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ECOLOGY OF COMMON BOTTLENOSE DOLPHINS ALONG THE NORTH-WESTERN SARDINIAN COASTAL WATERS (ITALY)

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ABSTRACT

In this paper, the temporal distribution of dolphins, group dynamics, site fidelity and abundance of common bottlenose dolphins along the North-western coastal waters of Sardinia (Italy) was assessed through mark–recapture photographic-identification techniques. Prior to this study, no research has previously focused on bottlenose dolphins within these waters, despite the potential for human impacts on this species. A total of 196 days with boat-based observations, spanning 28 months and 11 seasons, were spent at sea between September 2008 and March 2011. Common bottlenose dolphins were observed in all seasons, though seasonality was evident, with more encounters during the autumn and winter, and larger groups sighted during spring. The average number of photographic recaptures per individual was 4.6 ± 0.7, with only 9 individuals (12%) resighted over 10 times. The abundance estimate of approximately 55 bottlenose dolphins represents an approximation of dolphins occurring within these waters. The movement of prey species and interaction with marine fin fish aquaculture could be potential explanations for the seasonal variation in the presence of bottlenose dolphins. Moreover, photo-identification studies show that few individuals used the north-western coast of Sardinia on a regular basis, while others were present less often. While their occurrence in these waters is frequent, it appears to be only a component of a much larger area of distribution for this bottlenose dolphin population.

Key words: bottlenose dolphins, mark-recapture, photo-identification, site fidelity, Mediterranean Sea.

RESUMEN

En este trabajo se evaluó mediante marcado-recaptura e identificación mediante técnicas fotográficas la distribución temporal de los delfines, la dinámica de grupo, la fidelidad al sitio y la abundancia de los delfines mulares comunes a lo largo de las aguas costeras del noroeste de Cerdeña (Italia). Antes de este studio no se ha publicado ninguna investigación sobre delfines mulares en estas aguas, a pesar del potencial de los impactos humanos sobre esta especie. Un total de 196 días con observaciones desde embarcaciones, que abarca 28 meses y 11 estaciones, se emplearon en el mar entre septiembre de 2008 y marzo de 2011. Los delfines mulares se observaron en todas las estaciones, aunque con evidente estacionalidad, con más encuentros durante el otoño y el invierno, y grupos más grandes avistados durante la primavera. El número medio de recapturas fotográficas por individuo fue de 4,6 ± 0,7, con solamente 9 individuos (12%) vistos de nuevo más de 10 veces. Se efectúa una estimación de la abundancia de delfines mulares en estas aguas de aproximadamente 55. El movimiento de las especies presa y la interacción con los peces de aleta de acuicultura marina podría ser posibles explicaciones para la variación estacional de la presencia de delfines mulares. Por otra parte, estudios de identificación fotográfica muestran que pocos individuos están presentes en la costa noroccidental de Cerdeña de forma regular, mientras que otros aparecen de manera eventual. Aunque su presencia en estas aguas es frecuente, parece ser sólo un fragmento de un área mucho más amplia de distribución para esta población de delfines mulares.

Palabras clave: delfines mulares, marcado y recaptura, foto-identificación, fidelidad al sitio, Mar Mediterráneo.

INTRODUCTION

Ranging from tropical to temperate waters, common bottlenose dolphins (*Tursiops truncatus*) show extreme diversity in abundance, distribution, and habitat use (Wells and Scott, 1999; Reynolds *et al*., 2000). Some inshore populations reside entirely within confined coastal areas (Wells *et al*., 1987; Owen *et al*., 2002; Wells, 2003; Lusseau *et al*., 2003; Díaz López and Shirai, 2008; Merriman *et al*., 2009; Gnone *et al*., 2011), and some are migratory (Kenney, 1990) while others appear to be transient (Tanaka, 1987; Balmer *et al*. 2008).

Mediterranean common bottlenose dolphins sightings occur regularly in a number of coastal areas, but empirical data on the abundance and site fidelity of these communities is lacking (Bearzi *et al*., 2008). This Mediterranean population is more related to the inshore ecotype (Gnone *et al*., 2011), due to its shallow water habits. Therefore, Mediterranean bottlenose dolphins may be particularly vulnerable to anthropogenic influences.

