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Bottlenose dolphin (*Tursiops truncatus*) presence and incidental capture in a marine fish farm on the north-eastern coast of Sardinia (Italy)

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On the north-eastern coast of Sardinia, from November 2004 to January 2006, the first attempt in the Mediterranean basin to obtain information on encounter rate, group size and incidental capture of bottlenose dolphins in a marine fish farm was assessed, combining direct observations from fish farm boats with photo-identification studies. During 15 months of research, 79 d (65.3% of the total monitored days) were spent in direct observation of 146 groups of bottlenose dolphins around the fish farm cages. There was a peak in bottlenose dolphin presence during winter. Photographs were taken in the fish farm area during 79 encounters on 61 different days (totalling 34 marked individuals). The regular occurrence of some dolphins suggests individual preferences for the fish farm area. The incidental bottlenose dolphin capture observed in large, loose predator nets (1 dolphin per month) is cause for concern, as it is questionable whether or not the bottlenose dolphins in the area can sustain incidental capture of this magnitude. The information gained from this study shows the necessity for further regulations to be established, both in the use of predator nets and management of marine fish farms.

INTRODUCTION

Coastal marine fish farms attract a large range of predator species (Beveridge, 1996) such as harbour seals (*Phoca vitulina*), grey seals (*Halichoerus grypus*), cormorants (*Phalacrocorax carbo*), shags (*Phalacrocorax aristotelis*), herons (*Ardea cinerea*), otters (*Lutra lutra*) and mink (*Mustela vison*). These species have been reported to cause problems at farm sites around the world (Ross, 1988; Rueggeberg & Booth, 1989; Pemberton & Shaughnessy, 1993; Carss, 1994; Morris, 1996; Kemper et al., 2003).

Marine aquaculture and, in particular intensive fish farming, have shown a large expansion in most Mediterranean countries over the last ten years (UNEP/MAP/MED POL, 2004). To curb predation, many marine fish farms employ control methods which exclude, harass or remove predators (Quick et al., 2004). One such method, predator netting, creates a physical barrier which protects farmed fish from attacks by airborne and underwater predators.

The incidental capture of marine mammals by commercial fisheries is often a controversial and emotive issue. A potential impact on marine mammals as a result of aquaculture interaction is death or injury through entanglement in gear (Würsig & Gailey, 2002).

The literature to date has focused on how aquaculture influences dolphin distribution (Watson-Capps & Mann, 2005; Díaz López et al., 2005), but there is a lack of information on dolphin incidental capture in marine fish farms. Most records of incidental capture of bottlenose dolphins in the Mediterranean Sea come from gill-net fisheries (Bearzi, 2002; Díaz López, 2006a).

This study focuses on the Gulf of Aranci where the presence of a floating marine fin-fish farm, with sea bass (*Dicentrarchus labrax*), gilthead sea bream (*Sparus auratus*), and corb (*Sciaena umbra*) has been linked to a change in bottlenose dolphin distribution as a result of high fish density around the floating cages in the farming area (Díaz López et al., 2005; Díaz López, 2006b). This study represents the first attempt in the Mediterranean basin to obtain information on encounter rate, group size and incidental capture of bottlenose dolphins in a marine fin-fish farm. Even though these data are only from one study site, it is possible to extrapolate to other areas where bottlenose dolphins have been observed interacting with fin-fish farms

MATERIALS AND METHODS

The marine fish farm

Data were collected at a fin-fish farm located in the Gulf of Aranci (40°59'N 9°37'E) on the north-eastern coast of Sardinia (Figure 1). This coastal sea-cage fish farm was set up in 1995 and consisted of 21 floating cages. The floating cages were grouped into three rows of seven cages. Each floating cage was constructed of nylon mesh netting and was 22 m in diameter and 15 m deep. The cages were situated at approximately 200 m from the shore, with a minimum depth of 18 m and a maximum depth 26 m. The fish farm covered 2.4 ha and contained 800–900 tons of ichthyic biomass, sea-bass, sea bream and corb. The water temperature underwent yearly variation, with surface temperatures ranging between 11°C (March) and 26°C (August). Water clarity, measured by Secchi disc, varied between 11 m (January) and 22 m (July). The sea bottom in the fish farm area was characterized by mostly mud with scattered areas of rock and sand.

