 in the central Adriatic, and seven in the northern Adriatic (Podestà and Bortolotto, 2001), suggesting a gradient of occurrence that reflects the bathymetry of the basin. An apparent slight increase in striped dolphin sighting and stranding reports in the northern Adriatic in recent times (compared with the lack of historical literature accounts) may be a function of an increased research effort and reporting efficiency. The hypothesis of a progressive extension of the species' range would be consistent with the generalized expansion that has occurred in the Mediterranean basin in recent times (Aguilar, 2000; Bearzi *et al.*, 2003). However, given that striped dolphins typically inhabit deep-water areas, it seems unlikely that they will colonize in any great number the shallow northern Adriatic.

### COMMON DOLPHINS

The presence of common dolphins in the northern Adriatic Sea until the 1970s is well documented (Giglioli, 1880; Peksider-Srica, 1931; Dulic and Miric, 1967; Pilleri, 1970; Pilleri and Gühr, 1977; Pilleri and Pilleri, 1982, 1983, 1987). Nardo (1853) tentatively listed the common dolphin as the only regular cetacean species in the Adriatic. De Marchesetti (1882) claimed that the most common Adriatic species was *D. delphis*, and that *Delphinus tursio* (= *T. truncatus*) was less frequent. (Note, scientific names are used again in this section and elsewhere to avoid misunderstanding between the common name of an animal (as in 'the common dolphin') and its reported abundance (as in 'a very common dolphin'); also, they are used to stress that the authors specifically referred to scientific names rather than common names (in the latter case it would be difficult to assess whether a dolphin was described as 'common' to indicate the species or because of its perceived abundance).) Similarly, Faber (1883) regarded *D. delphis* as the most common cetacean species in the Adriatic, but his claims of the occurrence of other marine mammal species are not very reliable. Brusina (1889), one of the most authoritative zoologists of the time, reported *D. delphis* and *T. truncatus* as the most common Adriatic cetaceans. Trois (1894), a reliable observer, reported that *D. delphis* was more abundant than *T. truncatus* in the Gulf of Venice. Common dolphins were claimed to follow ships into ports (Kolombatovic, 1882; Trois, 1894). Trois (1894) reported that common dolphin specimens were often put for sale at the Venice fish market after being caught in the inner channels of the Venice lagoon. Today, the occurrence of any cetacean in the lagoon is an exceptional event (Bearzi and Ferretti, 2000). Ninni (1901, 1904) considered *D. delphis* very common in the Adriatic Sea compared with *D. tursio*, which he thought rare in the region. However, several inconsistencies and a report of a presumed *D. tursio* that was 6 m long (Ninni, 1901) suggest that some cetological accounts by this author should be taken with caution. Vatova (1928) listed *D. delphis* as common throughout the Adriatic, where the species was said to be present in large groups, while *T. tursio* (= *T. truncatus*) was considered 'very rare' in the region. However, the same author subsequently listed both *D. delphis* and *T. tursio* among the commonest marine animals to be found near Rovinj, Croatia (Vatova, 1932). In the catalogue of Former Yugoslavia's

mammals by Dulic and Tortic (1960), *D. delphis* was the only cetacean species listed as frequent, probably as a result of an incomplete literature review rather than first-hand assessment. The catalogue of the Croatian Natural History Museum lists 16 dolphins collected between 1873 and 1935 along the eastern Adriatic coastline: 10 common dolphins (of which eight were from the northern Adriatic), five bottlenose dolphins (three from the northern Adriatic) and one Risso's dolphin caught near Zadar. Although the numbers seem to indicate that common dolphins were more abundant than other cetacean species, the methods and criteria used to collect this osteological material are unknown. Pilleri and Gahr (1977) noted that large groups of common dolphins could be easily encountered near the coast in the Gulf of Trieste in the 1940s, but by the late 1970s there was a noticeable decrease of common dolphins in the northern Adriatic. In the 1980s and 1990s, common dolphins almost completely disappeared from the region (Bearzi, 1989; Notarbartolo di Sciara and Bearzi, 1992; Krystufek and Lipej, 1993; Notarbartolo di Sciara *et al.*, 1993; Azzali *et al.*, 1994; Bearzi and Notarbartolo di Sciara, 1995; Stanzani *et al.*, 1997; Gomercic *et al.*, 1998; Francese *et al.*, 1999; Bearzi *et al.*, 2000; Podestà and Bortolotto, 2001; Bearzi *et al.*, 2003). A sighting frequency for common dolphin groups two orders of magnitude smaller than the sighting frequency found for bottlenose dolphin groups was reported by Bearzi and Notarbartolo di Sciara (1995) based on surveys conducted between 1990 and 1995 in the Kvarneric (Figure 1). Only one group of four common dolphins was sighted in 1991. One of those four common dolphins was re-sighted once in 1994 and in 1995, in close association with bottlenose dolphins and without its conspecifics (Bearzi, 1997). These observations