Currently, common bottlenose dolphins are listed under Annex II of the European Union's Habitats Directive which requires the designation of a Special Area of Conservation (SAC) for their protection. Additionally, the Mediterranean common bottlenose dolphin "subpopulation" is classified as "Vulnerable" according to the International Union for Conservation of Nature (IUCN) Red List criteria (Bearzi and Fortuna, 2006). Hence, it is widely believed that the number of Mediterranean common bottlenose dolphins has declined in recent decades as a consequence of human activities and habitat degradation (Bearzi *et al*. 2008) and there is a demand for the development and implementation of conservation management and monitoring programs.

The knowledge of habitat use is dependent upon the quality of information available. This information is necessary, not only for defining boundaries to such areas but also to understanding how these areas are used by the bottlenose dolphins and what factors affect their distribution and abundance.

Presently, the majority of the research carried out on Mediterranean common bottlenose dolphins in Sardinia, Italy has been along the North (Lauriano *et al*., 2003; Lauriano and Bruno, 2007; Lauriano *et al*., 2009) and North-eastern coast (Díaz López *et al*., 2005; Díaz López, 2006a; Díaz López and Shirai, 2007; 2008), with the absence of specific studies occurring on the North-western coast of Sardinia for comparison. Having information of the status of bottlenose dolphins in areas like this one, where human activities (fisheries, aquaculture and marine traffic) and habitat degradation are present, is fundamental for the development of future conservation management programs. The primary aim of this study was to assess the temporal distribution of dolphins, describe their group dynamics, and calculate their abundance. Dolphin abundance was estimated by implementing mark-recapture photographic-identification (photo-ID) techniques.

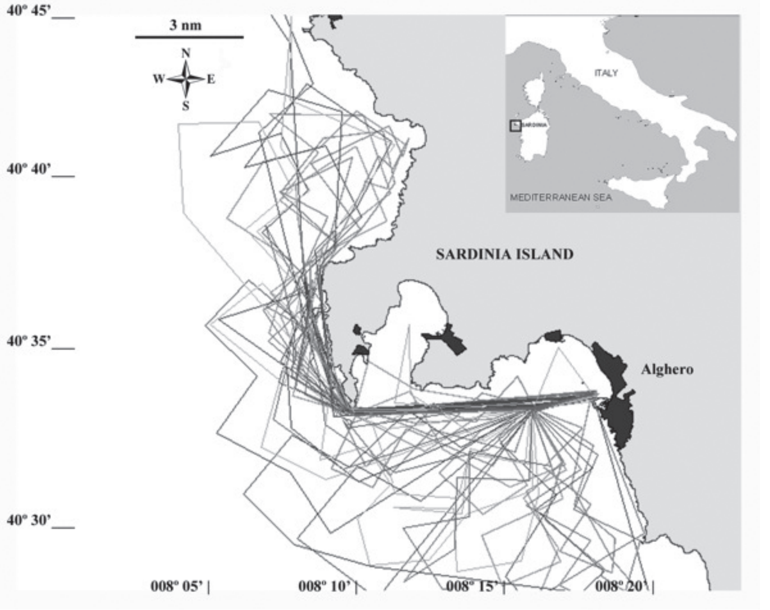

Figure 1:

Map of the study area along the north-western coast of Sardinia (Italy).

MATERIALS AND METHODS

Data collection

Boat-based observations were carried out year-round between September 2008 and March 2011 using a 5.10 m research vessel powered by a 40 hp outboard engine. The study area expanded about 6 km offshore, covering an approximate area of 200 km^2 of sea surface (Fig. 1). The majority of surveys began at Alghero (N 40º33.764, E 008º18.701) on the North-western coast of Sardinia (Italy) where the vessel was berthed.

The study site is situated over 25 nautical miles south of Asinara Island national park, beyond the Pelagos Sanctuary boundary, in a shallow water region of the North-western Sardinian coast. Inside of the study area the Capo Caccia-Isola Piana Natural Marine Protected Area (26 km^2) is presented. The study area was surveyed during daylight hours at a constant speed, between 4-5 knots, with at least two experienced observers scanning the sea surface in search of dolphins (with the naked eye and/or binoculars, 12x50). The number of observers and vessel speed remained consistent during the study period, making this data suitable for the comparative analysis of encounter rates.

