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Bottlenose Dolphin (*Tursiops truncatus*) Predation on a Marine Fin Fish Farm: Some Underwater Observations

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Abstract

This paper reports on the results of underwater observations of bottlenose dolphin feeding behaviour in a marine fin fish farm on the Sardinian coast in Italy from 2000 to 2005. During the study period, 178 underwater encounters were noted during 79 sightings of bottlenose dolphins at a fish farm. Total time spent underwater in the presence of dolphins was 284 min, with a mean encounter duration of 1.6 ± 1.3 min. Bottlenose dolphins were primarily observed hunting both schooling and solitary prey around the fish farm cages, using seven cooperative and individual feeding strategies throughout the water column. The underwater observations suggest that the use of different feeding strategies is consistent with the hypothesis that bottlenose dolphins apply common decision rules in relation to prey availability, resulting in the use of different foraging techniques. The observed frequency of the feeding strategies employed by dolphins preying directly on farmed fish could be worrisome for aquaculture.

Key Words: *Tursiops truncatus*, bottlenose dolphin, aquaculture, behaviour, predation, marine fin fish farm, Mediterranean Sea

Introduction

Marine aquaculture and, in particular, intensive fish farming have shown a large expansion in most Mediterranean countries over the last ten years (UNEP/MAP, 2004). Coastal sea-cage fish farms have been introduced into an environment that has a natural complement of fish-eating predators. Würsig & Gailey (2002) concluded that interactions between the food being raised by humans in coastal aquaculture and the predators that attempt to take advantage of it should be studied. Most of the literature to date has focused on how aquaculture influences dolphin distribution (Watson-Capps & Mann, 2004; Díaz López et al., 2005), but there is a lack of information on how dolphins interact with marine fin fish farms.

In this paper, underwater observations of bottlenose dolphin (*Tursiops truncatus*) feeding behaviour near a marine fin fish farm on the Sardinian coast in Italy from 2000 to 2005 are reported. This study focuses on the Gulf of Aranci where the presence of a floating marine fin fish farm, which raises sea bass (*Dicentrarchus labrax*), gilthead seabream (*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). Fish species such as common grey mullet (*Mugil cephalus*), salema (*Salpa sarpa*), and pilchard (*Sardina pilchardus*) are known to be attracted to floating fish farms; unused feed that falls through the cages may enhance the attraction (Dempster et al., 2004).

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. This study site provides a unique opportunity for close-up and regular observations of underwater bottlenose dolphin behaviour.

Materials and Methods

The Marine Fin Fish Farm

Data were collected at a fin fish farm located in the Gulf of Aranci (40º 59' N, 9º 37' E) in the northeastern coast of Sardinia (Figure 1). This coastal sea-cage fish farm was set up in 1995 and consists 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 of 26 m. The fish farm covered 2.4 ha and contained 800 to 900 tons of ichthyic biomass, sea bass, sea bream, and corb. The water temperature underwent yearly variation, with surface temperatures ranging between 11º C (March) to 26º C (August). Water clarity, measured by Secchi disk, varied between 11 m (January) and 22 m (July). The sea bottom in the fish farm area

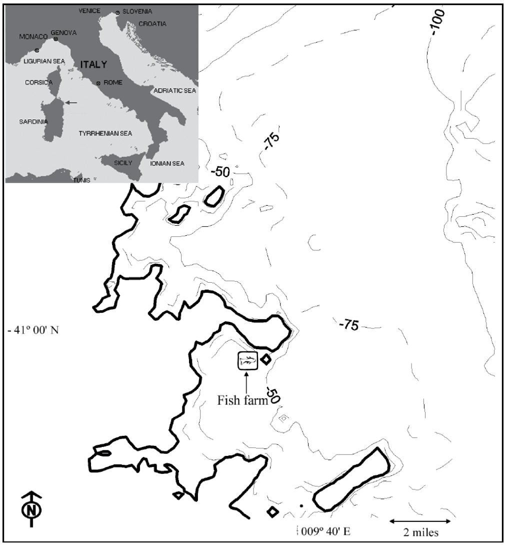

Figure 1. Map of the northeastern coast of Sardinia (Italy), showing the location of the marine fin fish farm

was characterized by mostly mud, with scattered areas of rock and sand.

