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Prey depletion caused by overfishing and the decline of marine megafauna in eastern Ionian Sea coastal waters (central Mediterranean)

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ABSTRACT

Surveys primarily aimed at determining dolphin encounter rates were conducted from small inflatable craft in eastern Ionian Sea coastal waters between 1997 and 2004. During 633 surveys totalling 21,276 km of effort, observations of cetaceans and other marine species spotted in a study area of 480 km^2 were systematically recorded. Common dolphin encounter rates declined 25-fold across the study period, steadily decreasing from 2.18 encounters/100 km in 1997 to 0.09 encounters/100 km in 2004. Encounter rates of tuna also declined significantly. Swordfish encounter rates dropped from 1.03 encounters/100 km in 1997 to 0–0.12 in 1998–2004. Encounter rates of bottlenose dolphins did not show significant trends. The decline of high-order marine predators feeding on epipelagic prey was consistent with the hypothesis of prey depletion, likely resulting from intensive exploitation of local fish stocks, particularly anchovies and sardines. The catholic feeding habits and opportunistic behaviour of bottlenose dolphins may allow them to withstand the effects of overfishing at their present low density.

1. Introduction

During a study focusing on dolphins inhabiting the coastal waters of the eastern Ionian Sea, started in 1991 and conducted systematically since 1997, we had opportunities to record changes in the marine ecosystem and see their impacts on the human community. Fishermen operating around the island of Kalamos, Greece, consistently lamented a decline in fish catches when interviewed individually, as do fishermen in many parts of the Mediterranean. In the last decade, there was an obvious decline in epipelagic fish, to the point that in the year 2004, due to the complete lack of sardines, the annual "festival of the sardine" (originally a way to get through plentiful catches) was celebrated in Mytikas, a small city in the core of the study area (Fig. 1), by serving farmed gilthead seabream *Sparus aurata*. Catches of tuna and swordfish *Xiphias gladius* were also said to have declined, both in numbers and individual size, by longline fishermen operating in the study area. This and other circumstantial evidence of catch decline offered signals that the local ecosystem was changing rapidly.

Ample evidence of prey depletion resulting from overfishing exists in the Hellenic Seas (Stergiou et al., 1997), including the eastern Ionian Sea. However, it would be difficult to document the full extent of change within the study area based on catch data, due to reasons including: (1) generally poor reliability of the landing data (Watson and Pauly, 2001), a well-known problem in the wider Mediterranean and in the Hellenic Seas in particular (Stergiou et al., 1997, 1998; Briand, 2000; EC, 2004); (2) the fact that at least some fishermen in the study area

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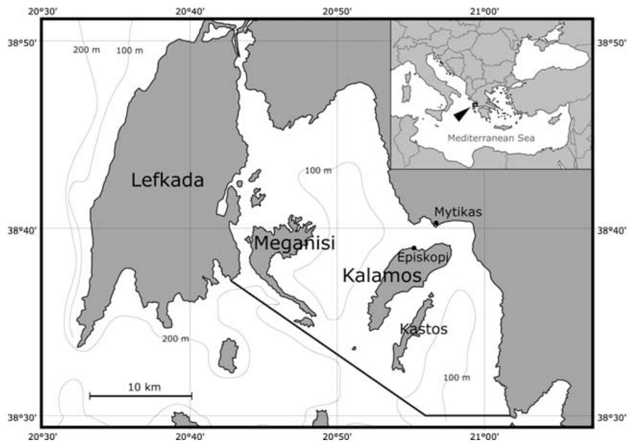

Fig. 1 – Study area (delimited by bold line) showing the locations cited in the text and bathymetric contour lines. The location of the study area in the Mediterranean Sea is shown in the inset.

deliberately misreported their catches with the intent of avoiding stricter regulations; (3) difficulty to relate the landing data to our small coastal study area, e.g., owing to the fact that fishing boats operate in a much larger area, and move to fish in far places whenever the local catches are too low.

These reasons prompted us to utilize information derived from boat surveys as an indirect indication of trends in the occurrence of megafauna within the 480 km^2 study area. Boat surveys to study short-beaked common dolphins *Delphinus delphis* (hereinafter referred to as common dolphins) and common bottlenose dolphins *Tursiops truncatus* (hereinafter bottlenose dolphins) were conducted in eastern Ionian Sea coastal waters between 1997 and 2004. All marine animals that could be sighted at the surface during visual surveys requiring continuous scanning of the sea surface were systematically recorded.

By presenting the encounter rates of several marine vertebrates, we document the precipitous decline of common dolphins between 1997 and 2004 (also see Bearzi et al., 2005). In addition, we examine the encounter rates of high-order marine predators including tuna and billfish, suggestive of decline in their yearly occurrence. Finally, we consider the possible reasons behind the observed trends and we relate them to patterns of overfishing and exploitation of epipelagic fish stocks, representing key prey for common dolphins, tuna and swordfish.