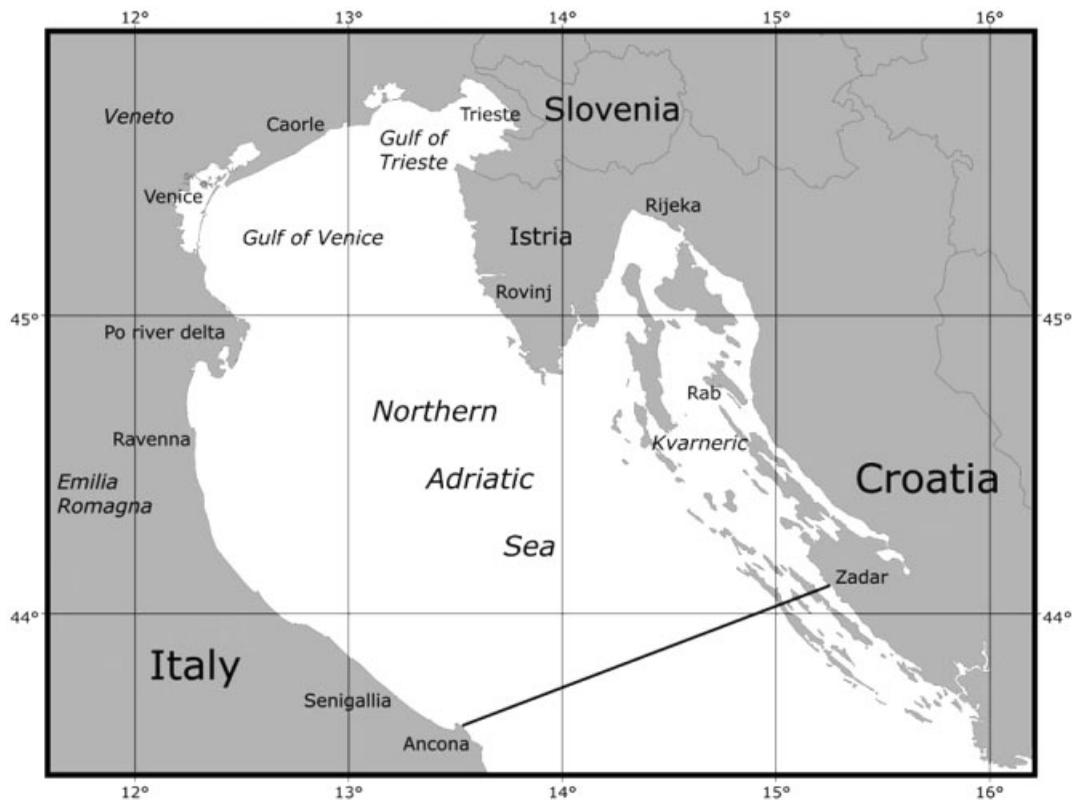


Figure 1. Map of the northern Adriatic Sea, delimited by an imaginary line connecting Ancona, Italy, with Zadar, Croatia. The map shows some of the locations cited in the text.

confirmed that only rare, scattered individuals can now be observed in the northern Adriatic (Bearzi and Notarbartolo di Sciara, 1995; Bortolotto, 1995; Affronte, 2000b).

