Interaction between bottlenose dolphins and fish farms: could there be an economic impact?

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Despite a number of studies focusing on the impact of aquaculture on marine mammals, the interaction between common bottlenose dolphins (*Tursiops truncatus*) with fish farms has been the subject of few investigations. In this paper we report the results of our research on the interaction between bottlenose dolphins with a fish farm on the Sardinian coast (Italy) from 1999 to 2004.

In order to know the interactions between the dolphins and fish farm, to conduct behavioural studies and to collect photographic data, fish farm based observations were regularly undertaken throughout the research period. The year was divided into seasons to assess differences in frequency of occurrence and behaviour of the bottlenose dolphins.

A total of 293 sightings of bottlenose dolphins interacting with the fish farm were carried out in 234 sighting hours over 218 days at sea.

Bottlenose dolphins were observed year round, but there was a seasonal variation in frequency of sightings (seasonal cycles). Group sizes ranged from 1 to 17 dolphins. There was a high presence of groups of females with immatures.

The nourishment coming from the fish farm increased the presence of "wild" fishes in the surrounding area favouring bottlenose dolphin opportunistic feeding. The most direct impact of fish farming on marine mammals is its need to control predators. Bottlenose dolphin attacks on farmed fish could present a problem to the industry in terms of financial loss. Double walls of netting are the most often used deterrent, but present problems of fouling and reduced water circulation.

Keywords: Bottlenose Dolphin, Aquaculture, Mariculture, fish farm, feeding behaviour.

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Introduction

The increasing presence of aquaculture in coastal waters calls for a better understanding of its environmental effects. Aquaculture, the farming of finfish or shellfish, has grown 11% in the last decade, becoming the fastest growing industry in the world food economy (Newton, 2000). Marine aquaculture and in particular intensive fish farming, has shown a large expansion in most of the Mediterranean countries over the last 10 years (UNEP/MAP, 2004). Most of the literature to date has focused on otters and pinnipeds that prey on fin fish and some shellfish farms, but there is a scarcity of information on cetaceans and aquaculture (Ross, 1988; Würsig and Gailey, 2002; Kemper et al., 2003; Quick et al., 2004; Watson-Capps and Mann, 2005).

To curb predation, many farms deploy control methods that exclude, harass or remove the predators. Predator netting creates a physical barrier to exclude attack by airborne and underwater predators.

Bottlenose dolphins (*Tursiops truncatus*) are appropriate and useful study animals in this case because of their world-wide distribution (Leatherwood and Reeves, 1983), the information gained in our study can be applied to management of fin fish farms world wide and, because they share valuable coastal habitats with humans, bottlenose dolphins may be particularly influenced by aquaculture.

Even though these data are from only one bottlenose dolphin study site, it is appropriate to extrapolate to other areas. Interactions between dolphins and marine fish farms in the Mediterranean Sea appear to be occurring with increasing frequency (Bearzi, 2002). In north-eastern Sardinia the construction of a floating fish farm has been linked to increased bottlenose dolphin abundance and habitat use, and dolphin behavioural changes were recorded as a result of high fish density around the farming area (Díaz López et al., 2001; Díaz López, 2002). Therefore, our study offers the best available test to date of the effects of a fish farm on small cetacean ranging.

Methods

In this paper we report the results of our research on the interaction between common bottlenose dolphins with a fish farm on the Sardinian coast (Italy).

Our study focuses on the northern coast of the Gulf of Olbia (Figure 1) where previous work (Marini, 1995; Díaz López, 2002; Díaz López et al., 2002) has shown a degree of residency of recognised animals and highlighted their abundance.

On the coast of the Gulf of Olbia the construction and transformation of a floating marine fish farm, with bass (*Dicentrarchus labrax*), gilthead seabream (*Sparus auratus*) and corb (*Sciaena cirrhosa*), has been linked to increased bottlenose dolphin presence, and dolphin behavioural changes were recorded as a result of high fish density around the floating cages in the farming area (Díaz López et al., 2001; Díaz López, 2002). The plant of the marine fish farm presents 21 floating cages constructed on nylon mess netting, until now it covers 2.4 ha. and contains 900 tons of ichthyic biomass.

