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Interactions between Mediterranean bottlenose dolphins (*Tursiops truncatus*) and gillnets off Sardinia, Italy

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A first attempt at analysing interactions between bottlenose dolphins and gillnets along the northeastern coast of Sardinia (Italy) was conducted between October 1999 and December 2004. A new approach was used: combining interviews with fishers with boat-based direct observations and behavioural and group size analysis. Fishers on monitored boats noted 2556 days on which gillnet damage was caused by bottlenose dolphins, 68.7% of the total fishing days, with no difference between seasons. An annual estimate of the number of bottlenose dolphins caught in the gillnets was 1.47 (0.98 immatures and 0.49 adults). In all, 317 days were spent making observations at sea, of which 330.6 h were spent directly observing the dolphins. There were no changes in the distribution of daily encounter rate among seasons, group size, or number of immatures, in the presence or the absence of gillnets. However, bottlenose dolphins spent more time both in the study area and feeding when gillnets were present. The extent of the estimated bycatch is worrisome in terms of the ability of bottlenose dolphins off Sardinia to sustain such an annual loss.

Keywords: behaviour, bottlenose dolphin, bycatch, fisheries, gillnets, Mediterranean Sea, trammel nets.

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Introduction

Cetacean populations are affected by man's use of coastal waters, particularly by fisheries activities and habitat modification (Fertl and Leatherwood, 1997). Northridge (1984), in a review of fisheries interactions throughout the world, concluded that no species of marine mammal can be excluded from the possibility of some conflict with fishers, but that the lack of adequate data prohibits an assessment of the full extent and potential impact of many of the interactions.

Interactions with fisheries are potentially harmful to marine mammals (e.g. depletion of fish stocks, direct kills in fisheries, and bycatch in fishing gear) and to man (e.g. gear damage and depletion of commercially valuable fish stocks; Beddington *et al.*, 1985). Although perceived conflict of interactions between bottlenose dolphins (*Tursiops truncatus*) and coastal, small-scale commercial fisheries has been reported from a number of Mediterranean areas, there have been few studies aimed at defining the extent of the conflict (Bearzi, 2002).

This study is a first attempt analysing the interactions between bottlenose dolphins and gillnets off the northeastern coast of Sardinia (Italy). The main purpose of the paper is to contribute towards a more detailed understanding of the relationships between bottlenose dolphins and gillnets. The study was based on a new approach combining interviews with fishers with boat-based direct observations and behavioural and group size analysis.

Methods

The study took place along the coast of northeastern Sardinia, Italy. The boundaries of the study area were Salina (40°55′N) in the south, and Punta Volpe (41°02′N) in the north, and the offshore extent was the 75 m isobath (Figure 1). Previous work (Díaz López *et al.*, 2004) showed a degree of residence of identifiable bottlenose dolphins and highlighted their abundance in the area. The town of Golfo Aranci (40°59′N, 009°37′E) encompasses the most representative harbour in terms of gillnet fishing effort on the northeastern coast of Sardinia, some 30 boats operating from there.

Fishing effort and interviews

The gillnet fishery described in this paper operates in the study area on a permanent basis, and is for a mixture of