Observational Methods

The fish farm plant was visited to observe bottlenose dolphin behaviour between 2000 and 2005, with the exception of 2003.

Dolphins became habituated to the presence of divers due to daily underwater maintenance checks in the fish farm area. This provided a good opportunity for underwater observations of dolphin activities without directly influencing their behaviour.

Group size and age categories were assessed visually *in situ* before entering the water, and the data were later verified with photographs and videos taken during each sighting. A group was defined by one or more dolphins observed in the fish farm area, usually involved in the same activity.

Underwater observations were collected while snorkelling, following two criteria: (1) extended dolphin presence between the cages of the fish farm (> 30 min) and (2) sea state < 4 on the Douglas scale (approximately equivalent to the Beaufort wind force scale). Group size observed underwater was not always consistent with group size determined at the water surface. Numbers of dolphins in association, observed during underwater encounters, were defined as a "subgroup." Every encounter continued until the subgroup was lost (a subgroup was considered lost after 3 min without a sighting). Dolphins were classified as either immature (< 2.5 m) or adult (> 2.5 m) based on body size.

Time, subgroup size, description of dolphin behaviour, and visual identification of the fish species present were recorded during snorkelling with a carbon pencil and underwater slate. Data were transcribed the evening of the observations and then entered into a database.

Data Analysis

All statistics were conducted with *Palaentological Statistics (PAST), Version 1.35*, a statistics software package (Hammer et al., 2001). Data are presented as means ± standard error. A nonparametric Kruskall-Wallis test was used to assess the difference between group sizes. Statistical significance was tested at the $p < 0.05$ level.

The frequency of foraging strategies observed was compared to that expected if they occurred randomly. The random frequency distribution of foraging strategies was conducted by repeatedly sampling from the seven different feeding techniques. The same number of different strategies were selected at random from each observed sighting, and this process was repeated for the total number of sightings (79). One hundred repetitions of this procedure were averaged to generate the frequency distribution if strategies were sampled at random. A Chi-square test was used to test for equal distribution of strategies between those observed and those expected.

Results

During a five-year study period, 178 underwater encounters were recorded during 79 sightings of bottlenose dolphins in the fish farm area. This corresponds to 2.25 ± 0.1 underwater encounters per sighting. The total time spent underwater in the presence of dolphins was 283.7 min, with a mean encounter duration of 1.6 ± 1.3 min.

Group sizes ranged from individuals to groups of 19 dolphins and showed a median group size of four dolphins (mean = 4.35 ± 0.37). The proportion of age classes observed was 85.7% adult and 14.3% immature. During the underwater encounters, the average subgroup size observed was 3.5 ± 0.24 dolphins per encounter.

During four of the study months (November 2000, April 2001, March 2002, and January 2005), there were eight separate occurrences of farmed fish escaping from the floating cages. Escapes resulted from damage to the nets of the floating cages; this damage was positively confirmed by fish farm divers, but there was no direct evidence that the dolphins were responsible for the escapes. Dolphin group size observed during these casual events was significantly higher (mean = 11.25 ± 1.8) than during the days in which there was neither net damage nor escape of farmed fish (mean

= 3.6 ± 0.2; Kruskall-Wallis test, H = 18.83, $p < 0.01$).

Bottlenose dolphins were primarily observed searching for and catching prey around the fish farm cages (Figure 2). The bottlenose dolphins were observed hunting both schooling and solitary prey in the fish farm area using seven solitary and group feeding strategies throughout the water column.

The frequency of the different feeding strategies which were observed in the fish farm area was not random (Figure 3); some strategies were seen more or less often than would be expected by chance (Chi-Square test, df = 6, $\chi^2 = 35.3$, $p < 0.01$).

The most frequently observed technique was called "encircling cage" (32.6% of underwater observations; 58 encounters). This strategy consisted of one or several dolphins swimming around a floating fish farm cage, facilitating search and capture of prey. This technique was subdivided into two categories: (1) cooperative and (2) individual, in relation to the number of dolphins present in the subgroup.

The cooperative method (72% of "encircling cage" observations; 42 encounters) consisted of one or more dolphins driving schools of wild fish (mainly common grey mullets) and salema around the outer wall of the cage towards other dolphins. One dolphin usually surfaced briefly, between two and four times, several seconds before the others. During this activity, echolocation clicks were audible under water.