In order to know the interactions between the dolphins and aquaculture, fish farm based observations were regularly undertaken from 1999 to 2004. All years but 2003 were sampled.

Beginning of sighting environmental measurements will be recorded including sea state, swell direction, wind speed and direction, air and water temperature, vertical visibility (using a Secchi disc) and cloud cover (% and general estimate). Attempts to photograph all members of the dolphin school will also be made before behavioural recording begins. Once a dolphin was encountered in the study site, the markings on the dorsal fin were photographed for individual identification using a Nikon D70 and the methods described by Würsig and Jefferson 1990.

Observations were made by experienced researchers. A dolphin "sighting" was defined as a dolphin or a group of dolphins usually involved in the same activity (termed focal group, Shane, 1990a). Sightings have considered satisfying when the visibility was not reduced by rain or fog and sea conditions were equal or below 3 of the Douglas scale. For each group we recorded on an audio tape: date, start and end time, description of behaviour states and number of bottlenose dolphin adults, immatures and newborns (Appendix A). The encounter continued until the group was lost (a group was considered lost after 15 minutes without a sighting). The year was divided into seasons to assess differences in frequency of occurrence of the bottlenose dolphin in the fish farm. Observations were made during daylight hours between 06:00 and 20:00h. Recorded data were transcribed on the evening of the observations.

Group follow protocols and continuous sampling methods are based upon Mann's (1999). Continuous recording of dolphin behavioural states will be used to assess duration of states, as well as determine the sequence of states. A focal group of dolphins was observed and onset and ending times of four behaviour states - Feed, Social, Rest and Travel (Shane 1990a,b) were noted. Opportunistic video recordings using a JVC digital camcorder were also made to document and verify behavioural interaction. Afterwards, each behavioural category was determined with objective parameters. Sightings under 10 minutes long have been selected as too short and they have not been considered in this behavioural study.

The manager of the fish farm sited in Golfo Aranci was asked to list the anti-bottlenose dolphin (antipredator) controls that they used on the fish farm. Farm manager were asked for information about the damages caused by dolphins and how often each type of antipredator control was used at his site.

Data analysis

Differences in number and duration of sightings of bottlenose dolphin among seasons were tested using one-way analysis of variance ANOVA (Underwood, 1981) followed by Tukey's honestly significant difference test. One way ANOVA were also used to compare mean times spent engaging in different behaviours. All data were checked for normality and homogeneity of variances. Data that failed to meet these assumptions were transformed ($\log_{10}x + 1$) and reassessed.

The evolution of the observed frequency of sightings close to the fish farm over time was analysed using Spearman's rank-order correlation.

Bottlenose dolphin group size was compared for different periods using a Mann-Whitney *U*-Test (Fowler and Cohen, 1993).

All statistics were performed with PAST a statistics software package (Hammer et al., 2001).

Results

A total of 292 sightings of common bottlenose dolphins interacting with the fish farm were carried out in 234.4 sighting hours over 218 days at sea (Table 1).

Bottlenose dolphins were observed close to the fish farm year round. A degree of temporary variation in bottlenose dolphin presence was not seen throughout the research between 1999 and 2004 ($P > 0.05$, Spearman's rs = 0.11209, n = 13, Figure 2). The continuous presence of the photoidentified dolphins during the research period shows that stables groups of common bottlenose dolphins are usually present close to the fish farm. This is supported by the presence of some individuals already identified in previous studies in the same area (Díaz López et al., 2001; Díaz López, 2002; Díaz

López et al., 2002). Some animals have been sighted only few times indicating their occasional use of the fish farm area.

There was a seasonal variation in the presence of bottlenose close to the fish farm (seasonal cycles) (ANOVA, $F= 104.1$, $p<0.01$) but there was not changes in duration of sightings (ANOVA, $F= 1.376$, $p>0.05$). The seasonal change suggests a habitat use pattern in this population, with an annual decrease in frequency of sightings close to the fish farm during the summer months, period of higher anthropogenic pressures.