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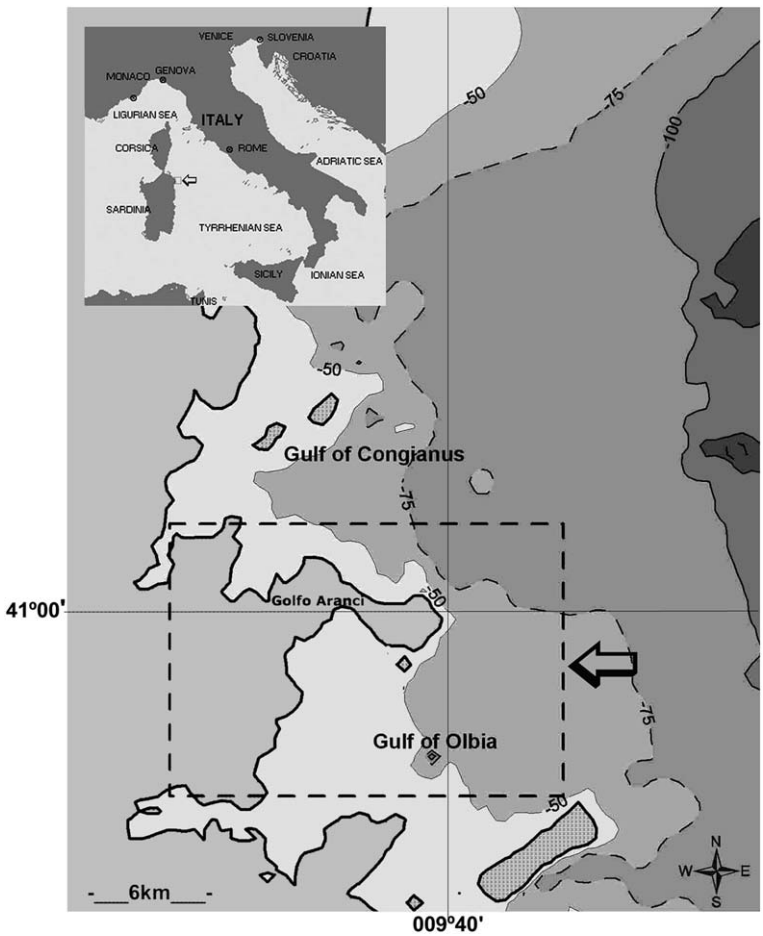

Figure 1. Map of the northeastern coast of Sardinia, showing the location of the study area.

species. Gillnets employed in Golfo Aranci consist of single or triple nets (known as trammel nets) mounted together on the same frame ropes. Occasionally, several types of nets may be combined in a single gear (e.g. a trammel net combined with a single net). The fishery is primarily conducted by resident fishers, so the activities were assumed to be relatively consistent with regard to distribution and effort year round.

From October 1999 to December 2004 (with the exception of 2003), gillnet fisheries were monitored through weekly interviews with the fishers operating six boats based in Golfo Aranci, some 20% of the total gillnet fleet. Boat selection was random each week, and no particular boat was monitored continuously during the entire period (Di Beneditto, 2003). Information requested from the fishers included: (i) days operating in the fishery, (ii) gillnet position at sea (fishing area and depth), (iii) days on which damage was caused to the gear by bottlenose dolphins, and (iv) bottlenose dolphin mortality.

Total fishing effort was based on the data obtained weekly, and was expressed as the number of days the monitored fishers deployed gillnets.

Direct observation

Boat-based observations were undertaken regularly between November 1999 and December 2004, again with the exception of 2003. In all, 31 months were spent in the field (October 1999−May 2000; September 2000−July 2001; September 2001−June 2002; and November and December 2004). Randomization of the surveys was attempted in order to cover the total study area every week, although the geographic distribution of effort could vary according to weather conditions and dolphin sighting frequency.

On each boat-based survey, I recorded the following: date, time, position (GPS), presence of fishing boats deploying or retrieving gillnets, gillnet buoys in the visual area, Beaufort and Douglas scales, and bottlenose dolphin

presence and group size. A "group of dolphins" is here taken to represent one or more bottlenose dolphins observed in the area, usually involved in the same activity. Sightings were considered satisfactory when the visibility was not reduced by rain or fog, and sea conditions were ≤4 on the Douglas scale (approximately equivalent to the Beaufort wind force scale). Searching effort stopped at sighting, and restarted when the sighting was finished. The encounter continued until the group was lost (a group was considered lost after 15 min without a sighting).

Observations were made year round in the presence and absence of gillnets, during daylight only between 06:00 and 20:00. Local time was converted to solar time when appropriate, to account for daylight saving. In order to analyse the seasonality of gillnet fishing operations, bottlenose dolphin interactions, and bycatch data, four seasons were defined: spring, April−June; summer: July−September; autumn, October−December; and winter, January−March.

Two arbitrary age classes were selected: (i) immatures, i.e. dolphins two-thirds or less the length of an adult which may sometimes swim in an echelon; and (ii) adults, i.e. dolphins approximately 2.5−3.0 m long. Classification was aided by observations of associates and behaviour. The size group and age categories were assessed visually *in situ*, and the data were later verified with photographs and videos taken during each sighting. As the number of sightings could depend on the search effort, a daily bottlenose dolphin encounter ratio (DER) was computed as DER = N_s/search effort (h), where N_s is the total number of sightings.