On each boat survey, the time, latitude, longitude, speed, environmental data (e.g., sea state, wind speed and direction, etc.), and anthropogenic data (e.g., number and type of boats, gillnets presence, etc.) were recorded every 20 minutes (following Díaz López, 2006c). A hand-held global positioning system (GPS) was used to record the latitude, longitude, and speed of travel (knots), and sonar was used to record the depth (m). This data were used to summarize field conditions irrespective of dolphin presence.

In order to analyse the seasonality of bottlenose dolphins in the study area, four seasons were defined, following Díaz López and Shirai (2007): winter (January to March); spring (April to June); summer (July to September); and autumn (October to December). Local time was converted to GTM when appropriate, to account for daylight savings. For the analysis of daily patterns, data was classified in three moments of equal duration (one-third the daylight hours) that cover all daylight hours: morning, afternoon and evening. Daily patterns were only compared within seasons and they were not compared across seasons as the moments were not equal since different seasons have different amounts of sunlight.

Upon sighting a group of bottlenose dolphins, searching effort ceased and the vessel slowly manoeuvred towards the group in order to minimise disturbance during the approach. We recorded their positions (while approximately 20m of the animals), time, and environmental and anthropogenic data. Group size and composition were also recorded at this time. A group of dolphins was defined as: one or more common bottlenose dolphins observed in the visual area, usually involved in the same activity, following Díaz López (2006a). An interaction with a dolphin group was termed an 'encounter'. Encounters were considered satisfactory when the visibility was not reduced by rain or fog, and sea conditions were < 3 on the Douglas sea force scale (approximately equivalent to the Beaufort wind force scale). Searching effort stopped at sighting, and restarted when the encounter was finished. The encounter continued until the group was lost (i.e. after 15 min without a sighting) (Díaz López, 2006a).

Temporal distribution

As the number of sightings could depend on the survey effort, a daily bottlenose dolphin encounter ratio (DER) was computed as DER = Ns/Se (h), where Se (search effort) is the time spent searching the dolphins (excluding time spent on sightings) and Ns is the total number of sightings (Díaz López, 2006a). By calculating DER we eliminated effort-related bias from derived distribution patterns arising from an uneven survey effort, caused by time and weather restrictions. Thus, for the seasonal and daily analysis, we examined the total DER for the entire survey routes, either for each survey season or survey moment, for the compiled years of 2008 to 2010. Seasonal and daily fluctuations in dolphin presence were tested using the Kruskal–Wallis test for non-parametric data calculated with PAST (Hammer *et al*., 2001). Statistical significance was tested at the $P < 0.05$ level.

Photo-identification

During each encounter, we attempted to photograph all members of the group in order to identify individuals with photographs of their dorsal fins and surrounding area, using natural marks (Würsig and Jefferson, 1990). Individual dolphins were identified based primarily on the size, location and pattern of notches on the trailing edge of the dorsal fin and the back, directly behind the dorsal fin. Features such as body and dorsal fin scars, lesions and tooth-rakings were also used as secondary characteristics, thereby reducing the possibility of false positives (Wilson *et al*., 1999). Digital photographs were taken using two DSLR cameras: Nikon D90 and D40, both equipped with 70–300 mm (f:4.5–5.6) telephoto zoom lens. Only photographs considered suitable for photo identification (i.e. those in focus, with the dorsal fin perpendicular to the plane of the photograph, or close enough to identify small notches) were used for subsequent analysis (Díaz