### BOTTLENOSE DOLPHINS

The presence of bottlenose dolphins in the northern Adriatic has been richly documented since historical times (Nardo, 1853; Giglioli, 1880; Kolombatovic, 1882, 1894, 1896; Faber, 1883; Brusina, 1889; Trois, 1894; Ninni 1901, 1904, 1917; Vatova, 1932; Dulic and Tortic, 1960; Dulic and Miric, 1967; Pilleri and Gühr, 1969, 1977; Pilleri, 1970; Rallo, 1976; Pilleri and Pilleri, 1982, 1987; and see under the Common Dolphin section). Today, the bottlenose dolphin is the only cetacean species that can be considered to occur regularly in the region (Notarbartolo di Sciara and Bearzi, 1992; Krystufek and Lipej, 1993; Stanzani *et al.*, 1997; Gomercic *et al.*, 1998; Bearzi *et al.*, 2000; Podestà and Bortolotto, 2001; Holcer *et al.*, in press).

Information on the present status of bottlenose dolphins in the region is rather limited. Between 1986 and 1989, Notarbartolo di Sciara *et al.* (1993) surveyed the upper half of the Adriatic Sea (most of the survey effort being in the northern Adriatic) and recorded the lowest cetacean density of all the central Mediterranean areas they surveyed. In the Gulf of Venice (Figure 1), opportunistic sighting data were collected between 1988 and 2002. Of a total of 58 confirmed sightings, the bottlenose dolphin was the only species observed (Bearzi *et al.*, 2000; Tethys Research Institute, unpublished data). In addition, cetacean surveys conducted in 2001 and 2002 east of Venice and the Po river delta up to 46 km from the coast resulted in low mean sighting frequencies, ranging between 0.3 and 0.6 bottlenose dolphin groups per 100 km (Tethys Research Institute, unpublished data).

An exception to the generally low levels of monitoring in the northern Adriatic is a study initiated in 1987 (Bearzi *et al.*, 1997, 1999) and still underway in the Kvarneric, Croatia. The study focuses on a community (*sensu* Wells *et al.*, 1987) of about 100 bottlenose dolphins showing a high degree of year-round site fidelity in a coastal area of approximately 800 km<sup>2</sup>. Intensive boat surveys were conducted between 1990 and 1994, resulting in a mean sighting frequency of 1.4 groups per 100 km surveyed (Bearzi *et al.*, 1997). (As the published information refers to the 'mean cumulative time spent searching for dolphins before sighting any under adequate weather conditions', sighting frequency data were recalculated and expressed here as groups per 100 km, based on the same dataset that was used by Bearzi *et al.* (1997).) Based on photographic mark-recapture, Fortuna *et al.* (2000) estimated the size of this community at 98 dolphins (95% CI = 94–105, SE = 5.75) within a 700 km<sup>2</sup> area. When the survey area was expanded by about 40% (i.e. 1000 km<sup>2</sup>), the resulting estimate was 113 dolphins (95% CI = 107–121, SE = 6.97).

A mean group size of 7.4 was reported by Bearzi *et al.* (1997) based on observations conducted in the Kvarneric between 1991 and 1994. Most groups (90.3%) included less than 15 individuals, and single animals represented 11% of all observations. In surveys conducted east of Venice and the Po river delta in 2001 and 2002, groups averaged 4.8 individuals (range 1–12; Tethys Research Institute, unpublished data). Further south, off the northwestern Adriatic coast, groups averaging 14.2 and 8.3 individuals were found in 2001 and 2002 respectively (Triossi and Tizzi, in press).

Apart from the relatively high levels of site fidelity in bottlenose dolphins living in the Kvarneric (Bearzi *et al.*, 1997), little is known about dolphin movement patterns in the northern Adriatic. Comparisons of dorsal fin photo-identification catalogues obtained in different portions of the Adriatic (e.g. Picciulin *et al.*, in press) may provide some insights into any long-range movements.

The available information indicates that bottlenose dolphin densities are generally low in the northern Adriatic (Bearzi *et al.*, 1997; Tethys Research Institute, unpublished data). Claims of high dolphin densities and increased dolphin abundance made in recent years by local fishermen, particularly in the northwestern portion of the northern Adriatic, could not be confirmed by subsequent surveys. The perception of high, or

increased, dolphin abundance may be the result of net depredation suffered by fishermen in some areas (e.g. off Caorle, Italy, and Istria, Croatia; Casale, in press; D. Holcer, unpublished data).