This study shows that dramatic changes are occurring in eastern Ionian Sea ecosystems. Such changes would remain largely undocumented if assessments rely exclusively on reported fishery landings that inter alia do not provide information on marine mammals. Once-abundant top predators such as the monk seal *Monachus monachus* have become ecologically extinct due to human impact (Panou et al., 1993; Sala, 2004). The trends reported here indicate that other high-order marine predators are at risk of approaching a similar fate unless appropriate management measures are implemented immediately, particularly with regard to fishing.

Evidence of cause–effect relationship provided in this article is particularly relevant to the conservation of the Mediterranean population of common dolphins. Once one of the most common cetacean species in the Mediterranean, the common dolphin has declined throughout the region during the last 30–40 years (Bearzi et al., 2003). In 2003, the Mediterranean common dolphin population was classified as Endangered in the IUCN Red List of Threatened Animals (www.iucnredlist.org). The causes of this generalized decline remain poorly understood but are thought to include prey depletion (Bearzi et al., 2003, 2004a). Largely based on the presence 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 ("Sites of Community Importance") under the 9243 EEC "Habitats" Directive (Frantzis, 1996). The area around the island of Kalamos has also been identified by ACCOBAMS (2002) as one where pilot conservation and management actions should be developed and implemented immediately to preserve common dolphin habitat. So far, however, no specific conservation actions have been taken.

2. Methods

2.1. *Study area*

The survey effort was concentrated within a core study area situated in eastern Ionian Sea coastal waters. The area is delimited by mainland Greece and the eastern coast of the island of Lefkada, and it includes the islands of Meganisi, Kalamos and Kastos. This area covers approximately 480 km^2 of sea surface (Fig. 1). The sea floor is mostly 50–150 m deep, with rocky coasts and shallows covered by seagrass meadows. Waters are transparent (Secchi disk readings ranging between 10 and 30 m), oligotrophic and unaffected by significant river and agricultural runoffs (Pitta et al., 1998). Sea surface temperatures (SST) were measured at noon between April and October throughout this study. A total of 362 SST samples were collected.

2.2. *Survey effort and encounter rates*

Surveys were conducted ad libitum from 4.7 to 5.8 m inflatable craft with rigid hulls powered by 50–80 HP four-stroke outboard engines in years 1997–2004. The survey coverage totalled 21,276 km on effort and 633 daily surveys, from June to September (Table 1). Survey methods, effort and area coverage remained consistent during the study period. Survey data were collected under the following conditions: (1) daylight and long-distance visibility (e.g., a seagull floating on the sea surface visible at 1 km); (2) sea state $\leqslant$1 Douglas with no swell (including either completely flat sea, flat sea with capillary waves or wavelets less than 10 cm high with no foam or breaking crests); (3) at least two experienced observers scanning the sea surface; (4) eye elevation of approximately 2 m for both observers; (5) survey speeds between 28 and 36 km/h. Binoculars were not used during navigation, but could be used to confirm species identification whenever necessary. All daily surveys started from the port of Episkopi (island of Kalamos, Fig. 1), and ended there. A daily survey was interrupted and navigation went off effort if: (1) dolphins were sighted; (2) sea or weather conditions deteriorated; or (3)

Table 1 – Survey effort in 1997–2004: number of daily surveys, encounters of megafauna (above) and Km surveyed on effort (below)

	Daily surveys					Encounters			
Year	Jun	Jul	Aug	Sep	Subtotal	Dt	Tt	Tuna	Billfish
1997	25	22	23	23	93	64	16	16	26
1998	17	22	21	26	86	57	15	8	19
1999	16	23	22	22	83	50	30	14	1
2000	22	23	24	21	90	54	26	4	2
2001	22	21	22	19	84	34	29	4	3
2002	19	16	24	11	70	19	32	0	5
2003	18	11	19	21	69	17	28	3	4
2004	17	11	19	11	58	5	36	0	3
Total	156	149	174	154	633	300	212	49	63
	Km surveyed "on effort"								
1997	626	522	428	581	2158				
1998	361	597	543	545	2046				
1999	549	548	689	662	2447				
2000	831	511	896	699	2937				
2001	472	552	934	478	2436				
2002	529	451	1021	454	2454				
2003	1059	783	1205	921	3968				
2004	668	287	1196	678	2829				
Total	5095	4249	6913	5019	21276				

other factors forced the crew to return to the port (e.g., late hour, running out of fuel, etc.). Marine animals encountered during the surveys were approached off effort at slow (<8 km/h) speed to confirm species identification whenever possible. All encounters related to species spotted as their entire body or portions of their body cleared the water surface. Given the low eye elevation, subsurface observations similar to those recorded during aerial surveys (e.g., Scott and Perryman, 1991; Schick et al., 2004) did not occur.

