Occurrence, site fidelity, and abundance of bottlenose dolphins (*Tursiops truncatus*) in the Western Ligurian Sea

Davide Ascheri[1], Elena Fontanesi[1,2], Marco Ballardini[2], Barbara Nani[2] and Jessica Alessi[3]

ABSTRACT

This study represents the first complete assessment of the population dynamics and residency of common bottlenose dolphins in the Western Ligurian Sea, an area where bottlenose dolphin sightings have been rare in the past. Despite being greatly affected by human pressure, information about this population is poor and sporadic. The study took place from April 2018 to December 2020. One hundred and seventy-one dedicated boat surveys were performed year-round resulting in 95 sightings, and 123 individuals were identified through mark-recapture photo-identification techniques. Dolphins were found to be present year-round. Most of the animals (79) used the area sporadically and only 19.5% of the dolphins (24) were seen regularly. Bottlenose dolphin abundance was estimated at 248 using open POPAN population models (CI 95% = 217–284). These results help fill a knowledge gap by highlighting the regular presence of bottlenose dolphins in the study area. Moreover, they represent a baseline for future studies investigating abundance trends and the conservation status of this population

KEYWORDS: BOTTLENOSE DOLPHIN; MEDITERRANEAN SEA; ABUNDANCE ESTIMATE; MARK-RECAPTURE; PELAGOS SANCTUARY; PHOTO-IDENTIFICATION; RESIDENCY PATTERNS

INTRODUCTION

Bottlenose dolphin (*Tursiops truncatus*) is one of the most studied cetacean species worldwide. The species is of conservation interest due to their coastal habitats, often fragile and highly threatened, and their frequent interaction with human activities (Reeves *et al*., 2003; Methion and Díaz López, 2018). The main anthropogenic stressors include overfishing, bycatch, chemical and noise pollution, collisions with boats, and habitat and shoreline degradation (Derraik, 2002; Díaz López, 2012; Read *et al*., 2006). For coastal species like bottlenose dolphins, small-scale studies conducted over limited spatial range allow scientists and managers to localise specific threats and ultimately help provide solutions to mitigate them (Connor *et al*., 2000).

Bottlenose dolphins have a cosmopolitan distribution except for polar waters, showing a high degree of local adaption (Menchaca *et al*., 2019) and an extreme diversity in occurrence, residency patterns (Blasi and Boitani, 2014), distribution and abundance, with reports worldwide of population sizes varying from a few individuals to thousands (Reynolds *et al*., 2000). Residency patterns and home ranges of a population or portion of the population can vary from resident with a strong site fidelity to one area (Gonzalvo *et al*., 2014; Augusto *et al*., 2011; Akkaya *et al*., 2018; Estrade and Dulau, 2020), to migratory or transient (Díaz López *et al*., 2013; Bouveroux *et al*., 2014; Dinis *et al*., 2016; Ribaric, 2017).

In the Mediterranean Sea, bottlenose dolphins normally occur in coastal habitats on the continental shelf, although their presence in pelagic waters is not unusual (Bearzi *et al*., 2009; Panigada *et al*., 2021). Mediterranean