Group sizes ranged from singletons to groups of 19 dolphins (Figure 3) and showed a median group size of 3.0 (Mean = 4.37, SD = 3.74, range = 1 – 19). During the study there was a high presence of groups of females with immatures close to the fish farm (Figure 4).

Observations of behaviour have been carried out on a total of 13874 minutes recorded during 231 sightings. Mean time observation for each session was 60.27 minutes (range= 10-521, median= 44, SD= 65.42).

Feeding resulted as the most frequent behaviour during years and seasons (One way ANOVA, $F= 527.3$, $P<0.01$), both as frequency- it occurred in the 86.6 % of sightings -, both as time budget in the 77% of the total time (Figure 5). There were not changes in feeding behaviour during seasons (ANOVA, $F= 1.947$, $p<0.05$) (Table 2).

Dolphins were observed to feed, around the fish cages in the fish farm, wild fishes (mainly common grey mullet (*Mugil cephalus*), bogue (*Boops boops*), salema (*Boops salpa*), pilchard (*Sardina pilchardus*) and garfish (*Belone belone*)) and octopus (*Octopus vulgaris*) attracted by the fish farm.

Dolphins were observed to bite the nets with farmed fish (mainly bass and corb). There is a reduction in the amount or value of the farmed bass and corb as the dolphins mutilate.

In total, 3 different types of control (double nets, tensioned nets and human presence) were in use during the research study. A description of each control method is given in Appendix B.

It is clear from the fish farm manager' responses that double and tensioned nets are generally used for the entire study period. The most effective bottlenose dolphin controls were double nets sites in 80% of cages with anti-bottlenose dolphin controls.

Discussion

Predators of cultured stock may build up round marine farms, since they supply an abundant source of food. Predation by birds and seals is a severe problem for finfish farmers in some parts of the world (Carss, 1993; Pemberton and Shaughnessy, 1993). The fish farm studied here acts as a Fish Aggregating Device (FAD) and where bottlenose dolphins have been attracted by aquaculture (Dolphin Aggregating Device, DAD). The fish species responsible for the increase in abundance near fish farms are not those usually found beneath cages in the Mediterranean Sea (Machias, 2005; Dempster, et al., 2002; Smith, et al., 2003), which are likely to feed on particulate wastes from the fish farms. A possible reason for the increase could be either an increase in primary production due to increased supply of dissolved nutrient wastes from the fish farms. Opportunistic feeding by cetaceans in association with fish farms is perhaps best exemplified by bottlenose dolphins feeding on discarded dead farm fishes. Typically, the animals have been seen to wait between the fish farm floating cages for fish to be discarded.

Detailed 293 sightings around the fish farm provided the strongest evidence that dolphins are attracted by fish farm. Seasonal cycles in presence of bottlenose dolphins close to the fish farm may be induced by a number of ecological, anthropogenic and environmental factors.

The association of common bottlenose dolphins with this marine fish farm indicates the behavioural flexibility of these animals to capitalize on human activities. This feeding pattern may be beneficial in that it reduces time required to forage, and provides the animals with an easier way to obtain food.

The fishes identified leaping during feeding bouts were grey mullet, pilchard and garfish, but we could not be certain that every leaping fish was a direct prey. Barros and Odell (1990) suggested that observations of mullet leaping when pursued by bottlenose dolphins have led to an overestimate of the importance of mullet as a dolphin prey item.

Groups of females with immatures, in particular, have been observed feeding in the fish farm, and it has been speculated that the immatures learn this foraging behaviour by observation and participation. Studies of other marine mammals, such as sea otters (*Enhydra lutris*) and killer whales (*Orcinus orca*), have suggested that youngsters develop feeding skills through imitation of the mother's feeding behaviours (Riedman et al., 1989; Guinet, 1991; Guinet and Bouvier, 1995). It has been speculated that females with immatures may be taking advantage of the concentrated food resource provided by the marine fish farm to meet increased energetic needs due to lactation. The association of common bottlenose dolphins with the fish farm may well be a strategy to increase the rate of feeding, while decreasing the energy expenditure associated with foraging.