The main study area was subdivided into a total of 222 cells of 1′ latitude by 1′ longitude (1852 × 1460 m). Encounter rates were calculated for each year by the ratio n/L, where n is the total number of sightings and L is the total number of km spent on effort. This is equivalent to computing the weighted mean of the encounter rates (n_i/l_i) recorded within each cell, where n_i and l_i are the number of sightings and the number of km spent on effort in each cell, respectively, and the weights are given by the ratio l_i/L (Bearzi et al., 2005). The sampling variance of the encounter rate was then calculated using the formula (Buckland et al., 1993)

$$\mathrm{Var}(n/L) = \frac{\sum_{i=1}^{k} \frac{l_i}{L}\left(\frac{n_i}{l_i} - \frac{n}{L}\right)^2}{k-1},$$

where k is the number of cells surveyed.

Cells with a total survey effort lower than a cell's diagonal (2358 m) in any given year were excluded from the analysis of encounter rates for all years, resulting in a single set of representative cells used for all analyses (Fig. 2, inset). To check if encounter rates for these cells were effort-biased, we tested the correlation between encounter rates and km surveyed, and between encounter rates and number of sightings. Both correlations were not significant ($p > 0.10$ and $p > 0.30$, respectively).

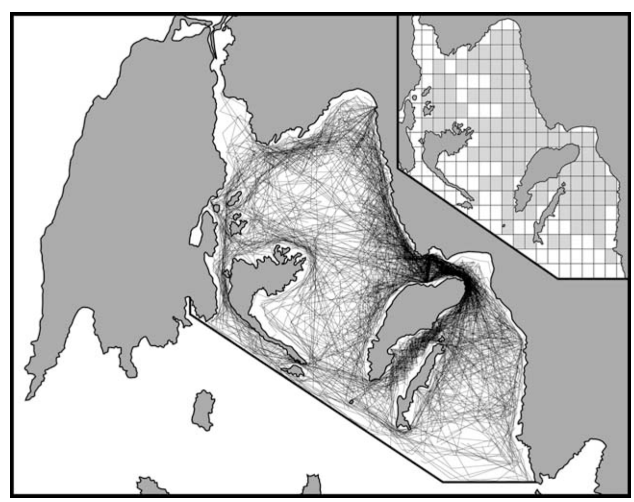

Fig. 2 – Survey effort in the study area between 1997 and 2004. Cells used for the analysis of encounter rates (see Section 2) are shown in the inset.

To test whether the cells were spatially auto-correlated, and hence not independent, the Moran's I index was computed for encounter rates of common dolphins and bottlenose dolphins in years 1997–2004, by using the MapStat extension to ArcView. Indices ranging between −0.0065 and 0.1318 showed that cells were not spatially auto-correlated for the species focus of this study.

2.3. Statistical analyses

Non parametric multiple comparisons (Kruskal–Wallis tests) were applied by using the standard Bonferroni formula ($P/k-1$). Temporal trends were evaluated by means of regression analyses using both an ordinary least square method and a weighted least square method (hereinafter referred to as WLS regression). The latter method was chosen to account for the variability in the yearly variance of the encounter rates (Mickey et al., 2004). The regression statistics presented in the Results section refer to the weighted least square trends estimators. Missing values of encounter rate variance were substituted with the mean of the other variances whenever encounter rates were zero (Afifi and Elashoff, 1966).

2.4. Prey identification

To investigate prey preferences of common dolphins and tuna and explore diet overlap between the two predators, drifting scales lost by fish prey were opportunistically collected when predatory events occurred at the surface. Drifting fish scales could be detected visually up to a depth of 1–2 m due to shining as they reflected sunlight. Scales were collected by means of a dip net (mesh size 0.4 mm) and preserved in labelled vials with ethanol 80%, each vial containing one or more scales sampled in a given feeding spot. Between May and October 1997–2002, a total of 537 fish scales were collected during 98 sampling events in different spots, spread across the study area. Scales from common dolphin prey totalled 77 vials collected during 43 days, each vial including 1–20 scales (median = 3, interquartile range = 6). A total of 21 vials from tuna prey were obtained during 16 days, each including 1–50 scales (median = 5, interquartile range = 5). Scales were hydrated with distilled water for approximately 5 h, placed in a 10% potassium hydroxide solution for 30 min, gently brushed, and observed through a Nikon stereo microscope (×0.8–×4.0 lens). The scales were then matched with a photo atlas of scales from known fish species collected in the study area. As morphological variability exists among scales from different body parts of the same individual, the atlas included photographs of scales collected from four different body parts, for fish of various sizes (Patterson et al., 2002). Scales of European pilchard (*Sardina pilchardus*) and gilt sardine (*Sardinella aurita*) could not be reliably discriminated and were therefore pooled together. To avoid repetitive calculation of samples from the same prey school, for each day only one vial was randomly extracted. Diet overlap analysis were therefore computed on a subset of 43 vials of common dolphin prey and 16 vials of tuna prey. The Pianka's niche overlap index (Pianka, 1974) was used to assess diet overlap between the two predators.