Behaviour

The duration of each behavioural activity performed by a dolphin group during a sighting (focal group sampling) was recorded (Altmann, 1974; Mann, 1999). A group of dolphins was observed, and the start and end times of the four behavioural categories, feeding, socializing, resting, and travelling, were noted. These states were similar to those used in other studies (Shane, 1990; Díaz López, 2005). The definition of each behavioural category was attempted *a posteriori* following data analysis strictly based on objective, non-discrete parameters, including dive duration, swimming direction and speed, visible prey, presence of gillnets, contact among individual dolphins, and other variables.

Photographs and video recordings were also made to document and verify activities visible at the surface. As in most behavioural studies on cetaceans, it was also assumed that activities visible at the surface were representative of activities beneath the surface. All data were tape-recorded, then transcribed on the evening of the observations before being entered into the database.

Data analyses

Data were analysed with Palaeontological Statistics, PAST, version 1.35 (Hammer *et al.*, 2001). Data are presented as means ± the standard error. Statistical significance was tested at the $p < 0.05$ level.

A χ^2 test known as the "Goodness-of-Fit" procedure (Brower *et al.*, 1984) was used to test whether the distribution of days with gillnet damage caused by bottlenose dolphins noted by the fishers interviewed was homogeneous between seasons in relation to interview distribution. To account for the proportionality of data collected during boat-based observations in the presence and absence of gillnets, it was decided arbitrarily to select at random 10 days at sea per season, first in the presence of gillnets, and second in their absence. These independent data subsets were used to perform a two-way ANOVA to test the DER (in the presence and absence of gillnets) among seasons.

Sightings of <10 min duration were not used in any of the analyses because they were considered too short, both to determinate behavioural category and to assess accurately the group size and age categories *in situ*. To account for the proportionality of sighting data collected in the presence and absence of gillnets, 80 sightings in the presence of gillnets and 80 sightings in the absence of them were selected randomly. These independent data subsets were used to perform a two-way ANOVA to compare the differences in time spent in various activities according to the presence or absence of gillnets.

All data tested with ANOVA were checked graphically for normality and homoscedasticy. If assumptions for ANOVA were violated, variables were $\log_{10}$ transformed, and the residuals were examined. If the ANOVA showed significant inequality of the means, a Student's t-test was carried out. A non-parametric Kruskal−Wallis test was used to assess differences in group size as well as in the number of immature dolphins and the duration of sightings in the presence and absence of gillnets.

Results

Interviews with fishers

During the period of study, 744 interviews with fishers were carried out; the results and the season when they were carried out are listed in Table 1. Throughout the study area, gillnet operations were conducted close to shore, in water 4−63 m deep (mean = 19.7 m, s.e. = 0.8).

The variability in the number of interviews per season was due to poor weather (e.g. strong winds), which forced the fisheries to stop temporarily. Fishers on the boats monitored noted 2556 days when there was gillnet damage caused by bottlenose dolphins, i.e. 68.7% of the total fishing days. Days with bottlenose dolphin damage to the gillnets did not show any significant differences between seasons (goodness-of-fit: $\chi^2 = 1.9$, d.f. = 3, $p > 0.05$).

Incidental takes of bottlenose dolphins in gillnets were observed: three dolphins were captured in 3720 days (0.29 dolphins year^{-1}), two immatures (0.19 dolphins year^{-1}), and one adult (0.1 dolphins year^{-1}). No other

Table 1. Seasonal distribution of fishing effort, days with gillnets damaged, and bottlenose dolphin bycatch in the study area obtained from interviews with fishers.

Season	Number of months	Number of interviews	Fishing effort (days)	Days with gillnet damage	Days with bycatch
Winter	9	216	1 140	792	2
Spring	8	192	1 092	766	0
Summer	3	72	432	282	0
Autumn	11	264	1 056	716	1
Total	31	744	3 720	2 556	3

marine mammal bycatch was recorded. Two of the entrapped dolphins were dead, but one immature was cut from the net alive and released. Assuming a constant probability of bycatch by the entire gillnet fleet (30 boats), the estimated annual number of bottlenose dolphins caught in gillnets along the northeastern coast of Sardinia would be 1.47 (0.98 immatures, 0.49 adults).