During the study period, two types of underwater nets were employed in the fish farm to deter attacks of bottlenose

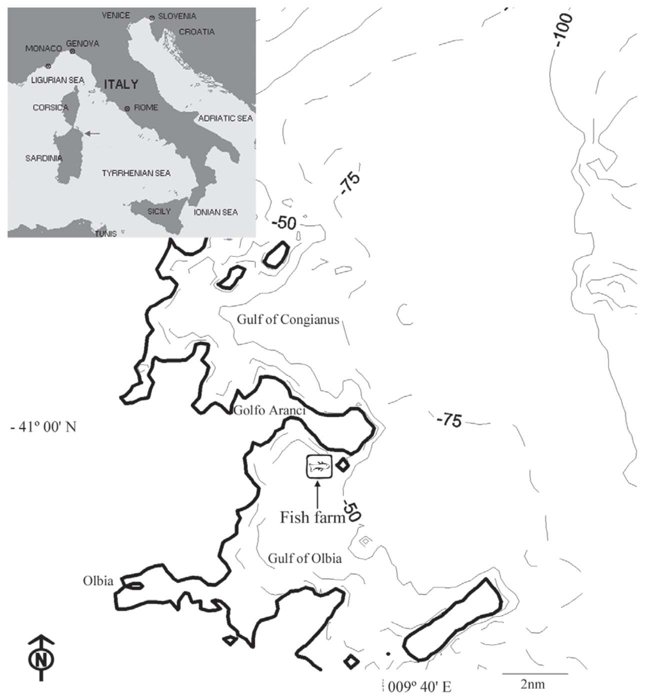

Figure 1. Map of the north-eastern coast of Sardinia (Italy), showing the location of the marine fin-fish farm.

dolphins on farmed fish: (i) Type 1 was characterized by a double wall of netting (0.5 mm diameter of monofilament nylon and <5 cm mesh) encompassing individual floating cages. These nets were often weighted at the bottom to create tension. This antipredator control method was used for the entire 15-month study period in four floating cages (two cages with sea bass and two cages with corb), which corresponded to 19% of the total number of cages; and (ii)

Table 1. *Seasonal distribution of the daily encounter ratio (DER).*

	Mean	SE	Number of days at sea
Winter	4.70**	1.70	25
Spring	0.28	0.07	34
Summer	2.90	0.11	32
Autumn	1.06	0.30	30
Total	1.40	0.38	121

**, $P<0.001$.

Type 2 was characterized by a large, loose-mesh underwater predator net (0.75 mm diameter of monofilament nylon and 15 cm mesh). This net was used for a three-month period (November 2005–January 2006) around one floating cage containing sea-bass.

Observational methods

A total of 121 days of observations was completed in the fish farm area, from November 2004 to January 2006, in order to evaluate the predator controls employed, bottlenose dolphin presence and incidental mortality. On each fish farm-based survey, we recorded the following: date, time, sea condition with Douglas scale (approximately the equivalent to the Beaufort wind force scale), number of bottlenose dolphin encounters and group size. The number and type of predator nets employed was obtained through communications with fish farm workers. Incidences of bottlenose dolphin entanglements in predator nets were also recorded.

Observations were made year round, during daylight hours. Four seasons were defined: spring (April–June), summer (July–September), autumn (October–December) and winter (January–March).