bottlenose dolphins have recently been reassessed as 'Least Concern' on the IUCN Red List after a change of status in 2021 from 'Vulnerable' (Natoli *et al.*, 2021; Notarbartolo di Sciara and Tonay, 2021). The first basin-wide distance sampling abundance estimate (2018) suggests a population of about 60,000 bottlenose dolphins (95%CI = 45,000–79,000) (Panigada *et al.*, 2021). However, this is an underestimate given that some areas where the species could be present were not covered (Natoli *et al.*, 2021; Panigada *et al.*, 2021). The large amount of new data and information available suggests an overall stable population (Natoli *et al.*, 2021), contrary to the declines registered in the past (e.g. Bearzi *et al.*, 2008) although their exposure to human impacts is still high. Moreover, genetic studies have shown that Mediterranean bottlenose dolphins are genetically distinct from the Atlantic Ocean bottlenose dolphins (Natoli *et al.*, 2004), which further emphasises the importance of the conservation of this sub-population and its genetic diversity. The species is included in 'Appendix I' of the Red List of Italian Vertebrates as a 'near threatened' species (Rondinini *et al.*, 2013). Bottlenose dolphins are protected by several international conventions, including the Bern Convention on the Conservation of European Wildlife and Natural Habitats (Appendix II), Barcelona Convention (Annex II) and Washington Convention. The species is listed among the Species of Community Interest and as needing a strict protection regime in the European Habitats Directive (Council Directive 92/43/EEC, Annex II and IV) and in the Italian law n. 157/'92, requiring the designation of Special Areas of Conservation (SACs). The presence and distribution of bottlenose dolphins inside the Pelagos Sanctuary (a Specially Protected Area of Mediterranean Importance (SPAMI) located in the North Western Mediterranean Sea, for the conservation of cetaceans, see below) has been extensively studied on both a large scale (Gnone *et al.*, 2011; Alessi and Fiori, 2014, Gnone *et al.*, 2022) and locally in several regions: France (Di-Méglio *et al.*, 2015; Gannier, 2005; Labach *et al.*, 2019), the Eastern Ligurian coast (Alessi *et al.*, 2019; Gnone *et al.*, 2006), Tuscany and the Tuscan Archipelagos (Nuti *et al.*, 2006), the West and South coast of Corsica (Dhermain and Cesarini 2007; Di-Méglio *et al.*, 2015), and the North coast of Sardinia (Fozzi *et al.*, 2001; Lauriano *et al.*, 2003). Despite the significant research effort in the Pelagos Sanctuary, bottlenose dolphins have been only sporadically reported inside the study area, on the West coast of Liguria (Azzellino *et al.*, 2008; Bearzi *et al.*, 2008) and their abundance and population dynamics are poorly known. This part of the basin in fact shows a narrow continental platform and it is mostly investigated to monitor pelagic species of cetaceans (Gnone *et al.*, 2011; Notarbartolo Di Sciara and Birkun 2010). Only in recent years bottlenose dolphins have shown a possible increase in number of sightings (De Santis *et al.*, 2018). The study presented here used mark-recapture techniques to provide the first estimate of abundance, occurrence and residency of this species in this area, using year-round samples. Results from this study represent a baseline for long-term monitoring bottlenose dolphin in this part of the Ligurian Sea where the data are missing and to inform the development of conservation plans for their protection.