The individual method (28% of "encircling cage" observations; 16 encounters) was observed when a solitary dolphin encircled the cage at an approximate depth of 4 or 5 m, lurking below a group of common grey mullet. This was followed by a sudden, fast upward movement of the dolphin, effectively driving the fish towards the water surface. During this technique, it was possible to observe the fish leaping out of the water.

Another strategy, termed "feeding rush" (Shane, 1990), was observed in 25.3% of underwater observations (45 encounters). Dolphins using this technique were observed using the nets of the cages as barriers to feed on wild fish (mainly common grey mullet, pilchard, and garfish [*Belone belone*]). Typically, one or several dolphins in echelon (mean subgroup size = 3.2 ± 0.2), 15 m away from the cage, suddenly increase swim speed in the direction of the wild fish adjacent to the cage. Just before reaching the cage, the dolphins would suddenly make hairpin turns on their sides to catch the disoriented fish. Dolphins were occasionally observed capturing fish with this method.

Figure 2. Group of bottlenose dolphins searching for prey between the floating cages of the marine fin fish farm

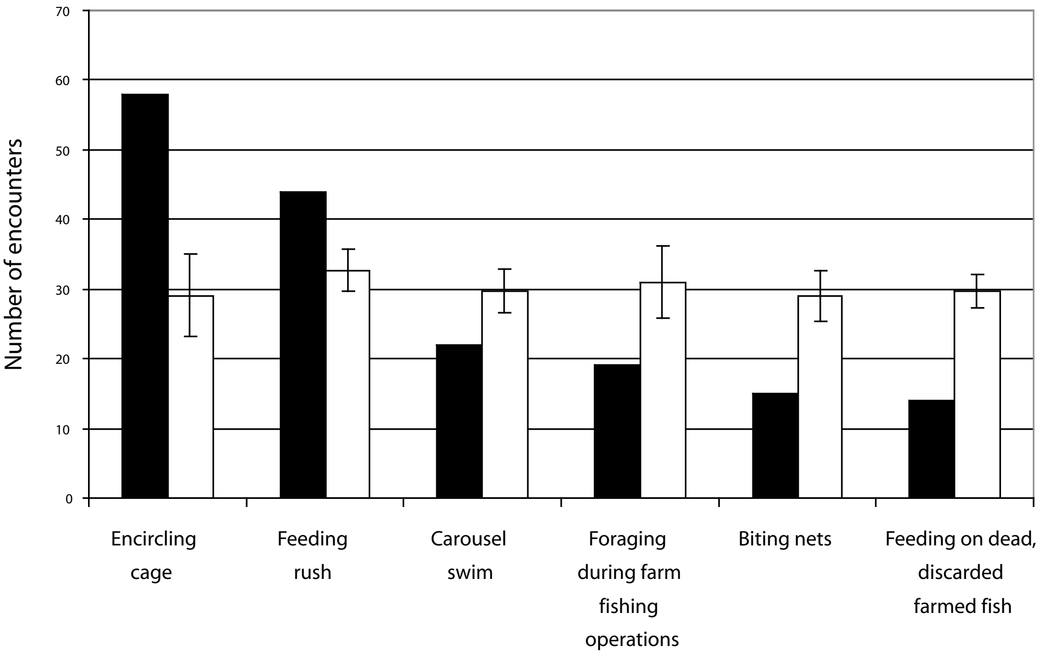

Figure 3. Distribution of bottlenose dolphin strategies observed during the study period (solid bars), together with the expected distribution assuming a random sampling; open bars, mean values, and SD of 100 permutations shown.

A cooperative technique called "carousel swim" (Bel'kovich et al., 1991), which was observed in 10.7% of underwater observations (19 encounters), consisted of dolphins surrounding wild fish schools, forcing fish to swim in a concentrated ball. The dolphins swam in circles around the fish, gradually tightening the school. Occasionally, one of the dolphins would leap laterally against the school of fish.

Dolphins preying directly on farmed fish play an important role in the feeding strategies in the fish farm area (31.5% of underwater observations; 56 encounters). There were three different strategies which capitalized on the presence of the fish farm. Two of these occurred during the operation of the fish farm, while the third was related to the consumption of dead, discarded farmed fish.