### DOLPHIN TAKES IN THE ADRIATIC

The direct killing of small cetaceans has and continues to pose significant threats to dolphin populations worldwide (Mitchell, 1975; Reeves *et al.*, 2003). Dolphin killings, often promoted by state bounties, have been supported by several governments for at least a century (Smith, 1995). Deliberate dolphin killings in the Adriatic have been reported to occur since historical times, and mostly involved measures to reduce conflict with fisheries. The available documents make a distinction between northern and other portions of the Adriatic difficult. Little direct information exists on the species caught, as most records refer to 'dolphins' or even to 'mammals'. In addition, only partial records are available on the numbers killed each year.

According to literature reports from the 19th century, dolphins must have been extraordinarily abundant throughout the Mediterranean Sea. Conflict with fisheries was acute, and a main concern of some fishery managers was to develop and deploy new means of killing the largest possible number of dolphins (Gourret, 1894; Barone, 1895; Del Rosso, 1905; Cuculic, 1960; Stoka, 1962). However, until the end of the 19th century it was generally thought that not enough was being done, at least as far as the Italian seas were concerned. Dolphins were depicted as 'ichthyophagous monsters', 'phony and noxious pirates' and 'man's worst enemies' (Del Rosso, 1905). In such a context, the large-scale destruction of dolphins carried out in the Black Sea (Mitchell, 1975; Birkun, 2002) was seen as a positive example of appropriate fisheries management (Gourret, 1894; Del Rosso, 1905). This attitude was in striking contrast with other reports, in which it was claimed that at the end of the 19th century dolphins were seldom destroyed by Adriatic fishermen 'by whom they are considered a favourable augury of a plenteous catch' (Faber, 1883). It has been speculated that a positive attitude toward dolphins by at least some fishermen, in the Adriatic and elsewhere, was rooted in ancient superstitions of dolphins being reincarnated humans, as stated in Oppian's 2nd century AD treatise 'Halieutica' (De Marchesetti, 1882; Del Rosso, 1905). However, it is likely that occasional positive attitudes towards dolphins in historical times also depended on the fact that the animals did not overly compete with fishermen in some areas that were still productive and unaffected by overfishing. Conversely, dolphins may have become a 'problem' as fishing pressure increased.

In his review of eastern Adriatic fisheries, De Marchesetti (1882) depicted dolphins as pests deserving systematic extermination, with clear reference to *D. delphis*; reported to be the most common Adriatic species, and *T. truncatus*, said to be less frequent. Dolphin meat was considered of little value, but it was used for human consumption in some Adriatic areas (De Marchesetti, 1882; Parenzo, 1894). Despite the animosity described by some authors, and the practice of killing dolphins whenever possible, it seems unlikely that in the 19th century takes for human consumption, sport or as a measure to reduce conflict had a major impact on the reportedly very abundant dolphin populations. For instance, landing reports in Adriatic fish markets provided by De Marchesetti (1882) and Faber (1883) are indicative of a relatively low number of dolphins being sold for human consumption, compared with the reported abundance of dolphins at sea. Although the reports by De Marchesetti (1882) refer to either number of 'mammals' or weight, it can be estimated that, on average, less than 10 dolphins per year were landed over the period 1877–1882 at eight northern and eastern Adriatic fish markets. Faber (1883) includes in his statistics of Hungarian fisheries the landings of three *D. delphis* specimens totalling 230 kg, out of a total of about 530 000 kg yr<sup>-1</sup> of fishery products.

This situation apparently changed in the first half of the 20th century, when culling became one of the most important causes of dolphin mortality in the region. Evidence for the systematic killing of a large number of dolphins in the Adriatic was first presented by Holcer (1994). This significant information went

unnoticed for three decades, probably because it was published in Croatian (e.g. Crnkovic, 1958) and, therefore, not readily accessible to international scrutiny.

The first record of a monetary reward being offered for a killed dolphin in the northern Adriatic dates back to 1872, when maritime officials in Trieste and Rijeka attempted to mitigate conflict with fisheries by promoting culling (Crnkovic, 1958). No information is available to indicate the scale and duration of this first campaign. Between the World Wars I and II, the government of Yugoslavia paid two types of bounty, one for dolphins caught incidentally and the other for those killed intentionally. A partial record of animals caught at this time, kept by Srajber (in Crnkovic, 1958), reports that 335 dolphins were caught and killed between 1933 and 1935. There are no records to indicate species, scale or duration of the campaign.