MATERIALS AND METHODS

Study area

The study area (Fig. 1) is located in the Western Ligurian Sea, in the 'Pelagos' Sanctuary, a marine area established in 1999 for the conservation of marine mammals and classified as a Specially Protected Area of Mediterranean Importance (SPAMI) in 2002. The Sanctuary covers an area of about 87,500 km^2 extending over the waters of France, Italy and Principate of Monaco including both coastal and offshore waters (Notarbartolo di Sciara *et al.*, 2008). Inside the study area 11 Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) of the Natura 2000 network designated under the Habitat Directive of 1992, are present. The study area covers approximately 812 km² and in its entirety reaches the Italian-French border in the West (43°47'06"N, 7°31'44"E) and Capo Noli in the East (44°11'53"N, 8°25'30"E), extending from the shoreline to the 500m bathymetric contour. It is characterised by distinct oceanographic, climatic and morphological features in comparison to the rest of the Mediterranean Sea. The Ligurian Sea, especially the Western basin, has a high level of primary productivity and intense biological activities (Notarbartolo di Sciara *et al.*, 2008). The continental platform, which extends from the shore to a depth of 200 m, is very narrow. The coastal floor is crossed by numerous submarine canyons, mainly as a prolongation of the main mountain-supplied rivers (Migeon *et al.*, 2011), creating important areas rich in primary production and biomass (Würtz, 2012).
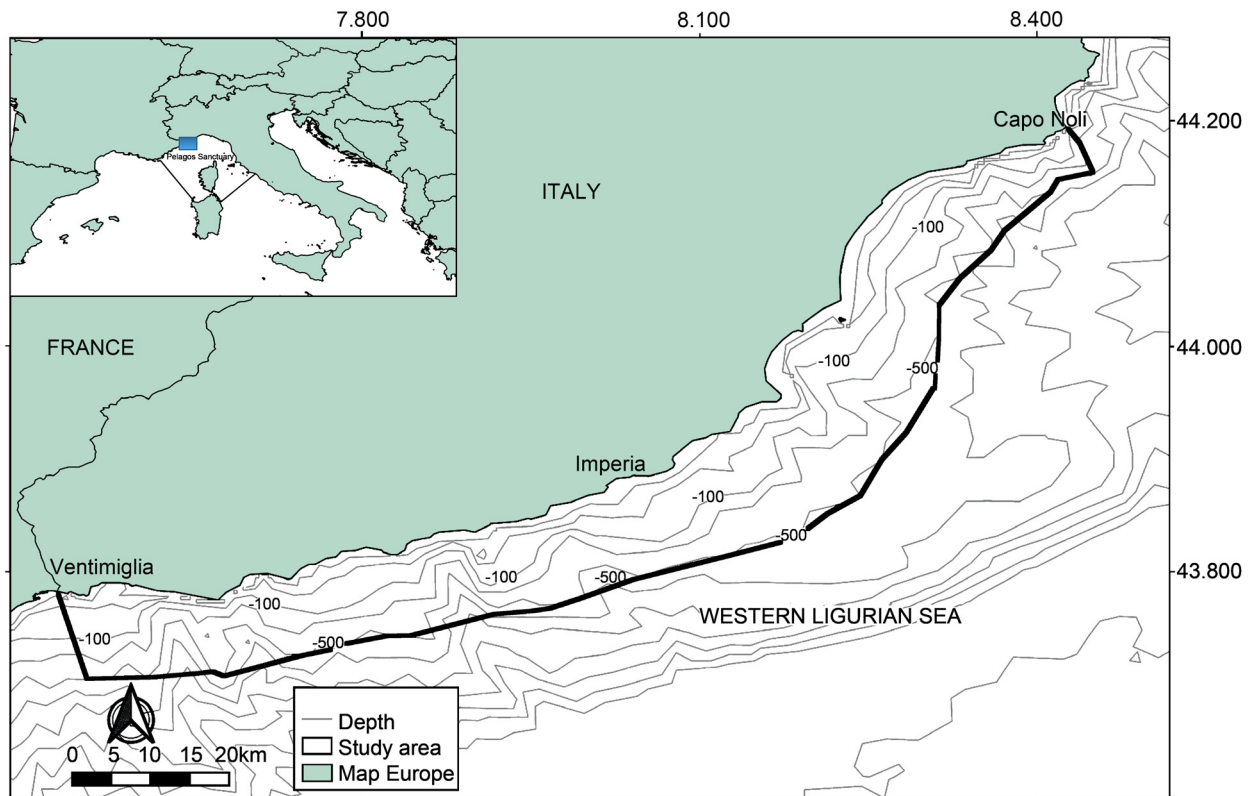
Fig. 1. Map of the study area.

Data collection

Data were collected from April 2018 to December 2020 during dedicated boat-based visual surveys conducted from a 5.2m zodiac equipped with a 40hp outboard engine. Tracks were randomly created (La Manna *et al.*, 2016; Pace *et al.*, 2021), based on the weather conditions, aiming to cover the whole study area equally and trying to alternate effort on the western and eastern sides, from the city of Imperia, located in the middle. A track was generally composed of two random routes parallel to the shore and about 2 nautical miles distant from each other to avoid surveying the same area on the way back. During each season, we attempted to survey the entire area as homogeneously as possible, although the coverage of effort could vary according to the weather conditions and the dolphins' distribution (Díaz López and Methion, 2017; Genov *et al.*, 2019). The central part of the study area received more coverage than the lateral parts, due to the location of the home port and dolphin encounters. Surveys were carried out when conditions were at a sea state Douglas 2 or less, with wind speeds lower than 10 knots and in good visibility. Boat speed was kept to less than 10 knots while at least two experienced observers covered 360° degrees of observation, with and/or without the aid of binoculars (7×50). Any time the weather conditions worsened, the searching effort stopped. The position of the zodiac was automatically recorded by a portable GPS (Garmin Etrex 32×) at 2 minute intervals, to register the whole track. On each survey, data collected including the geographic position, time, environmental data (sea state, wind state, degree of glare, visibility and cloudiness) and marine traffic data (number of type of boats, number of nets in the area) was recorded every 30 minutes.