Bottlenose dolphin attacks on farmed fish (bass and corb) could represent a problem faced by the industry in terms of financial loss through:

- Damage to floating cage's nets in the form of holes in the nets as the bottlenose dolphins attempt to remove fish.
- Reduction in the amount or value of the farmed fishes as the dolphins mutilate.
- Indirect damages caused by induced stress (reduction in the size or quality of the farmed fish as the frequent bottlenose dolphins' presence).

The common bottlenose dolphins cause direct gear damage but there is no evidence that they may cause indirect impact (e.g., by induced stress in farmed fish caused by the presence of predators or by released of fish) to marine fish farms.

Many methods have been tried but none are considered to be effective. Double walls of netting are the most often used deterrent, but present problems of fouling and reduced water circulation.

Underwater netting provides a defence against bottlenose dolphins that is analogous to that provided by top nets against birds. However, bottlenose dolphins are stronger than birds and can manipulate nets in a way than birds cannot. Furthermore, attacks by bottlenose dolphins are out of the sight of farm workers, and many fish may be lost before it is realised that there is a problem.

There is a need for a range of antipredator devices to be tested under controlled conditions to determine under which circumstances each is most effective. Bottlenose dolphin predation is not considered to be a substantial problem worldwide. The significance of bottlenose dolphins in Sardinia should not be dismissed, because they have the potential to do most damage to marine fish farms.

Acknowledgements

I would like to thank the manager of the "Compagnie Ittiche Riunite" Fish Farm Clemente Graziano PhD., for his much appreciated assistance and support for this project. A special thank goes to Federico Polo, Dr. Luca Marini, Andrea Shiray and numerous friends, colleagues and volunteers at the "Accademia del Leviatano" for their invaluable assistance and support with data collection.

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Table 1. Observation effort, sighting hours and observed frequency of sightings per each season when sampling was carried out.

	Observation Effort	Research Effort [a]	Number of Sightings	Sighting Effort (h)	Days at sea	Index of presence [b]
Spring	329.93 h	263.11 h	94	66.81 h	81	**0.3572**
Summer	108.91 h	76.9 h	*21***	32.01 h	27	**0.2730**
Fall	200.66 h	142.18 h	79	58.55 h	53	**0.5556**
Winter	210.31 h	133.28 h	99	77.69 h	57	**0.7352**
Total	**849.83 h**	**615.48 h**	**293**	**234.41 h**	**218**	**0.4744**

[a] Time spent in the field searching the dolphins, excluding the sighting time; [b] The observed frequency of sightings (number of sightings per research effort); ** ANOVA, df= , *F*= , p<0.01.

Table 2. Behavioural states per each season when continuous sampling was carried out.

	Feeding	Travelling	Socializing	Resting	Days at sea
Spring	2918 min	711 min	165 min	132 min	**72**
Summer	1694 min	109 min	108 min	1 min	**19**
Fall	2492 min	265 min	323 min	11 min	**55**
Winter	4075 min	616 min	249 min	5 min	**85**
Total	**186.3 hours**	**28.2 hours**	**14 hours**	**2.5 hours**	**231**

Figure 1. Map of the north-eastern coast of Sardinia showing the location of the fish farm and the area were the present study was carried out.