3. Results

3.1. Species encountered

Common dolphins and bottlenose dolphins were the focus of this study and species identification was always certain and documented (Bearzi et al., 2005). During this study we recorded 300 encounters of common dolphins and 212 of bottlenose dolphins. All encounters were of groups composed of only one species.

Scombridae estimated visually to be longer than approximately 80 cm were recorded as "tuna" (49 encounters). This category included mostly or exclusively northern bluefin tuna *Thunnus thynnus* and albacore *Thunnus alalunga* (Bauchot, 1987; Stergiou et al., 1997). During the surveys, tuna were spotted at the surface exclusively when they were feeding. Small fish prey was consistently seen at the surface in those occasions.

"Billfish" (63 encounters) likely referred exclusively to swordfish *X. gladius*, the most common billfish species in the Mediterranean. Swordfish could be easily identified at sea owing to their characteristic morphology, and were easily spotted as they breached (often repeatedly) and when they swam with their dorsal and caudal fins out of the surface. Other billfish members of the family Istiophoridae (particularly Mediterranean spearfish *Tetrapturus belone* and Atlantic sailfish *Istiophorus albicans*) reportedly occur in Greek waters (Nakamura, 1985; Bauchot, 1987) and may be mistaken for swordfish as they do not always erect their highly distinctive, large dorsal fins at the surface. However, Istiophoridae appear to be rare in the study area and catches of these billfishes were never reported.

Based on visual assessments of body size, "tuna" (i.e., Scombridae >80 cm) encountered in the study area during the surveys averaged 1.3 m, and billfish 0.8 m. Other large marine species were occasionally observed in the study area. These included an individual fin whale *Balaenoptera physalus* repeatedly observed in August 2001, striped dolphins *Stenella coeruleoalba* ($n = 1$), Mediterranean monk seal *Monachus monachus* ($n = 7$), loggerhead turtle *Caretta caretta* ($n = 8$), devil fish *Mobula mobular* ($n = 17$), ocean sunfish *Mola mola* ($n = 3$), greater amberjack *Seriola dumerili* ($n = 3$), European barracuda *Sphyraena sphyraena* ($n = 1$), and unidentified shark species ($n = 7$). Trends in the encounter rates of these species were not considered owing to low sample numbers. A total of 25 encounters of unidentified fish estimated to be longer than 80 cm (possibly including tuna, billfish, shark, greater amberjack, European barracuda and/or other species) were excluded from the analyses.

3.2. Encounter rates

Encounter rates of common dolphins showed a significant decrease between 1997 and 2004 (Kruskal–Wallis rank test $H = 43.96$, $df = 7$, $p < 0.001$; Fig. 3). Regression analyses confirmed that there was a highly significant, steady decline in common dolphin encounter rates (ANOVA for regression $F = 220.2$, $df_1 = 1$, $df_2 = 6$, $p < 0.001$).

Bottlenose dolphin encounter rates ($\text{mean}_{1997–2004} = 0.63$ groups/100 km) did not show significant variations in years 1997–2004 (Kruskal–Wallis rank test $H = 10.31$, $df = 7$, $p = 0.172$; Fig. 4). WLS regression analyses showed no significant temporal trend (ANOVA for regression $F = 0.005$, $df_1 = 1$, $df_2 = 6$, $p = 0.948$).

Encounter rates of tuna showed a significant decrease between 1997 and 2004 (Kruskal–Wallis rank test $H = 21.26$, $df = 7$, $p < 0.05$; Fig. 5). Multiple comparisons showed that

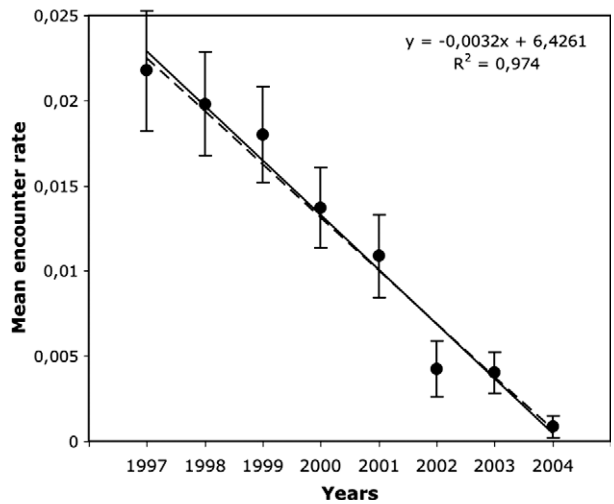

Fig. 3 – Common dolphin mean encounter rate by year, 1997–2004. Error bars represent ±1 standard deviation. Regression lines are shown based on ordinary least squares (solid line) and weighted least squares (dashed line).