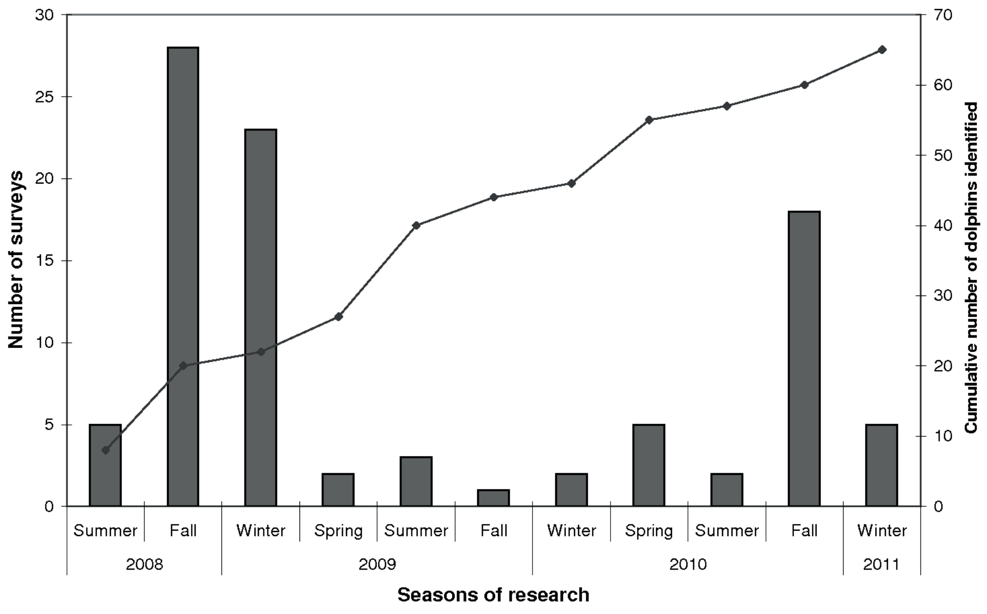

Figure 2:

Discovery curves of the cumulative number of bottlenose dolphins identified between August 2008 and March 2011 along the north-western coast of Sardinia (Italy). The bars represent the observation effort during each season of study and the solid line represents the cumulative number of dolphins identified.

López and Shirai, 2007; 2008). A marked individual is one that is recognized not by a single feature, but by several features. Unmarked individuals were excluded from this analysis.

Group Dynamics

Group size was estimated based on the initial count of different individuals observed on the surface. The group size and age categories were assessed visually *in situ*, and the data was later verified with photographs and videos taken during each sighting (Díaz López and Shirai, 2008). Age class definitions followed those by Díaz López (2006b), where dolphins were classified as either: (i) immature, dolphins two thirds or less the length of an adult they consistently swam beside and slightly behind; or (ii) adults, those estimated to be longer than 2.5m. Field data was later adjusted, based on photo-identification data, by increasing the number of individuals present if more marked individuals were photographed than was estimated by the field data. Group composition was determined by counting the minimum number of adults and immature dolphins present.

Seasonal and daily fluctuations in group size were tested using a Kruskal–Wallis test for non-parametric data performed with PAST (Hammer *et al*., 2001). If the test showed a significant inequality of the medians, a Tukey's post-hoc contrast was performed (Zar, 1999).

Abundance Estimation

Spatial and temporal distribution of the surveys, time spent at sea, and the choice of the most appropriate data sets and abundance models were made to minimize violation of mark-recapture assumptions. Thus, a number of fundamental assumptions were made: i) marked dolphins will always be recognized; ii) photo-identified dolphins must be representative of the population being estimated; iii) every dolphin should have the same probability of being photographed within any one sampling occasion. We defined the term "population" as the number of bottlenose dolphins frequenting the study area (Williams *et al*., 2002) and used the terms abundance and population size synonymously.

Using POPAN in SOCPROG 2.3 (Whitehead, 2009), abundance estimates were calculated and fitted with four population models: (1) Mortality, this model assumes a population of constant size, where mortality (which may include permanent emigration) is balanced by birth (which may include immigration). The population size and mortality rate (per sampling period) were estimated by maximum likelihood; (2) Mortality + Trend, this model assumes a population growing or declining at a constant rate. The population size, mortality rate (per sampling period) and growth or decline of the population (instantaneous proportional rate per sampling period) are estimated by maximum likelihood; (3) Reimmigration, this is the model

Table 1:
The observation effort, number of surveys, number of encounters, and the mean daily encounter ratio (DER) across: A) each survey season; B) each moment of the day. Asterisks (**) represent statistical difference at P<0.001.