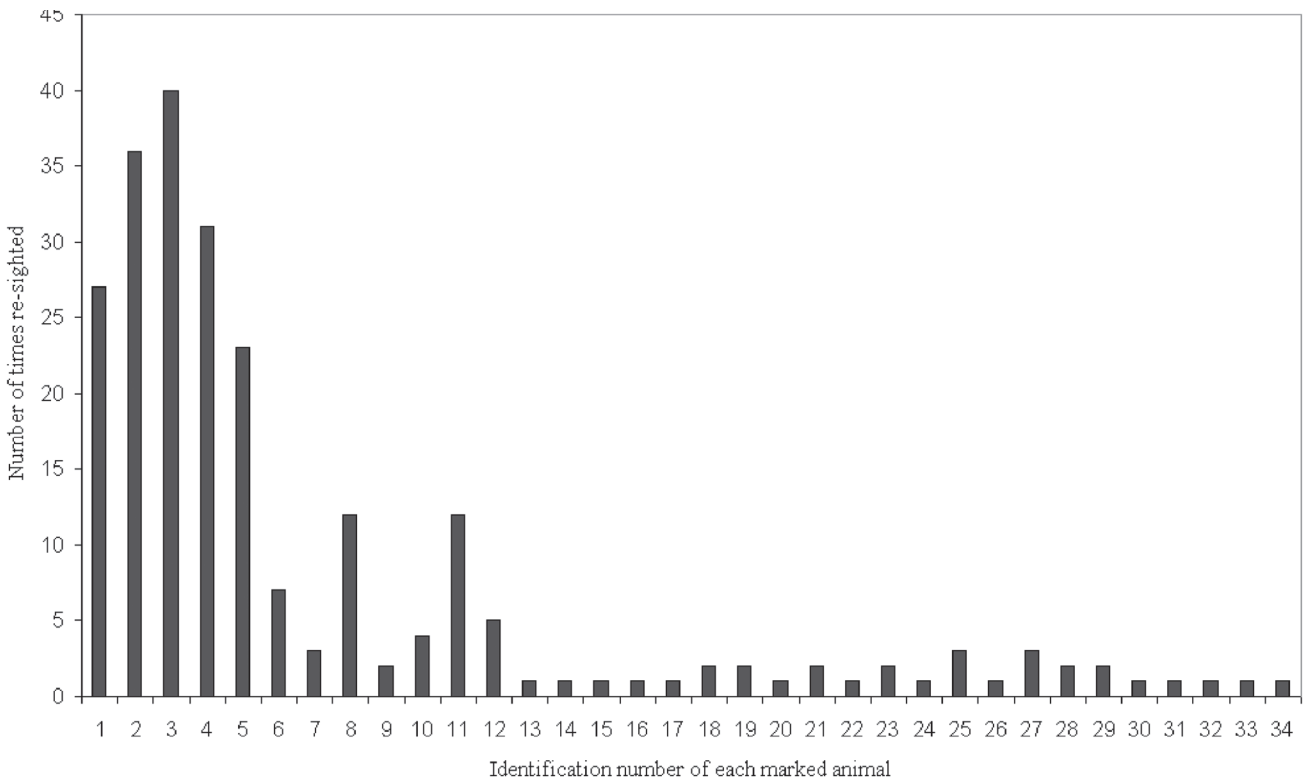

Figure 2. Frequency of re-sighting of bottlenose dolphins photo-identified during the study period.

Table 2. *Distribution of bottlenose dolphin incidental capture observed in the different predator nets from November 2004 to January 2006.*

Predator net	Nb	c	m	MEc
Type 1 (<5 cm mesh)	0	4	15	0
Type 2 (15 cm mesh)	3	1	3	1
Type 1 & Type 2	3	5	15	0.2

Nb, total number of entangled dolphins; m, predator net soaking time in months; c, the number of cages where the predator net was sited; MEc, monthly entanglement ratio per cage.

Observations were considered satisfactory when the visibility was not reduced by rain or fog, and sea conditions were $\leq$4 on the Douglas scale. As the number of sightings could depend on the search effort, a daily bottlenose dolphin encounter ratio (DER) was computed as DER=Ns/search effort (h), where Ns is the total number of sightings (Díaz López, 2006a).

A group represents one or more bottlenose dolphins observed in the fish farm area, usually involved in the same activity (Díaz López, 2006a). The group size and age categories were assessed visually *in situ*, and the data were later verified with photographs and videos taken during each sighting. Dolphins were classified as either immature ($<$2.5 m) or adult ($\geq$2.5 m) based on body size (Díaz López, 2006b).

During encounters, photographs were taken with a 35 mm Nikon D70 auto focus camera with 80–200 mm (F: 4.5/5.6) and 100–300 mm (F: 5.6/6.7) zoom lenses. The aim during an encounter was to take sequential photographs of the dorsal fins of those individuals present. Only good quality photographs (in focus, un-obscured, with the dorsal fin perpendicular to the plane of the photograph and with the dorsal fin large enough to identify small notches) were used in the analyses. Individual dolphins were identified from photographs based primarily on the size, location and pattern of notches on the trailing edge of the dorsal fin and on the back, directly behind the dorsal fin (Würsig & Jefferson, 1990). Individuals without dorsal fin or back notches could often be identified based on other features (e.g. pigmentation patterns, dorsal fin shape, skin scrapes or scars).

In order to identify the dolphins entangled in predator nets, photographs of the dorsal fin were taken and sex recognition was carried out. A monthly entanglement ratio per cage (MEc) was calculated by:

$$MEc=(Nb/m)/c$$

where Nb is the total number of entangled dolphins, m=predator net soaking time in months, and c=the number of cages where the predator net was employed.