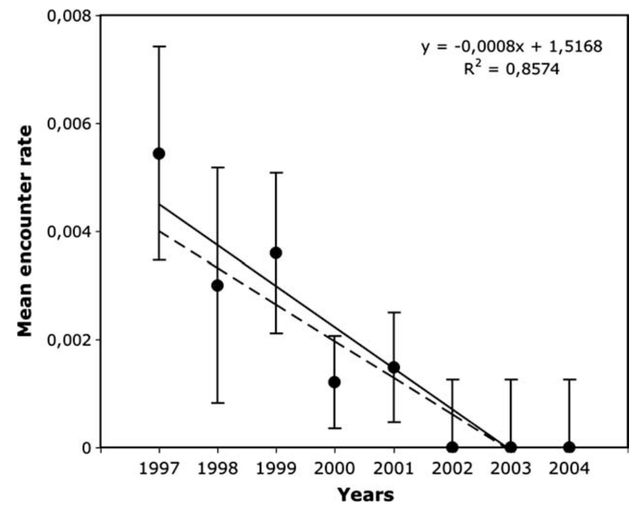

Fig. 5 – Tuna mean encounter rate by year, 1997–2004. Error bars represent ±1 standard deviation. Regression lines are shown based on ordinary least squares (solid line) and weighted least squares (dashed line).

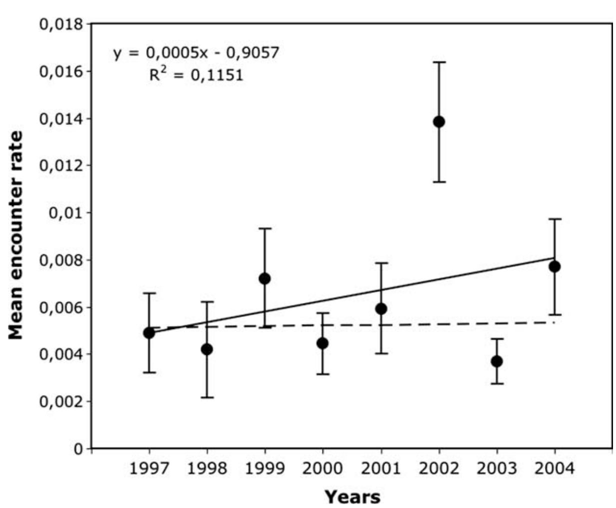

Fig. 4 – Bottlenose dolphin mean encounter rate by year, 1997–2004. Error bars represent ±1 standard deviation. Regression lines are shown based on ordinary least squares (solid line) and weighted least squares (dashed line).

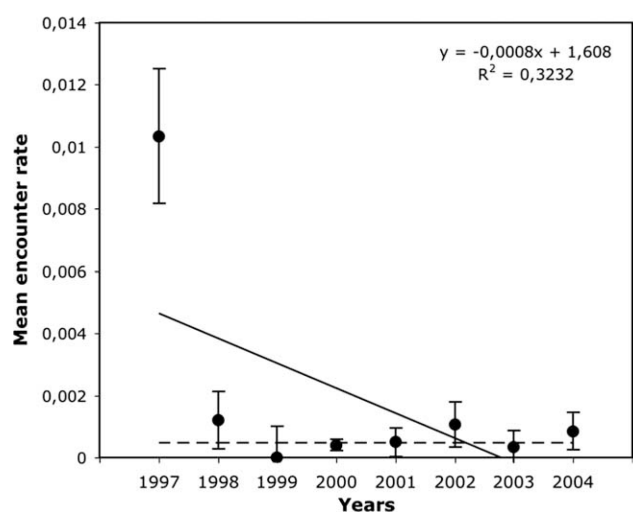

Fig. 6 – Billfish mean encounter rate by year, 1997–2004. Error bars represent ±1 standard deviation. Regression lines are shown based on ordinary least squares (solid line) and weighted least squares (dashed line).

encounter rates of tuna in 1997 (0.54 groups/100 km) were significantly higher than in 2002–2004. Regression analyses confirmed that there was a significant decline in tuna encounter rates (ANOVA for regression $F = 20.9$, $df_1 = 1$, $df_2 = 6$, $p < 0.01$).