During a sighting, searching effort was suspended (and restarted at the end of the sighting) and animals were cautiously approached following a trajectory that became progressively parallel to their route in order to minimise disturbance or excessively interfere with their behaviour (Wilson, 1995). Position of the animals, time, group size, composition of the group and any interaction with human activities were recorded. Photographs of the flanks of animals and their dorsal fins were taken, whenever possible, at a perpendicular angle using a *Canon* Eos 6D equipped with a 100–400mm *Canon* L series zoom lens and a Nikon D7200 with a 70–300mm *Nikon* lens and attempts were made to photograph all the animals present. Following Luis *et al*. (2015) a sighting refers to

the encounter of a group where a group was defined as a solitary dolphin or an aggregation of animals within 100m of each other, interacting or showing the same behaviour (Lusseau *et al.*, 2006; Methion and Díaz López 2018; Wilson, 1995).

Data analysis

Occurrence

The bottlenose dolphin encounter rate (ER) was calculated as the number of sightings per km on effort (defined as the time spent searching for dolphins, in good weather condition and excluding the time spent on sightings) to estimate a value for the whole study area, for 2018, 2019, 2020 and total. Four seasons were defined: Winter (January–March), Spring (April–June), Summer (July–September) and Autumn (October–December) following Díaz López and Shirai (2007). Seasonal ER were also calculated and compared using the Kruskal-Wallis test for non-parametric data with R 4.0.3 Software (RStudio Team, 2015), with a statistical significance tested at the p-value < 0.05.

Photo-ID analysis

Animals were identified using natural markings of the dorsal fins (Würsig and Würsig, 1977; IWC, 1990). The photo-identification analysis was performed independently by two experienced researchers. Photos were classified by their quality, based on consistent criteria that incorporated focus and clarity, contrast, angle of the fin, and percentage of the fin visible, by assigning a quality value (Q) between 1 (low quality) and 5 (high quality) (Pace *et al.*, 2021). Only photos with Q ≥ 4 were further used for the analysis. The best pictures of each individual were graded by the distinctiveness (D) of marks using the scale described by Read *et al.* (2003); dolphins with the most distinctive features were scored D1; those with intermediate features (at least two distinguishing features or one major feature) were scored D2; and animals with few or no distinctive characteristics received a score of D3. To minimise identification bias and to avoid over/underestimation only well-marked individuals were considered in the analysis (i.e. D1 and D2 categories), and all the unmarked animals (including calves and juveniles) were excluded. Marked animals were identified by comparing marks and nicks on the dorsal fin and the best pictures of every marked dolphin were collected in a catalogue. Whenever a new dolphin was identified, it was assigned an alphanumeric code and was added to the catalogue.

Site fidelity and residency

To analyse the presence and residency of identified individuals in the study area, seasonal occurrence rate (SOR) was calculated as the number of seasons a recognisable dolphin was identified in proportion to the total number of seasons surveyed and in which at least one dolphin was identified (Benmessaoud *et al.*, 2013; Díaz López *et al.*, 2013).

Based on the seasonal occurrence rate of each dolphin, three categories of residency in the study area were considered (Díaz López, 2012; Parra *et al.*, 2006):

(1)   Resident = dolphins regularly observed in the study area with a SOR higher (or equal) than 0.5.

(2)   Frequent = dolphins showing a SOR lower than 0.5 and higher (or equal) than 0.25.

(3)   poradic = dolphins seen only rarely in the study area with a SOR lower than 0.25.