A)

Seasons	No. of surveys	No. of months	Observation Effort (h)	No. of encounters	DER
Winter	30	7	107.4	31	1.10±0.42**
Spring	57	6	194.3	9	0.08±0.03
Summer	72	8	262.1	18	0.10±0.02
Autumn	46	7	178.0	50	0.62±0.40**
Total	205	28	741.8	108	0.36±0.07

B)

Moments	No. of surveys	No. of months	Observation Effort (h)	No. of encounters	DER
Morning	130	26	294.05	66	0.56±0.12
Afternoon	169	28	279.55	55	0.52±0.11
Evening	69	24	202.1	19	0.15±0.04

of Whitehead (1990) in which members of a population move from (emigration rate) and into (reimmigration rate) a study area. The population size in the study area, the total population size, the emigration and reimmigration rates are estimated by maximum likelihood; and (4) Reimmigration and mortality, this is the model 3) with the exception that mortality (which may include permanent emigration from the total population) is balanced by birth (which may include immigration). Parameters for these models are detailed in Gowans *et al*. (2000).

To obtain adequate sample sizes and to ensure an even coverage of the study area, the sampling period was set by season, resulting in 11 sampling periods. Model selection was based on the lowest Akaike's Information Criterion (AIC, Akaike, 1973). The Spearman's-rho rank order test for non-parametric data was used to test for correlation between the number of photo-identification surveys carried out and the number of animals identified in each season.

Our abundance estimates refer only to the marked individuals in the population. The total abundance was calculated using estimates generated from the most parsimonious model, and corrected by the mark rate for the animals inhabiting this region (Parra *et al*., 2006). The proportion of identified individuals or mark rate, described by θ in mark-recapture studies, was defined as the percentage of permanently marked individuals for each year (Parra *et al*., 2006). The mark rate (θ) was estimated by counting the number of "good" quality photos of recognisable individuals and dividing by the total number of "good" quality dorsal fin photos taken (Williams *et al*., 1993).

Site Fidelity

To investigate the presence of identified individuals in the study area over time, we calculated a temporal sighting rate on a seasonal basis (Parra *et al*. 2006). A seasonal occurrence rate was defined as: the number of seasons a recognizable dolphin was identified given as a proportion of the 11 seasons in which at least one bottlenose dolphin was identified.

RESULTS

Survey effort and temporal distribution

We surveyed a total of 196 days, spanning 28 months and 11 seasons. On average, 51.2±17 SE days per season and 124 ± 51 SE days per moment of the day were spent at sea. A total of 205 surveys were made between September 2008 and March 2011, totaling 742.5 hours and 2081 nau-

Table 2:

Median and mean group size (±SE) for bottlenose dolphin groups across each survey season. Asterisks (*) represent statistical difference at P<0.05.

Season	Number encounters	Group size	Number adults	Number immatures
Spring	9	7 (7.0±1.3)**	7 (6.5±1.3)**	0 (0.4±0.2)
Summer	18	4.5 (5.4±0.9)	4.5 (5.2±0.9)	0 (0.2±0.1)
Autumn	43	3 (4.0±0.4)	3 (3.9±0.4)	0 (0.06±0.03)
Winter	31	2 (2.3±0.3)**	2 (2.2±0.2)**	0 (0.2±0.08)
Total	108	3 (4.02±0.3)	3 (3.8±0.3)	0 (0.16±0.04)

tical miles. During this time there were 108 encounters with bottlenose dolphins, resulting in a total encounter time of 102 hours (average 56.8 ± 43 minutes).

Bottlenose dolphin groups were encountered during every year surveyed, covering all months of the year and all moments of the day. A significant difference in DER was found between seasons (Kruskal–Wallis test, $p < 0.05$), which is likely to have been caused by the higher seasonal daily encounter rates during the autumn and winter months (Table 1a). In contrast, the daily analysis did not show a varied DER over the survey moments (Kruskal–Wallis test, $p > 0.05$) (Table 1b).