Data analyses

All statistics were performed with Palaeontological Statistics, PAST, Version 1.35, a statistical software package (Hammer et al., 2001). Data were presented as mean ±standard error. Seasonal fluctuations in dolphin presence, group size and number of immatures were tested using a non-parametric Kruskal–Wallis test.

Table 3. *Summary of occurrence pattern of photo-identified bottlenose dolphins during the research period. The letter d indicates presence of animals at least during that month.*

Dolphin ID	Nov 04	Dec 04	Jan 05	Feb 05	Mar 05	Apr 05	May 05	Jun 05	Jul 05	Ag 05	Sep 05	Oct 05	Nov 05	Dec 05	Jan 06
1	d	d	d	d	d	/	d	d	d	d	d	d	d	/	d
2	d	d	d	d	d	d	d	/	d	d	d	d	/	d	d
3	d	d	d	/	d	d	d	d	d	d	d	d	d	d	d
4	d	d	d	/	d	d	d	d	d	d	d	d	/	/	/
5	/	d	d	d	d	d	d	d	d	d	d	d	/	d	d
6	/	d	/	/	d	/	/	/	/	/	/	d	d	d	/
7	d	d	d	/	/	/	/	/	/	/	/	/	/	/	/
8	/	d	d	/	d	d	d	d	/	/	/	/	/	d	d
9	/	/	d	/	/	/	/	/	/	/	/	/	/	/	/
10	/	/	d	/	/	/	d	/	/	/	/	/	/	/	/
11	/	/	d	d	d	d	d	/	/	/	/	/	/	/	/
12	/	/	d	d	/	/	/	/	/	/	/	/	/	/	/
13	/	/	/	d	/	/	/	/	/	/	/	/	/	/	/
14	/	/	/	d	/	/	/	/	/	/	/	/	/	/	/
15	/	/	/	/	d	/	/	/	/	/	/	/	/	/	/
16	/	/	/	/	d	/	/	/	/	/	/	/	/	/	/
17	/	/	/	/	/	d	/	/	/	/	/	/	/	/	/
18	/	/	/	/	/	/	/	/	/	/	d	d	/	/	/
19	/	/	/	/	/	/	/	/	/	/	d	/	d	/	/
20	/	/	/	/	/	/	/	/	/	/	d	/	/	/	/
21	/	/	/	/	/	/	/	/	/	/	d	/	d	/	/
22	/	/	/	/	/	/	/	/	/	/	d	/	/	/	/
23	/	/	/	/	/	/	/	/	/	/	/	d	d	/	/
24	/	/	/	/	/	/	/	/	/	/	/	d	/	/	/
25	/	/	/	/	/	/	/	/	/	/	/	d	d	/	/
26	/	/	/	/	/	/	/	/	/	/	/	d	/	/	/
27	/	/	/	/	/	/	/	/	/	/	/	d	d	/	/
28	/	/	/	/	/	/	/	/	/	/	/	d	/	/	/
29	/	/	/	/	/	/	/	/	/	/	/	/	d	/	/
30	/	/	/	/	/	/	/	/	/	/	/	/	d	/	/
31	/	/	/	/	/	/	/	/	/	/	/	/	d	/	/
32	/	/	/	/	/	/	/	/	/	/	/	/	d	d	d
33	/	/	/	/	/	/	/	/	/	/	/	/	d	/	/
34	/	/	/	/	/	/	/	/	/	/	/	/	d	/	/

RESULTS

Fish farm-based observations

Fish farm observations lasted on average 221 ±8.4 min per day. Observers noted the presence of dolphins in the fish farm area on 79 d (65.3% of the total 121 d at sea). A total of 110.4 h was spent in direct observation of 146 groups of bottlenose dolphins in the study area. There was a fluctuation in the distribution of the DER between seasons (Kruskal–Wallis test, P<0.001; Table 1). In particular, we observed a peak in the DER during the winter period.

Group size ranged from singletons to groups of 13 dolphins (mean=3.46 ±0.18), with a mean number of immatures of 0.41 ±0.05. Overall, 87% of bottlenose dolphins were adults and 13% were immatures. There were no observed seasonal differences in group size (Kruskal–Wallis test, P>0.05); however, there was a summer peak in immature dolphin presence (Kruskal–Wallis test, P<0.05).