The main culling campaign was launched in 1949 by the Ministry of Fisheries of the People's Republic of Croatia with the intent of eradicating dolphins from the Adriatic Sea. The Ministry offered rewards for each animal killed, but records on the number of rewards paid could not be found. In 1955, the campaign was taken over from the ministry by the Society for Marine Fisheries of Yugoslavia ('Udruzenje morskog ribarstva Jugoslavije'), which was in charge of making reward payments. Crnkovic (1958) presented a figure of 278 dolphins killed between April 1955 and November 1957. Of these, 153 were killed in the district of Rijeka alone, between 1956 and 1957. Marelic (1961) provided a more accurate description of the campaign, and reported 788 dolphins killed between 1955 and 1960. This figure included and supplemented the numbers presented by Crnkovic (1958). Again, there are no records of the species involved in the killings. However, we can infer from literature reports that common dolphins and bottlenose dolphins, i.e. the two regular cetacean species in these waters and those blamed for damaging the local fisheries (Faber, 1883; Brusina, 1889; Ninni, 1901; and see Bearzi (2002)), represented the main, if not the only, targets.

At the time of this culling campaign, Crnkovic (1958) claimed that about 1000–3000 dolphins inhabited the territorial waters of the Former Yugoslavia (today including the waters of Slovenia, Croatia, Bosnia-Herzegovina and Montenegro), whereas Marelic (1961) believed that there were 5000. Although these numbers have no scientific basis, they are indicative of the perception of a high dolphin abundance off the eastern Adriatic coasts until the late 1950s.

The culling campaign was supposed to last until 1965, but in 1959 bounties were dropped from 5000 dinars (roughly the equivalent of today's €100) to 3000 dinars (worth €60 today; Marelic, 1961). Monetary inflation after 1960 likely contributed to making the 3000 dinars bounty less and less appealing. There is no record of rewards for dolphin killings being paid after 1960. However, the end of rewarded culling should not be taken as evidence of a halt to dolphin killings. Even after 1960 fishermen in the eastern Adriatic often carried guns on board and dolphins were frequently shot (D. Holcer, unpublished data). At least until the early 1960s the animosity of eastern Adriatic fishermen towards dolphins was tremendous, and was further fuelled by fisheries officials (Cuculic, 1960; Marelic, 1961). During the eradication campaigns, every opportunity was taken to harm dolphins. A number of ideas were proposed to exterminate them, including the use of dedicated boats, special nets, harpoons, guns and other weapons. Articles in the popular press included invitations to participate in the 'great and exciting hunt for dolphins' and depicted dolphin hunting as an experience each hunter should try (Peksider-Srica, 1931). Although the perception of dolphins as mere competitors and game trophies progressively changed in subsequent years (Holcer, 1994), dolphin killings remained legal until 1995, when all marine mammals became protected under Croatian law.

Bounties to promote dolphin killings were also awarded in Italy from the early 1930s (Brunelli, 1932). On 1 January 1939, the Italian government issued a ministerial decree that rewarded the killing of a dolphin with L50 (roughly equivalent to today's €30), and this was raised to L100 if the animal was a pregnant female. A total of L40000 were budgeted for that fiscal year, but the number of dolphins that were landed was unreported. With reference to rewarded culling having occurred off the western Adriatic coasts around 1959–1961, Stanzani and Piermarocchi (1992) stated that, for an Italian fisherman, killing a dolphin was equivalent to earning an entire week's pay in a single day. However, the cumulative impact of culling off the Italian coasts of the Adriatic remains poorly documented. In addition, an unknown number of dolphins

were caught live in the northern Adriatic between 1964 and 1978 for display in captive facilities (Greenwood and Taylor, 1978; Duguay *et al.*, 1983; M. Affronte, pers. comm.). Killing dolphins for human consumption or sport was also a relatively common practice in Italy until a few decades ago (Lilli, 1964; Notarbartolo di Sciara and Bearzi, 2002). Even in the late 1960s dolphins were still regarded as food items by some (Palombi and Santarelli, 1969), and it was only in 1979 that the Italian Government prohibited unauthorized dolphin killings.