Residency was also investigated by calculating the lagged identification rate (LIR), i.e., the probability that an individual observed in the study area at time X will be observed again after a certain lag of time within the study area (Whitehead, 2001; Whitehead, 2009). The LIR was calculated for the whole study area, with the day as sampling occasion, using SOCPROG 2.7 (Whitehead, 2009) and the sighting histories of all individuals. LIR was plotted against time to provide an indication of the temporal use of the area by the animals. Eight different residency models were fitted to the data to test for closed and open population models, including various combinations of emigration, reimmigration and mortality (Whitehead, 2009). The quasi-Akaike information criterion (QAIC) was used to determine the best model and account for overdispersion of the data ($ĉ > 1.0$). The

lowest value of QAIC was used to determine the best fitted models (Whitehead, 2009). 100 bootstrap replicates were used to estimate the standard error and 95% confidence intervals for the LIRs.

Abundance estimate

A discovery curve was plotted on SOCPROG 2.7 to analyse the cumulative number of marked individuals and to investigate if the population was open or closed to immigration, emigration mortality or birth (Fury *et al*., 2008). If the discovery curve reaches an asymptote, this indicates that the whole population has been identified and that it is likely to be a closed population with no immigration or emigration (Wilson *et al*., 1999). The discovery curve of an open population influenced by births, deaths, immigration, or emigration is not likely to reach a plateau (Reisinger and Karczmarski, 2010). To obtain adequate sample sizes and to ensure a uniform coverage of the study area, the sampling period was set by season (Diaz Lopez *et al*., 2013).

Both closed and open population models were run in MARK software (White and Burnham, 1999). Only open population estimates, obtained using the POPAN parameterization of the Jolly–Seber model (Schwarz and Arnason, 1996), were deemed the best fitted in the results considering the results of the discovery curve shape (Fury *et al*. 2008) and also the fact that during the time span of the study, birth, death, immigration and emigration are likely to have happened. Open-population models are widely used to estimate the abundance of bottlenose dolphin populations (e.g. Félix *et al*. 2017; Bearzi *et al.,* 2021; Pace *et al*., 2021). This model provides abundance estimates by incorporating demographic parameters (i.e., births, immigration, death and permanent emigration) of the population under study. Under the POPAN formulation, the super-population size (N = the number of animals that theoretically used the study area during the course of the study, including those not captured) is calculated, the apparent survival (*phi*), the capture probability (*p*) and the probability of entry of individuals from the super-population to the local population present in the study area (*pent*) (Schwarz and Arnason, 1996). Model parameters were set as both temporally variable (t) and time-constant (τ), which allowed for the formulation of different models (Lebreton *et al*., 1992; White and Burnham, 1999). POPAN models have a few assumptions and their violation can lead to bias in population estimates (Amstrup *et al*., 2005; Read *et al*., 2003; Conn *et al*., 2011): (1) marks are not lost during the study period; (2) sampling is instantaneous, and each individual is released just after; (3) capture and survival probability among individuals is homogeneous. Despite considering the rigorous selection of high-quality data and photos (only good quality picture with Q ≥ 4 and well-marked individuals (i.e. D1 and D2 categories) for this analysis, for a gregarious species like bottlenose dolphin, overdispersion is observed most of the time because the survival of an individual living in a group is not independent from the fate of the others (Anderson *et al*., 1994). To validate the other assumptions, we used the goodness-of-fit (GOF) tests (Silva *et al*., 2009; Papale *et al*., 2016), which combines the hypothesis of equal capture and survival probabilities among the individuals and of closeness of the population, assessed in program RELEASE GOF in MARK. If the test is statistically significant (*p-value* < 0.05), the model does not effectively fit the data. The tests in the program explored whether assumptions were validated by the model: TEST 2 analysed capture homogeneity, TEST 3 homogeneous survival probability and TEST T3.SR was used for testing the presence or absence of transients in the population (i.e. dolphins sighted only once during the study period more often than expected) (Cooch and White, 2012). A variance inflation factor ($\hat{c}$ = the chi-square statistic divided by its degrees of freedom) was calculated based on the result of TEST 2 + TEST 3 to determine if the data show overdispersion ($\hat{c} > 1$) or underdispersion ($\hat{c} < 1$). A $\hat{c} < 3$ has been suggested as an acceptable measure of fit (Anderson *et al*., 1994); however, if overdispersion is present, $\hat{c}$ is manually adjusted in MARK. Model selection was guided by an examination of Akaike's Information Criterion (Akaike, 1973), corrected for small sample sizes (AICc). In case of overdispersion the value of $\hat{c}$ was used to adjust the output and model selection was based on values of quasi Akaike Information Criteria corrected for small sample size (QAICc) instead of AICc (Cooch and White, 2012), considered a more precise parameter to choose the best fitted model (Lebreton *et al*., 1992). Eight models were examined and the most parsimonious model was selected based on the lowest QAICc value due the overdispersion of the data ($\hat{c} > 1$) (Burnham and Anderson, 2002).