Photo-identification studies

Between November 2004 and January 2006, approximately 1220 photographs were taken in the fish farm area during 79 dolphin encounters on 61 different days. Nineteen individuals were identifiable based on notches on the trailing edge of the dorsal fin or back and 15 individuals were identified based on body or dorsal fin scars (within these individuals two immatures were present), totalling 34 marked individuals. On average, each dolphin was observed on 6.88 ±1.8 occasions (range=1–40). Some individuals were seen more frequently than others in the fish farm area (Figure 2). In particular, five dolphins were re-sighted in at least 11 of the 15 study months (Table 3).

Incidental bottlenose dolphin capture

The monthly entanglement ratio (MEc) for both Type 1 and Type 2 nets was 0.2 dolphins. Incidental capture of bottlenose dolphins in the fish farm was only observed in the cage protected by the Type 2 predator net (MEc=1). Three bottlenose dolphins were found entangled and dead in this netting (one in November 2005 and two in December 2005), two of which were examined. Both dolphins were male adults, measuring 3.05 m and 2.95 m in length. One of the entangled bottlenose dolphins was first recognized in 1999 and during this study was re-sighted in 31 encounters. The second dead dolphin was an unmarked animal.

DISCUSSION

By examining the results of this study, it is clear that bottlenose dolphins are present close to the marine fin-fish farm year round. The regular occurrence of some dolphins suggests individual preferences for the fish farm area. In the fish farm area, dolphins were typically observed in small groups. The mean group size and number of immatures were similar to those observed in the same region outside the marine fin-fish farm (Díaz López et al., 2005; Díaz López, 2006a). Small groups engaging in fish farm feeding activities could allow each animal an increased chance of catching limited prey, resulting in the highest rate of food intake (Würsig, 1986). This activity may be comparable with the associations of bottlenose dolphins with trawlers and gill-nets (Fertl & Leatherwood, 1997; Díaz López, 2006a), which have been explained as strategies which increase the rate of feeding while decreasing the energy expenditure necessary for foraging (Díaz López, 2006b).

The peak of dolphin presence in the fish farm area during the winter period, which is characterized as the season with the lowest fish presence in north-eastern Sardinia (local fishers, personal communication), was consistent with our hypothesis that opportunistic foraging effort should increase with decreasing prey encounter rate.

Although bottlenose dolphins benefit from feeding around the fish farm cages (Díaz López, 2006b), this relationship with aquaculture is harmful due to the antipredator control methods employed. Bottlenose dolphin incidental capture observed in this study (3 dolphins over 15 months, i.e. 2.4 dolphins per year) and precedent records of bottlenose dolphins becoming entangled in the predator nets around tuna cages in South Australia (an average of 3 entanglements per year: Kemper & Gibbs, 2001; Wursig & Gailey, 2002) confirm that the major problems for bottlenose dolphins in marine fin-fish farms are entanglement in the large-mesh predator nets (mostly ≥15 cm mesh). The incidental capture observed with this type of net is cause for concern, as it is questionable whether or not the bottlenose dolphins in the study area can sustain an incidental capture of this magnitude. Type 2 predator nets (0.75 mm diameter of monofilament nylon and 15 cm mesh) are loose in structure and may be highly influenced by strong sea conditions during the autumn–winter months, resulting in increased dolphin entanglements. As these nets were introduced for the first time in the fish farm area, dolphin inexperience may have contributed to the observed levels of incidental capture.

Future research and management recommendations

A science-based response to the conservation problems created by interactions between marine fish farms and bottlenose dolphins depends critically on accurate knowledge of the impacts caused by the interactions. The pressures of aquaculture on coastal bottlenose dolphin populations may add to existing by-catches caused by other human activities, e.g. gill-net fisheries (Díaz López, 2006a). Conservation and management strategies should therefore address the incidental capture issue by implementing mitigation methods to reduce dolphin mortality. This might include acoustic deterrent devices (ADDs), which are designed to alert mammals to the presence of netting, or acoustic harassment devices (AHDs), which are louder and aim to keep animals away from cages. Although acoustic deterrent devices appear to reduce by-catch for a large range of marine mammal species (Barlow & Cameron, 2003), we echo the concerns that have been expressed by many other authors that acoustic harassment devices may have adverse effects on the bottlenose dolphins.

The use of predator nets to reduce bottlenose dolphin attacks should be monitored to determine the deterrence efficiency as well as the rate of incidental capture. In order to realize both monitoring and subsequent regulations, cooperation between private marine fish farms and biologists is necessary.

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