The total number of Adriatic dolphins killed was certainly higher than the figures provided here, as wounded animals escaping capture and dying afterwards could not be reported and included in total counts (Mitchell, 1975). The numbers available refer only to a few years of a series of culling campaigns that encompassed almost a century. In addition, once a fishing community has been encouraged by authorities to engage in the practice of killing dolphins, many may be inclined to continue to do so unreported, for a number of reasons (e.g. to obtain meat for human consumption, to destroy perceived competitors, etc.), even after governmental programmes of rewards have been discontinued. Even without considering unreported killings, the reported numbers are considerable. For instance, the available data show that along the eastern Adriatic coast alone almost 800 dolphins were killed in only 6 years. The fact that these must have been common dolphins and bottlenose dolphins (see above) provides a causal link between the first reported evidence of dolphin decline in the early 1970s (particularly as far as common dolphins are concerned) and the results of intensive dolphin eradication campaigns that lasted until the 1960s.

#### HABITAT DEGRADATION AND MAN-INDUCED CHANGE IN THE NORTHERN ADRIATIC

At least until the early 1970s, the northern Adriatic Sea could be considered a relatively uncontaminated ecosystem, despite the presence of high concentrations of a few polluting substances within limited coastal zones. The situation deteriorated in the following three decades, particularly in western coastal waters (Nasci *et al.*, 1999). High levels of noxious polychlorinated biphenyls were found in tissues of bottlenose dolphins sampled in northern portions of the basin (Corsolini *et al.*, 1995) as well as in some of the dolphin's key prey (e.g. *Merluccius merluccius*; Focardi *et al.*, 1998; also see Blanco *et al.* (2001)).

Serious recent deterioration in the northern Adriatic has been related to the heavy nutrient input from rivers (primarily the River Po discharges), which exceeds the basin's natural assimilation capacity (Chiaudani *et al.*, 1978; UNEP, 1996; Solic *et al.*, 1997). The northern Adriatic is especially sensitive to variations of the anthropogenic nutrient load, the impact of which can be significantly influenced by changes in the oceanographic conditions (UNEP, 1996; Degobbi *et al.*, 2000). Occasional eutrophication phenomena became more frequent during the second half of the 20th century, with the first signs of anoxia becoming noticeable in the 1960s. Starting in the 1970s, algal blooms and the production of mucilage in large portions of the northern Adriatic have become a growing concern because of the frequency, intensity and geographic extension of such phenomena, much greater than in any other parts of the Mediterranean (Justic, 1987). Consequences included several anoxia and 'red tide' events in both coastal and open waters (Vollenweider *et al.*, 1992; Degobbi *et al.*, 2000). Starting from the mid 1970s, a number of environmental changes took place in the Adriatic (Regner, 1996; Dulcic and Grbec, 2000) that can be related in part to these eutrophication phenomena (either as promoting factors or as consequences) and in part to possible global change (Russo *et al.*, 2002). A steady increase in sea-surface temperatures and salinity was observed, together with a decrease in seawater transparency and oxygen saturation in bottom layers (Zore-Armanda *et al.*, 1987; Zore-Armanda, 1991). These shifts were associated with an increase in primary production (Pucher-Petkovic *et al.*, 1987) and occurred concomitantly with significant changes in the distribution of fish species representing key prey for common dolphins and bottlenose dolphins (Blanco *et al.*, 2001; Bearzi *et al.*, 2003). For example, large masses of round sardinella *Sardinella aurita* spread over the entire Adriatic and reached the Gulf of Trieste in 1979, then retreated to the southern Adriatic in the second half of the

1980s. As they spawn during the summer months, round sardinella could have functioned as competitors to European anchovy *Engraulis encrasicolus* postlarvae (Regner, 1996). Jellyfish blooms recorded between 1977 and 1985 may have had a further negative impact on Adriatic fish stocks (Regner, 1996). A remarkable increase in the number of thermophilic species has been recorded since 1973. In contrast, other fish species have become increasingly scarce or have disappeared (Dulcic and Grbec, 2000).