Direct observations of behaviour and group size

During 31 months of observations, 317 days were spent at sea, lasting on average 247 ± 7.46 min. Of this total time at sea, 330.6 h were spent in direct observation of 437 groups located in the study area. Seasonal distribution of search effort, number of sightings, and DER in the presence and absence of gillnets is listed in Table 2. There were no changes in the distribution of DER between seasons in the presence and absence of gillnets (two-way ANOVA: $F_{\text{gillnet presence–absence}} = 0.31$, d.f. $= 1$, $p > 0.05$; $F_{\text{season}} = 0.17$, d.f. $= 3$, $p > 0.05$; $F_{\text{gillnet presence–absence} * \text{seasons}} = 0.24$, d.f. $= 3$, $p > 0.05$).

In all, 349 sightings lasting 10+ min were selected for behavioural and group size analysis. The mean time of observation for each sighting was 55.9 ± 3.1 min. Group size ranged from singletons to groups of 20 dolphins, and showed a median group size of 4 (mean $= 4.95 \pm 0.3$). Overall 85% were adults and 15% were immatures. Neither group size nor number of immatures varied in the presence or absence of gillnets (Kruskal–Wallis test, $p > 0.05$; Figure 2).

Bottlenose dolphins spent more time in the study area in the presence of gillnets (mean $= 56.3 \pm 4.8$ min) than when they were not set (mean $= 39.4 \pm 4$ min; Kruskal–Wallis test, $p < 0.05$). There were differences in the time spent engaging in different behaviours in the presence and absence of gillnets (two-way ANOVA: $F_{\text{behaviour}} = 333$, d.f. $= 3$, $p < 0.01$; $F_{\text{gillnet presence–absence}} = 11.8$, d.f. $= 1$, $p < 0.01$; $F_{\text{behaviour} * \text{gillnet presence–absence}} = 0.3$, d.f. $= 3$, $p > 0.05$; Figure 3). In particular, dolphins spent more time foraging in the presence of gillnets than when they were absent (Student's t-test, $t = 2.1$, $p < 0.05$; Table 3).

Discussion

By examining the results of the interviews and the direct observations it is clear that bottlenose dolphins are present off northeastern Sardinia all year round irrespective of the presence of gillnets. Further, when gillnets are present, there is regular, year-round interaction between the dolphins and the fisheries. Although currently it is not possible accurately to quantify the economic impact of bottlenose dolphins on the gillnet fishery, the 68.7% of fishing days with reported gillnet damage could have a relatively large impact on a fisher's livelihood. The resulting economic cost explains why Sardinian fishers complain so vociferously about the depredations of bottlenose dolphins and perceive these animals as competitors. Similar observations have been recorded elsewhere in the Mediterranean (Tringali *et al.*, 2004), and on the northern coast of Sardinia, the construction and transformation of a floating marine finfish farm have been linked to increased fish density around the farm area (Díaz López *et al.*, 2004). Interaction between the gillnet fisheries and bottlenose dolphins may be increasing in the vicinity of the farm because the fish targeted as prey by dolphins and by fishers overlap; perhaps the fish farm is acting as a fish aggregating device (Díaz López, 2005).

Bottlenose dolphins clearly spend more time in the study area, usually feeding, when gillnets are set, an observation

Table 2. Seasonal distribution of search effort, number of sightings, and daily encounter rate (DER) with bottlenose dolphins in the presence and absence of gillnets during boat-based observations.