To obtain the total population size (*N total*), the unmarked portion of the population also needs to be included. The estimated population size of marked individuals (N_D) was divided by the mean proportion of marked

individuals within the population (θ): *N total* = $\boldsymbol{N_D}$ / θ (Wilson *et al.* 1999). The mark rate θ was calculated as the number of well-marked individuals (D1) divided by the total number of individuals observed in each sighting, including unmarked animals (D1 + D2 + D3) (See Photo-ID analysis section): $\theta = \mathbf{N_{D1}/N_{D1} + N_{D2} + N_{D3}}$

The standard error for the total population size N total, were derived using the delta method as follows (modified from Nicholson *et al.*, 2012; Williams *et al.*, 2002; Wilson *et al.*, 1999):

$$SE(N_{TOTAL}) = \sqrt{N_{TOTAL}\,2\,\frac{SE(N_D)^2}{(N_D)^2} + \frac{1-\theta}{k\theta}}$$

where *k* = total number of groups from which θ was estimated.

The 95% confidence intervals (CI) were derived assuming log-Normal distribution as proposed in Burnham *et al.* (1987).

RESULTS

Field effort and occurrence

A total of 171 surveys (Fig. 2) were conducted from April 2018 to December 2020, totalling 8647.72 kilometres of survey effort. The effort was not equally spread across months and seasons due to meteorological conditions that permitted very few surveys in certain periods of the year, especially the Winter months (January–March). The maximum effort was obtained in Summer (July–September) with 4096.91 km surveyed. Bottlenose dolphins were encountered during every season on 82 out of 171 days spent at sea (48% of total days). Ninety-five groups were observed and photo-identified inside the study area (Fig. 2). The study area, except for the lateral edges located far from the home port of Imperia, showed an equal coverage of effort.