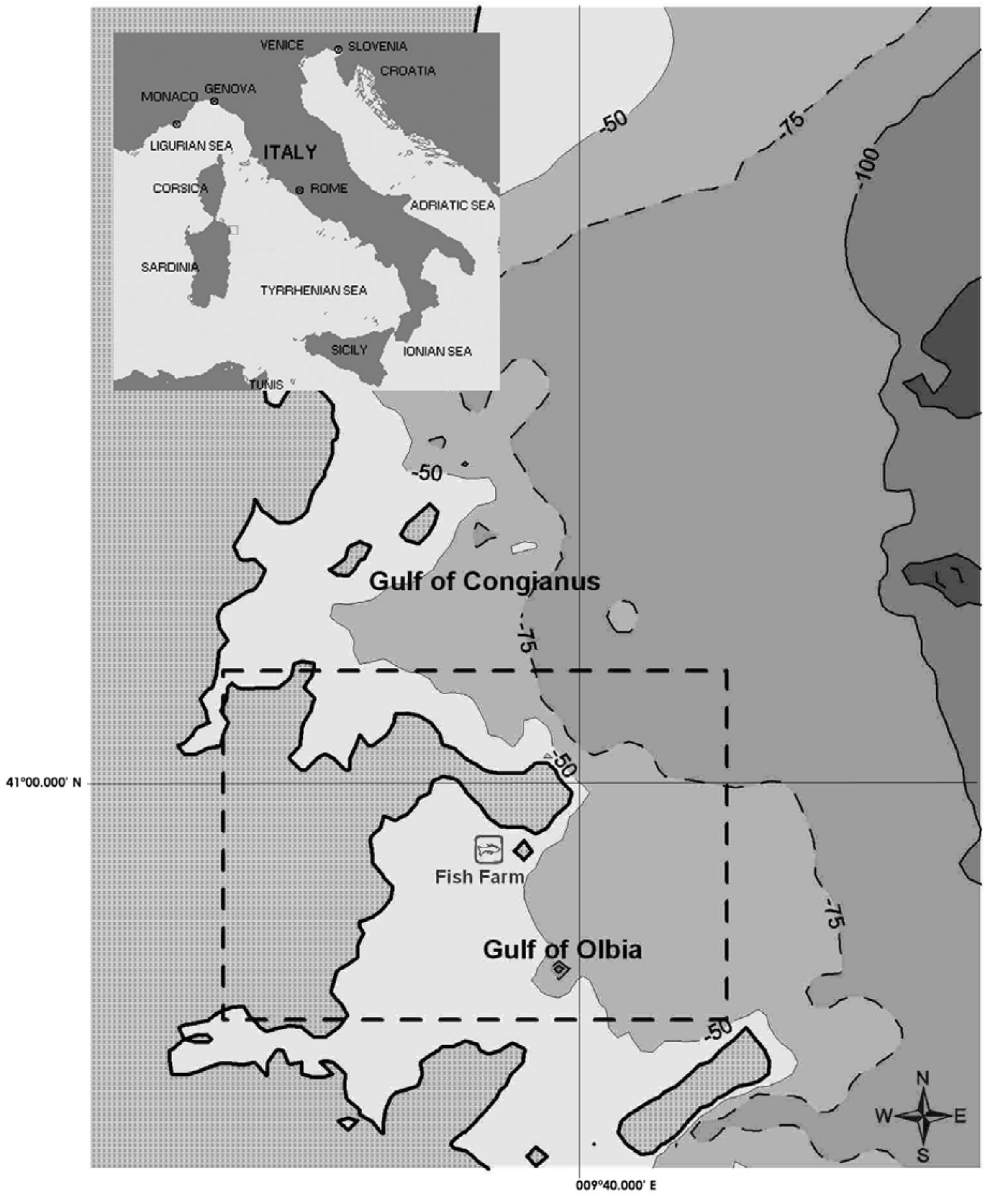


Figure 2. Evolution of the observed frequency of sightings over seasons (Spearman's rank-order correlation p =0.7154; Spearman's rs = 0.11209).