	Presence of gillnets			Absence of gillnets		
Season	Search effort (*h*)	Sightings	DER	Search effort (*h*)	Sightings	DER
Winter	102.7	63	0.61	225.8	98	0.43
Spring	142.4	43	0.30	191.7	69	0.36
Summer	22.1	6	0.27	26.6	8	0.30
Autumn	110.3	71	0.64	163.4	79	0.48
Total	377.5	183	0.48	607.5	254	0.42

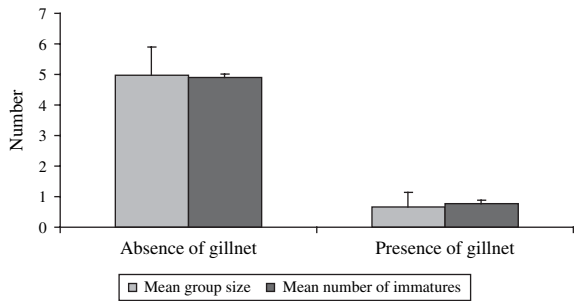

Figure 2. Mean group size in the presence and absence of gillnets. Error bars represent standard error.

consistent with the hypothesis that generalist predators should exhibit plasticity in their behaviour in response to fluctuating prey type and availability. Feeding at gillnets provides the dolphins with an alternative foraging method, and it is also likely that the dolphins find it easier to exploit a concentrated food source at a gillnet. This relationship may well be compared with the association of cetaceans with trawlers (Fertl and Leatherwood, 1997), explained as a strategy to increase the rate of feeding while decreasing the energy expenditure associated with foraging.

Although dolphins benefit from taking fish entangled in gillnets, the association with gillnets can be harmful because it exposes bottlenose dolphins to additional risk. The annual bycatch estimated here is 3.54% of 42 individuals frequenting the study area estimated from photo-identification (Díaz López *et al.*, in press). Such a level is cause for concern, because it is questionable whether the bottlenose dolphins in the area can sustain such an annual bycatch magnitude. The higher annual numbers of immature dolphins than adult bottlenose dolphins caught in gillnets is consistent with the hypothesis that lack of experience by immature dolphins, together with their tendency to play and/or to spend a lot of time scouting, may make them more vulnerable to entrapment in gillnets (Mann *et al.*, 1995). However, there is very little scientific information on the subject, and for most Mediterranean countries only anecdotal reports exist (Bearzi, 2002). Therefore, it is very difficult to evaluate the impact of such a threat to coastal cetaceans between areas.

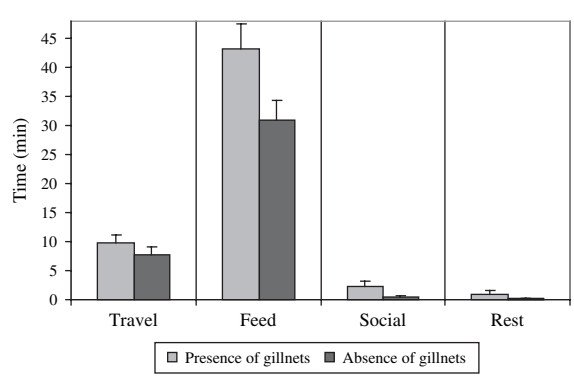

Figure 3. Mean time spent engaging in different behaviour in the presence or absence of gillnets. Error bars represent standard error.

Table 3. Mean times bottlenose dolphins spent engaged in different behaviour in the presence and absence of gillnets.

	Presence of gillnets		Absence of gillnets	
Behaviour	Mean time (min)	s.e.	Mean time (min)	s.e.
Feeding	43.2*	4.2	31*	3.4
Travelling	9.7	1.4	7.7	1.3
Socializing	2.3	0.8	0.8	0.3
Resting	1	0.5	0.1	0.13

*$p < 0.05$.

A number of additional assumptions are relevant to the interpretation of the 1999–2004 results. The first relates to the use of a fishing day as the unit of effort in the study; this requires the assumption that the number and the length of fishing nets employed by each fisher per day are constant. A second assumption is that the density of bottlenose dolphins in the study area is constant. This second assumption is crucial to how the information derived from fishers is interpreted; there is a good chance that fishers may have regarded each interview as an opportunity to voice their concerns about gear damage, biasing upwards the number of nets damaged, so inflating the real number. Opposing this, however, would be the possibility that fishers may not have wanted to advertise the fact that bottlenose dolphins were coming into contact with their gear, specifically if it resulted in injury or death to the animals. Taken together, it is likely that the bycatch estimates reported here should be treated as minima.

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