During the fishing operation, a quantity of farmed fish must be transferred from a large cage (22 m diameter) to a smaller cage (9 m); this is accomplished by connecting the nets between cages and driving fish from one cage to the other. It is common for small quantities of farmed fish to escape from the nets during this operation. Bottlenose dolphins were observed swimming in close proximity to the cages in question, capturing escaped farmed fish (41% of opportunistic strategies; 23 encounters). It is important to note that when farmed fish escape, they generally remain close to the net.

In 30.4% of opportunistic strategies (17 encounters), the dolphins were observed biting the nets of the cages, causing direct damage to farmed fish as they attempted to remove them. On three occasions, bottlenose dolphins were observed damaging the nets in the form of small holes.

The third opportunistic strategy is related to dead, discarded farmed fish. When there is a high level of mortality (due to natural causes) in the cages, fish farm workers remove the dead fish and discard them into the sea. In 28.6% of opportunistic observations (16 encounters), we witnessed bottlenose dolphin consuming these dead, discarded farmed fish.

Discussion

Predators of cultured stock may build up around marine farms as they provide an abundant source of food (Quick et al., 2004). Increased bottlenose dolphin encounters in the Gulf of Aranci have coincided with the presence of a marine fin fish farm (Díaz López et al., 2005). In the current study, dolphins were seen to feed both cooperatively and individually on wild and farmed fish in the fish farm area. The observed frequency (31.5%) of feeding strategies employed by dolphins preying directly on farmed fish could be worrisome for aquaculture.

The underwater observations suggest that bottlenose dolphins apply common decision rules in relation to prey availability, resulting in the use of different foraging techniques. This was made evident by examining the variability in techniques employed by the dolphins to capture farmed (i.e., sea bass, sea bream, and corb) and wild (i.e., common grey mullet, pilchard, salema, and garfish) fish. Dolphins capitalize on the presence of farmed fish by employing unique feeding strategies.

The current observations of bottlenose dolphin predation on a marine fin fish farm show that both farmed and wild fish are prey for this species. Direct observations of wild fish being pursued and/or caught by bottlenose dolphins have led to the conclusion that species such as common grey mullet, pilchard, salema, and garfish are important prey items for bottlenose dolphins. These wild fish species are commonly associated with marine fish farms in the Mediterranean Sea (Dempster et al., 2004).

In the fish farm area, dolphins were typically observed in small groups. The median group size was the same as those observed in the same region outside of the fish farm (Díaz López et al., 2005; Díaz López, 2006). 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). Significantly larger groups of dolphins were associated with the cages only when farmed fish escaped. Occasional, large groups could take advantage of sensory integration and cooperative feeding in order to capitalize on this high availability of prey (Norris & Dohl, 1980).

Although sightings of bottlenose dolphins feeding cooperatively have been reported in many parts of the world (Leatherwood, 1975; Norris & Dohl, 1980; Würsig, 1986; Shane, 1990; Bel'kovich et al., 1991; Rossbach, 1999; Gazda et al., 2004), there are few detailed descriptions of underwater dolphin interactions with human activities. Some of the strategies described in this study have been previously reported such as the carousel swimming (Bel'kovich et al., 1991) and use of barriers to trap fish (reviewed in Connor, 2000). This study presents specific feeding strategies which are clearly related to the structure and operation of the marine fish farm.

Feeding in the fish farm area provides an effective foraging alternative, and this activity may be comparable with the associations of cetaceans with trawlers and gillnets (Fertl & Leatherwood, 1997; Díaz López, 2006), which have been explained as strategies which increase the rate of feeding while decreasing the energy expenditure necessary for foraging.

Bottlenose dolphin attacks on farmed fish could represent a problem faced by the industry in terms of financial loss, damage to floating cage nets, and a reduction in the amount or value of the farmed fish. There is no evidence, but bottlenose dolphins could produce indirect damage to marine fin fish farms in the form of induced fish stress which could result in a potential reduction in size or quality of the farmed fish as related to the presence and attacks of bottlenose dolphins. Also, dolphins may be directly responsible for the escape of farmed fish through holes made in the netting.

Future studies concentrating on specific opportunistic feeding behaviours may provide a better understanding of their advantages, and may offer further insight into the behaviour of a marine predator and, more specifically, their potentially conflicting role with human activities.

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