Encounter rates of billfish were relatively high in 1997 (1.03 groups/100 km) but collapsed subsequently ($\text{mean}_{1998–2004} = 0.059$ groups/100 km; Kruskal–Wallis rank test $H = 69.65$, $df = 7$, $p < 0.001$; Fig. 6). Multiple comparisons confirmed that encounter rates in 1997 were significantly higher than in all other years. However, WLS regression analyses showed no significant temporal trend (ANOVA for regression $F = 0.00002$, $df_1 = 1$, $df_2 = 6$, $p = 0.907$).

3.3. *Sea surface temperatures*

SSTs in the study area ranged between 14.5 and 29.6 °C (April–October, 1997–2004). A WLS regression showed no significant SST trend during the study period (ANOVA for regression $F = 0.487$, $df_1 = 1$, $df_2 = 6$, $p = 0.511$).

Encounter rates of common dolphins, bottlenose dolphins and tuna did not show correlation with SSTs based on WLS regression analyses (ANOVA for regression, $df_1 = 1$, $df_2 = 6$;

common dolphins $F = 3.056$, $p = 0.131$; bottlenose dolphins $F = 0.842$, $p = 0.394$; tuna $F = 0.042$, $p = 0.844$).

3.4. Prey identification

Fish scale samples collected following predatory events by common dolphins and tuna included Engraulidae and Clupeidae. Each sample vial contained scales from only one taxon (i.e., scales of Engraulidae and Clupeidae were never found together in the same vial). European anchovies (*Engraulis encrasicholus*) represented 37.2% of common dolphin prey and 87.5% of tuna prey. Sardines constituted 62.8% of common dolphin prey and 12.5% of tuna prey. The analysis of fish scale samples collected in the study area revealed a considerable diet overlap between common dolphins and tuna as far as surface feeding was concerned, as indicated by a Pianka's niche overlap index of 0.63.

4. Discussion

Encounter rates of cetaceans during visual boat-based surveys can be directly related to their relative or absolute abundance (Buckland and York, 2002; Forney, 2002) due to the need by marine mammals to come regularly to the surface to breath. On the other hand, tuna and billfish spend at the surface only a small, variable proportion of their time and this can affect their detectability. For instance, schools of northern bluefin tuna may spend less than 12% of each day at the surface, where they can be detected by aerial surveys (Lutcavage et al., 2000; Brill and Lutcavage, 2001). While we feel confident in our observer's ability to detect surface activity, we acknowledge the limitations the survey method places on our interpretation of these results. Indeed, encounter rates of fish obtained from boat-based visual surveys provide little information on their absolute abundance, neither do they allow to compare the relative abundance of different species. However, this is not necessarily a problem if encounter rates are used primarily to investigate longitudinal changes in the relative occurrence of individual species. Thus, the observed changes in fish encounter rates recorded during this 8-year study provide insight on their yearly occurrence in the study area and can be used as a proxy for abundance trends. In other parts of the world visual data obtained during aerial and ship surveys were used to investigate inter alia the distribution and abundance of northern bluefin tuna (Lutcavage and Kraus, 1995; Lutcavage et al., 1997a,b; Schick et al., 2004), flyingfish (Parin, 1983; Nesterenko, 1993; Oxenford et al., 1995), sharks (Kenney et al., 1985), mobulid rays (Notarbartolo di Sciara and Hillyer, 1989) and to study aspects of the ecology of sea turtles and ocean sunfish (Shoop and Kenney, 1992; Kenney, 1996). Despite their limitations, including possible longitudinal variations in time spent by fish at the surface, visual assessments of fish encounter rates provide information that can complement and/or validate information obtained from fishery catch data. As Mediterranean fisheries statistics are generally considered incomplete and poorly reliable (Briand, 2000, 2003), information derived from visual surveys may help detect longitudinal trends in abundance and overcome gaps – or remark possible flaws – in the fishery reporting system. This information is also valuable to assist in the identification of management measures that are particularly urgent, as in the case of quickly declining communities of Mediterranean common dolphins (Reeves et al., 2003).

A decline of common dolphin occurrence in the area of Kalamos until 2003 was reported by Bearzi et al. (2005), based on: (1) decreasing encounter rates; (2) decreasing group sizes (common dolphin mean group size was 13 between 1993–1996 and 7 in 1997–2001); (3) decreasing total number of recognizable individuals encountered each year; (4) low rates of immigration. Such a negative trend not only continued but was particularly pronounced in 2004, when common dolphin encounter rates were 25 times lower than in 1997 (2.18 encounters/100 km in 1997 and 0.09 encounters/100 km in 2004; Fig. 3). This study also indicates that other high-order predators, besides common dolphins, may be declining.