Quantitative data on the status and trends of Adriatic fish stocks prior to 1975 are largely unavailable, and indication of change owing to overfishing in those years (e.g. Grubisic, 1974) is limited. However, trends in commercial fish stocks over the last 25 years imply acute shifts (Bombace, 1992; Solic *et al.*, 1997; Degobbi *et al.*, 2000). Wide fluctuations were recorded in the biomass of the most important small pelagic resources. European anchovy catches, which were very high in the late 1970s (average 1978–1980: 53000 t), decreased in the following years until they collapsed in 1987 (3700 t with unchanged fishing effort). Overfishing likely contributed to the poor recovery of anchovy stocks (Cingolani *et al.*, 1996), which has been relatively slow until present times (Santolanni *et al.*, 2002). Catches of European pilchard *Sardina pilchardus*, round sardinella and Atlantic horse mackerel *Trachurus trachurus* fluctuated widely between 1981 and 1986 (Santolanni *et al.*, 2001, 2002; Cingolani *et al.*, 2002). Moreover, catches of demersal fish in the Adriatic have declined dramatically over recent decades. Comparative trawl surveys carried out in the Adriatic Sea in 1948 and 1998 showed the almost complete disappearance in 1998 of large sharks and rays, which were abundant in the 1948 catch (Jukic-Peladic *et al.*, 2001). A catch reduction in the northern Adriatic mainly concerning demersal fish species was recorded in 1982–1987, when catch-per-unit-effort declined by half (Bombace, 1992). Although ecological and climatic factors were said to contribute to changes in Adriatic fish stocks during the 1970s and 1980s (Bombace, 1992), overfishing certainly played a significant role in the decline or collapse of some commercial species. A recent assessment by the European Commission concluded that the overall Mediterranean production and catch rates have been steadily decreasing despite the increase in fishing effort, compared with yields obtained 20 years ago or more, and it was estimated that in the Adriatic Sea the overall catch rates per unit of effort have diminished by more than 60% (EC, 2003).

The information summarized above documents some of the changes that have occurred in the northern Adriatic over the past 30–40 years. The cumulative impact of increased contamination and commercial exploitation of both demersal and pelagic fish stocks, as well as the increased occurrence of eutrophication phenomena and anoxia, has been remarkable and most northern Adriatic ecosystems are now far from 'pristine' (*sensu* Jackson and Sala, 2001). Owing to insufficient research, the resulting impact on common dolphins and bottlenose dolphins cannot be quantified; however, it would be unreasonable to assume that these top predators were unaffected by dramatic changes in their habitat.

## CONCLUSIONS

Although information on past and present numbers of dolphins living in the northern Adriatic is unavailable, a qualitative assessment of the existing literature indicates that common dolphins, as well as bottlenose dolphins, have been regular components of the northern Adriatic fauna at least since the late 18th century. Perceived high levels of conflict with fisheries and culling records (Marelic, 1961) strongly suggest that dolphin numbers in the Adriatic were still remarkably high until the early 1950s, despite about a century of deliberate takes. However, by the early 1960s their numbers must have been greatly reduced owing to a protracted and systematic campaign that peaked in the previous decade, when hundreds of dolphins were culled, in particular off the eastern Adriatic coasts. The existing literature and records make it difficult to evaluate the relative impact of these killings on the two regular cetacean species, i.e. common dolphins and bottlenose dolphins, and to assess their conservation status in the 1960s. However, the

available information suggests that both species, although impoverished by culling, were still present in the northern Adriatic through the 1970s.

Today, the disappearance of common dolphins from the northern Adriatic is manifest. Unfortunately, it is difficult to appreciate the full extent of the changes to ecosystems given shifting baselines as to what is considered a pristine ecosystem (Pauly, 1995; Jackson *et al.*, 2001). After decades have elapsed, and in the absence of solid supporting data, it now seems impossible to formulate testable hypotheses to explain such a conspicuous dolphin population decline. However, the combination of habitat degradation (e.g. diminished carrying capacity due to overfishing, presence of noxious xenobiotics in the trophic web, etc.) and intensive culling, which may have been particularly penalizing for these populations, represent valid explanations for common dolphin decline in the region.