Group size and group composition

Group size ranged from 1 to 13 individuals (mean = 4.02±0.31 SE), with most groups (n = 108, 83%) containing < 7 animals. Group composition showed that 96% of the observed individuals were considered adults; thus the remaining were categorized as immature dolphins. Moreover, 25% of the observed individuals were solitary, 13.9% of the groups contained immature dolphins and 61.1% of the groups were formed only by adults. Group sizes between groups with immature dolphins and groups formed only by adults were significantly different (8.06 ± 0.89 groups containing immatures vs 3.3 ± 0.27 groups containing adults only; Kruskal–Wallis test, $p < 0.05$). This tendency for groups was consistent throughout the study period.

Our results revealed seasonal variations in the group size (Kruskal–Wallis test, $p < 0.05$), with a peak in the number of adult bottlenose dolphins observed during the spring (mean = 6.5±1.3) and a minimum number during the winter (mean = 2.2±0.2; Kruskal–Wallis test, $p < 0.01$). However, group size did not exhibit daily variations (Kruskal–Wallis test, $p > 0.05$).

Photo-identification catalogue and abundance estimates

A discovery curve of photographic captures of new permanently marked individuals (N = 74) showed a steady increase over time, suggesting that the population was open for the duration of the study and/or unrecognizable animals acquired new marks as our study progressed (Fig. 2). The period of higher survey effort and the number of new permanently marked animals identified showed an overall peak during autumn 2008. Moreover, there was no correlation between the number of photo-identification surveys carried out and the minimum number of animals identified in each season (Spearman's rank order correlation: $r_s = 0.59$, $n = 11$, $p > 0.05$).

The abundance estimates are shown in Table 3. Based on the lowest AIC value, the "mortality model" was selected as the most parsimonious. Based on the ratio of marked individuals, which was approximately 84% of the catalogued dolphins, we estimated that 54.8 (95% CI = 44.8 to 69.5) number of animals inhabiting this area.

Site Fidelity

The average number of photographic recaptures per individual was 4.6 ± 0.7 SE (from 1-28, n = 74), with only 9 individuals (12%) resighted over 10 times. Hence, 30 dolphins (40.5%) were identified only once throughout the study period. This shows that few individuals used the north-western coast of Sardinia on a regular basis, while others were present less often. Relative to the total number of seasons surveyed (n = 11), most common bottlenose dolphins identified were sighted sporadically (mean seasonal occurrence rate = 0.21 ± 0.03 SE resightings per season).

Individual dolphins were divided subsequently into three arbitrary categories based on their temporal occurrence rates (following Díaz López, 2012):

Table 3:
Abundance estimates of common bottlenose dolphins along the north-western coast of Sardinia (Italy) between August 2008 and July 2010.

	Marked bottlenose dolphins						Model Selection				Total population		
Models	N	CI	m (CI)	t (CI)	e (CI)	re (CI)	Nc	sp	LogL	AIC	θ	Nt	CI
		41.6	0.05										44.8
Mortality	50.7		0.10	n.a.	n.a.	n.a.	74	11	-189.8	377.6	0.84	54.8	
		64.0	0.16										69.5
		37.6	0.01	0.05									49.5
Mortality + Trend	46.1		0.07	0.13	n.a.	n.a.	74	11	-190.6	384.9	0.84	60.3	
		58.4	0.13	0.19									76.2
		40.6			0.14	0.10							44.8
Reimmigration	41.8		n.a.	n.a.	0.22	0.16	74	11	-189.8	377.6	0.84	54.8	
		54.0			0.29	0.35							69.5
		47.8			0.06	0.01							49.5
Reimmigration + Mortality	49.0		0.00	n.a.	0.11	0.03	74	11	-190.6	384.9	0.84	60.3	
		58.4			0.16	0.13							76.2

Notations: n = estimated population size; CI = 95% confidence interval, bootstrapped (*n* = 500) *SOCPROG*; Model results; n.a = not available; m = estimated mortality rate; t = estimated trend rate; e= estimated emigration rate; re= estimated reinmmigration rate; nT= estimated total population size; Nc = number of animals captured; s.p.=number of sampling periods; θ = ratio of marked to total animals documented; Nt = estimate of total population size after correcting for proportion of identifiable individuals; AIC = Akaike Information Criterion: LogL: Log Likehood

1. Regular visitors: bottlenose dolphins seen regularly on the North-western coast of Sardinia, with seasonal occurrence rates higher than 0.5. This category contained 4 identified bottlenose dolphins, accounting for 5.4% of the total 74 identified dolphins.
2. Frequent visitors, bottlenose dolphins with seasonal occurrence rates higher than 0.25. This category contained 10 identified bottlenose dolphins, accounting for 13.5% of the total 74 identified individuals.
3. Sporadic visitors, bottlenose dolphins rarely seen in the study area, with seasonal occurrence rates lower than 0.25. This category contained 60 bottlenose dolphins, accounting for 81.1 % of the total 74 identified individuals.