It must be noted that while the decline in the occurrence of both common dolphins and tuna in the study area was also highlighted by WLS regression analyses, such analyses did not show a significant trend in billfish encounter rates across the study period. However, a non-linear decline was apparent as billfish encounter rates collapsed after the first year of the study, from 1.03 encounters/100 km in 1997 to 0–0.12 encounters/100 km in 1998–2004. Care should be taken in the interpretation of billfish temporal trends until more information becomes available.

No obvious trends in encounter rates were recorded for bottlenose dolphins, that showed a low (0.63 groups/100 km) but relatively stable occurrence throughout this study, with an average group size of 7 individuals (Bearzi et al., 2005). Bottlenose dolphins often manage to survive at low population numbers under unfavourable circumstances (e.g., see Bearzi et al., 2004a), largely owing to adaptive strategies involving a high degree of flexibility of diet, social organisation and behaviour (Shane et al., 1986; Shane, 1990; Bearzi et al., 1999; Blanco et al., 2001). Opportunistic foraging near fish farm cages was repeatedly observed in the study area (Bearzi et al., 2004c; Tethys Research Institute, unpublished data). Bottlenose dolphins were rarely seen feeding at the surface, as common dolphins routinely did. This fact, together with literature information (e.g., Blanco et al., 2001) and observations of diving behaviour (Bearzi et al., 1999; Ferretti et al., 1999), suggests that epipelagic schooling fish are not important prey for bottlenose dolphins around the island of Kalamos.

In the study area, species with declining encounter rates included high-order predators for which epipelagic fish such as anchovies and sardines represent either the main prey or important diet components (common dolphin: Chalabi and Ifrene, 1992; Orsi Relini et al., 1995; Bearzi, 2000; Bearzi et al., 2003; northern bluefin tuna: Collette and Nauen, 1983; Sanz Brau, 1990; Orsi Relini et al., 1995; albacore: Collette and Nauen, 1983; swordfish: Salman, 2004). Analyses of fish scales sampled around Kalamos during surface feeding by common dolphins and tuna confirmed that Engraulidae and Clupeidae are important prey for both predators. The diet of swordfish in the study area could not be investigated directly. However, Salman (2004) found that the proportion of teleosts in the stomach of 108 swordfish sampled in the Aegean Sea (Greece) was 81.5%, followed by cephalopods (17.8%) and crustaceans (0.7%). Among teleosts, the majority of prey in terms of frequency of occurrence were European pilchards (49.5%) and European anchovies (39.8%).

The possible reasons behind the precipitous decrease of common dolphin numbers in the area of Kalamos were discussed by Bearzi et al. (2005), who did not regard direct killings, bycatch and contamination by xenobiotics as primary causes of the observed decline. Changes in oceanographic parameters can have large-scale impacts on the distribution and/or abundance of high-order predators, primarily by influencing the availability of their prey. In the study area, however, SSTs did not show obvious annual trends and were not correlated to the observed encounter rates. The potential effect of monthly SST fluctuations could not be considered due to small sample sizes. However, such short-term fluctuations would not be especially good candidates for explaining the regular, continuous decline of common dolphins throughout the study period. Whether the observed trends were simply a consequence of migratory behaviour or long-range movements is not known, and this hypothesis certainly deserves further investigation, also considering the relatively small size of our study area. To date, surveys conducted outside the study area between 1997 and 2004 provided no evidence to suggest that the core of the common dolphin community has shifted elsewhere (Bearzi et al., 2005).

The patterns observed in the eastern Ionian Sea are consistent with the hypothesis of a decreased availability of key prey in the study area, making this coastal habitat less capable of sustaining large predators. Although prey overlap between high-order predators and fisheries does not necessarily imply direct competition (Briand, 2004), it is reasonable to assume that such competition might occur when key prey for high-order predators is scarce and subjected to heavy exploitation (Trites et al., 1997). Excessive fishing pressure is a growing concern, worldwide (e.g., Jackson et al., 2001; Pitcher, 2001; Pauly et al., 2002) and is having profound direct and indirect impacts on Mediterranean ecosystems (Sala, 2004). Although in the Mediterranean there is an acute lack of historical data (Briand, 2000, 2003), it is acknowledged that unsustainable harvesting led to the decline of many fish stocks (Caddy and Griffiths, 1990; De Walle et al., 1993; Stanners and Bourdeau, 1995; Caddy, 1997; Briand, 2000; FAO, 1997, 2000; Pauly and Palomares, 2000). Many stocks are considered to be outside safe biological limits and some are in a critical state, largely because more fishing is allowed than is recommended by scientific advice (EEA, 2003). Overall, 60% of European fish catches would exceed safe limits, i.e., levels above which the biomass removed by fishing is no longer replaced by population growth (EEA, 2004). In the wider Mediterranean, dramatic ecological changes were highlighted inter alia by Caddy (1997), who expressed concern about the stock status of northern bluefin tuna and swordfish, threatened by the apparently unrestrained growth of surface gillnet and longline fisheries, as reflected by progressive decreases in mean size and age at capture (Stergiou et al., 2003). In a review of the state of exploitation of Mediterranean fish stocks between 1950 and 1994, the FAO (1997) reported European pilchards to be Moderately exploited/Fully exploited; European anchovies and swordfish were reported as Fully exploited/Overfished; northern bluefin tuna and albacore as Depleted.