The reason why bottlenose dolphins have managed to persist to the present date whereas common dolphins have disappeared remains unclear. As far as the impact of culling is concerned, it can be speculated that species-specific features may have been a factor in the differential decline of common and bottlenose dolphins. Such features may have included: (1) relative body size, with bottlenose dolphins being larger, heavier and, therefore, comparatively more difficult to capture and land (e.g. to cash a bounty) than the smaller and lighter common dolphins; (2) a greater propensity to bow-ride and to approach boats by common dolphins (see Würsig (2002)), in contrast to the warier bottlenose dolphins, and the habit of the former to occur in larger groups, possibly making common dolphins easier to spot, follow, shoot or harpoon; and (3) other species-specific behavioural traits, such as the capability by bottlenose dolphins to perform dives up to 8 min long (Bearzi *et al.*, 1999; Fortuna *et al.*, 1999) also see Ferretti *et al.* (1999)), and therefore, 'disappear' from sight as soon as the group perceives a danger. In addition, species-specific differences in behavioural flexibility, diet and resilience in degraded habitats may have played a role once rewarded takes were halted.

It has been suggested that the decline of the common dolphin in large portions of its former Mediterranean range has been driven largely by depletion of key prey, resulting from either overfishing or ecosystem change, or both, possibly in combination with the toxic effects of tissue contamination by anthropogenic chemicals (Bearzi *et al.*, 2003; Fossi *et al.*, 2003). This combination of threats has certainly been at play in the northern Adriatic, adding up to large-scale culling that may have disrupted common dolphin population dynamics and social organization, and eventually transforming what otherwise might have been reversible events into a possibly irreversible loss of biodiversity.

Bottlenose dolphins remain the only regular cetacean in the region, but their conservation status represents a source of concern. The impact of threats such as prey depletion (Bearzi, 2002), contamination by xenobiotics (Corsolini *et al.*, 1995) and residual animosity by fishermen (Casale, *in press*) on bottlenose dolphin groups living in the northern Adriatic deserves the greatest attention. The only relevant information on the dolphins' feeding ecology comes from the Kvarneric, where prey depletion has been suggested as a factor to explain the unusually high proportion of time (about 80%) consistently devoted to behaviour indicative of foraging and wandering in search for food (Bearzi *et al.*, 1999). Although small bottlenose dolphin concentrations, such as those living in the Kvarneric, are apparently stable (Fortuna *et al.*, 2000), they seem to be confined to those portions of the basin that still offer minimal but sufficient resources and habitat quality (Bearzi *et al.*, 1999). Evidence of isolation by Adriatic bottlenose dolphins is provided by ongoing genetic studies carried out at the University of Durham, UK, indicating that the Mediterranean population is fragmented into small, isolated groups (A. Natoli, *pers. comm.*). This situation carries risks of local or regional extinction from stochastic processes, which can be reduced by preserving as much genetic diversity as possible (Shaffer, 1987; Lande, 1988).

To preserve the few cetacean groups presently living in the northern Adriatic, and to encourage immigration from southern portions of the basin, measures should be taken to restore the local ecosystems. Habitat quality will benefit from a further reduction of contaminant and nutrient loads, especially along the

northwestern shores affected by the discharges from the large Italian rivers (Degobbi *et al.*, 2000), and from improved fisheries management aimed at preserving healthy fish stocks. The creation of appropriate networks of specially protected areas for cetaceans, such as those provided for under the auspices of the ACCOBAMS Agreement and of the SPA Protocol of the Barcelona Convention — both in bottlenose dolphin critical habitats (Mackelworth *et al.*, in press) and as a means to enhance the local fish stocks (Roberts *et al.*, 2001) — may provide substantial benefits to Adriatic dolphins.

This review: (1) stresses the importance of documenting past events and historical trends that may go unnoticed, owing to factors such as difficult access to the relevant literature and scarcity of quantitative reports; (2) suggests that the long-term impact of dolphin killings may be higher when combined with habitat degradation, resulting in dramatic changes; (3) highlights the imperative of avoiding culling, deliberate killings and other takes for cetacean species that are already exposed to a wide array of environmental threats in the Mediterranean Sea; and (4) urges the adoption of mitigation measures to improve habitat quality and prevent a further decline of northern Adriatic dolphins.

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