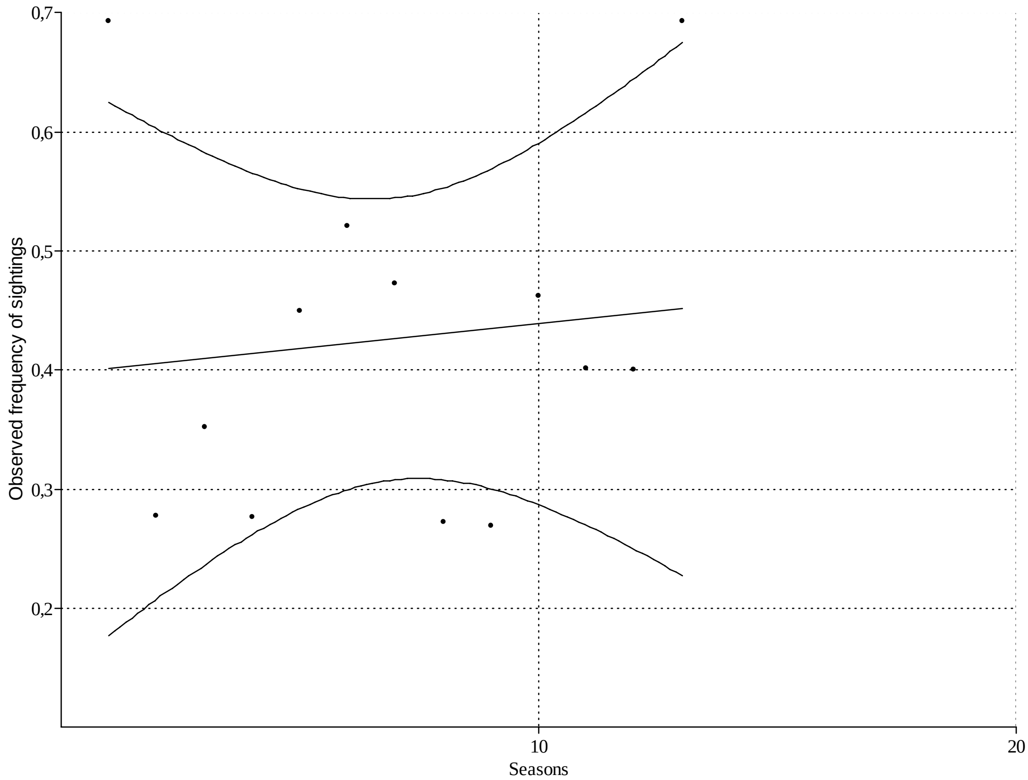


Figure 3. Frequency distribution of group sizes.

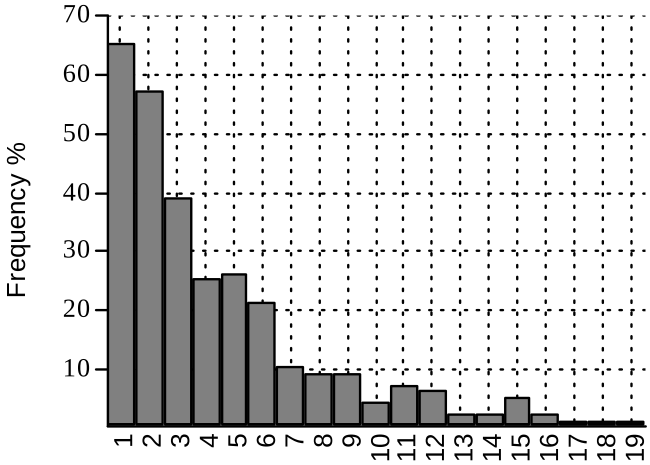


Figure 4. Distribution of group types.
Individual dolphin; Couple of adults; Adults with immature; Group of adults (more than 3 dolphins) without immature; Couple female and immature (a dolphin was considered a female if she was sighted swimming with a newborn).