In the Hellenic Seas, fishing effort has been rapidly increasing since the 1960s (Stergiou et al., 1997). Based on the online database of worldwide catches managed in the context of the "Sea Around Us Project" (www.seaaroundus.org), fishery landings within Greece's EEZ have constantly increased between the early 1970s and 1994 as a result of growing fishing effort (Stergiou et al., 1997). However, total landings have declined rapidly after 1994 (Fig. 7). Accordingly, an analysis of the monthly landings per day trends of the data kept in the Institute of Marine Biology of Crete (IMBC) database also showed that between 1996 and 2000 most target species exhibited negative trends in the catch per day of the main gear in their main fishing grounds (EC, 2004).

In the eastern Ionian Sea much of the fish fauna has been reduced by intensive fishing, and the potential exists for exploitative competition (Keddy, 1989) between high-order predators such as common dolphins, tuna, swordfish and local mid-water fisheries targeting their prey, particularly anchovies and sardines (Pusineri et al., 2004; Bearzi et al., 2005). The mean trophic level of fishery catches in the eastern Ionian Sea coastal waters encompassing the study area has been decreasing over the past 20 years (Stergiou and Koulouris, 2000), indicating that the effect of fishing down the food web (Pauly et al., 1998) is at play in this part of the Mediterranean. Around the island of Kalamos, total landings decreased since the mid 1980s (Papaconstantinou et al., 1988; Papaconstantinou and Stergiou, 1995; Stergiou et al., 1997), and intensive trawling reportedly led to the decline of European hake *Merluccius merluccius* stocks (Papaconstantinou et al., 1985). In particular, the mean trawl catch per day in the Greek Ionian Sea declined significantly between 1996 and 2000, indicating a decline of demersal resources (EC, 2004; K. Stergiou, pers. comm.). Purse seine catch per day time series and especially those referring to vessels larger than 15 m, which account for the majority of the small pelagic catch, exhibited a declining trend. Purse seine catches per day of both

Fig. 7 – Total reported landings within Greece's EEZ, 1970–2001, according to the Sea Around Us Project database (www.seaaroundus.org).

anchovies and sardines declined in the eastern Ionian Sea between 1996 and 2000 (EC, 2004, p. 359).

A possible "fishing down" impact on marine food webs (Pauly et al., 1998) such as that resulting from longline fishing targeting tuna and swordfish, combined with "food web competition" (*sensu* Trites et al., 1997) deriving from intensive fishing of small epipelagics, would ultimately affect top predators as well as the local fisheries targeting them. We hope that the evidence provided here will encourage further investigation based on quantitative assessments as well as management measures to prevent further decline and/or loss of suitable habitat for common dolphins and other megafauna. In the absence of clear evidence on cause–effect relationships, action aimed at controlling overfishing is certainly a management obligation, as well as an appropriate precautionary measure. Fishery management aimed to reduce the heavy exploitation of epipelagic fish stocks would be likely to produce benefits. In particular, the stocks of European anchovy and European pilchard, representing important prey for common dolphins, tuna and swordfish, are being heavily exploited by purse seiners, and catches are known to have declined dramatically in the study area in recent years. As the requirements to protect ecosystems from the wider impacts of fishing are already embedded in existing legislation and treaties (Bearzi et al., 2004b; Jennings, 2004; Owen, 2004), we suggest that simply fulfilling the existing obligations aimed to restrict fishing would represents an obvious but effective conservation action that can be implemented immediately to stop the decline of common dolphins and other high-order marine predators in the eastern Ionian Sea. The creation of networks of marine reserves and no-take zones aimed at protecting resident and migratory fish stocks would be an appropriate second step (Agardy, 1997; Roberts et al., 2001; Stergiou, 2002). This will ultimately benefit the commercial fisheries for those species and ensure the maintenance of prey mass and quality needed to sustain viable populations of predators.

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