DISCUSSION

Abundance, distribution, and ranging patterns of common bottlenose dolphins in the Mediterranean Sea are not well understood (Bearzi *et al*., 2008). The data presented here represents the first systematic study about the ecology of Mediterranean common bottlenose dolphins in the North-western coastal waters of Sardinia (Italy).

This study shows that the bottlenose dolphins found in these waters likely form a part of a larger regional population that frequent the study area. The abundance estimate of approximately 55 bottlenose dolphins occurring in the north-western Sardinian waters represents an approximation of dolphins occurring within these waters. Therefore, it should be regarded with caution since it seems that most of the dolphins visit sporadically this area. This is further supported by the absence of a plateau in the discovery curve (suggesting a regular entrance of new individuals) and the fact that few individuals used the North-western coast of Sardinia on a regular basis.

Our results confirm that this population is not isolated or closed, providing the possibility that changes in density are driven by immigration and emigration and/or by births and deaths. This study also reveals that a small proportion (5.4% for all 74 identified individuals) of the population exhibits high site fidelity to the north-western coast of Sardinia. Although bottlenose dolphins were never absent from the study area, site fidelity of identified individuals suggest that most dolphins may visit adjacent habitats, such as Asinara Island National Park, where bottlenose dolphins have been reported (Lauriano *et al*., 2004; Lauriano & Bruno, 2007; Lauriano *et al*., 2009). Hence, these animals appear to use these waters as only one part of a much larger area of distribution.

Common bottlenose dolphins were observed in all seasons and moments surveyed, although seasonality was evident, with more encounters during the autumn and winter, but larger groups sighted during spring. Similar group sizes observed here were reported for other areas along the Sardinian coast (median = 3), where groups rarely contained more than 10 individuals (Lauriano et a., 2003; Díaz López, 2006a; Díaz López and Shirai, 2007, 2008).

There are numerous potential explanations for the seasonal variation in the presence of bottlenose dolphins along the north-western coast of Sardinia. These include factors such as the movement of prey species (Díaz López, 2006b; Díaz López and Shirai, 2007), interaction with artisanal fisheries (Díaz López, 2006a; Lauriano *et al*., 2004; Lauriano *et al*., 2009), and marine fin fish aquaculture (Díaz López *et al*., 2005; Díaz López, 2006b; Díaz López and Shirai, 2007). In this area a few bottlenose dolphins tend to interact with a marine fin fish farm during the autumn and winter months (Addis *et al*., 2010). Thus, bottlenose dolphins can presumably reduce the proportion of time spent searching for food and possibly increase the quantity and quality of the food they consume (Díaz López, 2006b; Díaz López and Shirai, 2007; Díaz López and Shirai, 2008).

It seems that large groups of bottlenose dolphins take advantage of the abundance of wild fish species in the area. Thus, during the spring and summer months, there may be plenty of small schooling fishes in waters offshore of the north-western coast of Sardinia, these include: sardines (*Sardina pilchardus*), garkfish (*Belone belone*) and anchovies (*Engraulis encrasicholus*) (local fishers pers. comm.). Therefore, it is equally possible that most individuals move into adjacent areas (e.g., Asinara island) and offshore waters during these seasons, where prey resources may be in higher abundance.

Optimal protection of a cetacean population requires the protection of the entire area inhabited year-round by that population (Reeves, 2000). It is therefore important that future studies include areas to the North, East and South of Sardinia to assess the population structure and how the movement of individuals between these areas might potentially affect abundance estimates at a local level. We also suggest that further studies are required to look at the type, abundance and distribution of potential prey species in these areas.

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