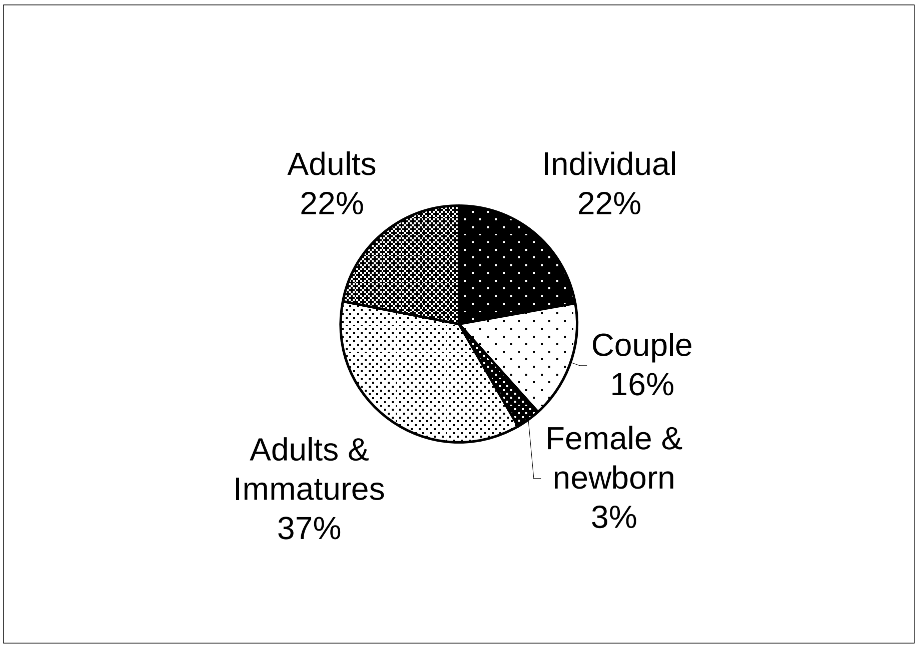
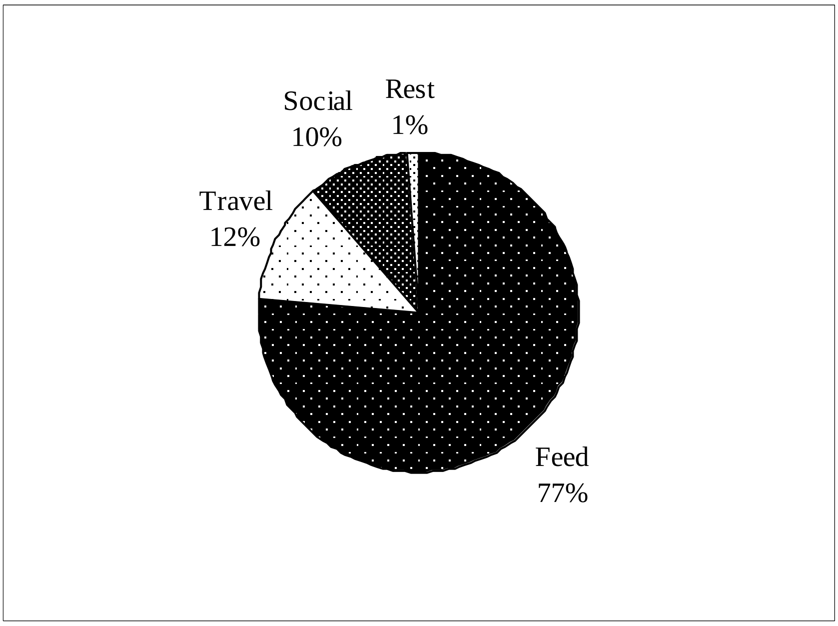


Figure 5. Time budget (n = 186.3 hours of sightings).



Appendix A. Descriptions of bottlenose dolphin controls used at marine fish farm in Sardinia, from this study.

Control Method	Description	how often each type of control was used
Double net	Underwater net comprising sheets of netting hung around a floating cage and often weighted at the bottom	80 % of cages
Cone Net	An underwater net shaped as a cone to minimise the bottom area where bottlenose dolphin attacks can occur	10 % of cages
Tensioned net	Netting that is tensioned and will not give with tidal movements but stay rigid.	10 % of cages
Human presence	farm workers positioned on cages to deter or scare off bottlenose dolphins	5 % of cages

Appendix B. Age Classes

Immature - Dolphins less than 2/3 the length of an adult with which they generally swim beside or in echelon. Dolphins approximately 1.5 to 2.0 meters in length.
Newborns - newborns were less than one year old and ranged in size from ~0.75 to ~1.5 meters in length. Very young newborns (< 1 month old) had visible fetal folds, slightly folded dorsal fin and fluke tips.
Adult - Dolphins approximately 2.5 to 3.5 meters in length.
NOTE: *The distinction between older newborns & immatures and older immatures & younger adults is difficult. Classification is aided by observations of associates and behavioural activity.*