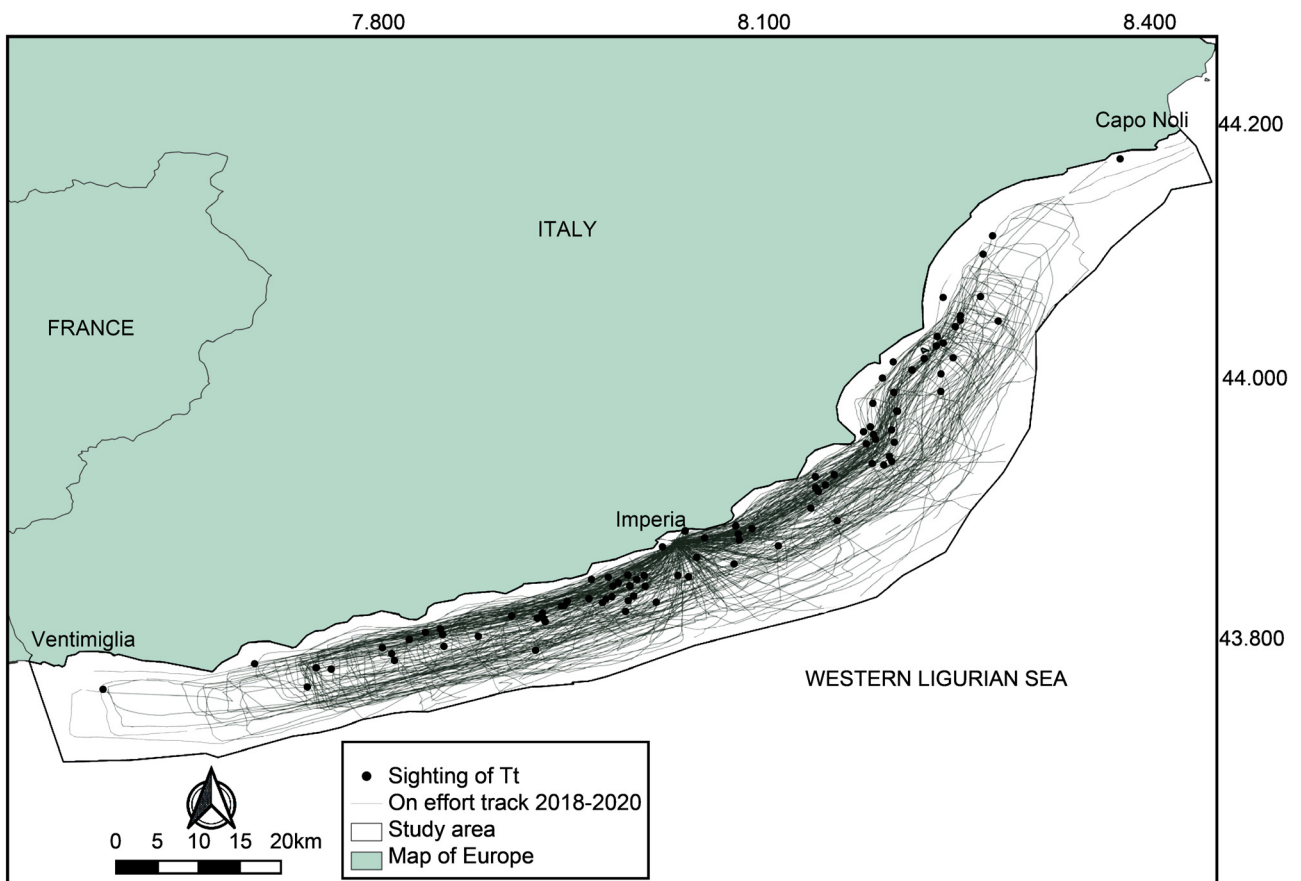

Fig. 2. Map showing the on-efforts tracks inside the study area from April 2018 to December 2020. Bottlenose dolphin (Tt) sightings are indicated by filled circles.

Table 1

Annual observation effort, surveys, sightings and encounter rate. The encounter rate (ER) was calculated by dividing the total number of encounters by the total number of kilometres spent on effort.

Year	Number of surveys	Number of sightings	On effort (km)	Encounter rate
2018	45	18	2,240.50	0.0080
2019	61	39	3,255.60	0.0120
2020	65	38	3,151.62	0.0121
Total	**171**	**95**	**8,647.72**	**0.0109**

Table 2

Seasonal observation effort, surveys, sightings and encounter rate. The encounter rate (ER) by seasons, was calculated by dividing the total number of encounters by the total number of kilometres spent on effort.

Season	Number of surveys	Number of sightings	On effort (km)	Seasonal encounter rate
Winter	16	10	656.015	**0.0152**
Spring	51	30	2,610.289	**0.0115**
Summer	77	46	4,096.908	**0.0112**
Autumn	27	8	1,284.509	**0.0062**

The Total Encounter Rate (ER) of groups of bottlenose dolphins for the study area was 0.0109 (sightings/km on effort) (Table 1). The seasonal analysis showed no differences in ER values, (Kruskal-Wallis test, p-value > 0.05) with a maximum value found in Winter (ER = 0.0152) and a minimum in Autumn (ER = 0.0062) (Table 2).

Site fidelity and residency

On a total of 69,737 pictures collected in the field, 30,684 (44% of the total) were selected for photo-identification analysis (Q ≥ 4) resulting in 123 dolphins identified through dorsal fin marks. The number of individuals captured more than once was 83 (67.5% of the total), almost a half of the animals was seen only twice (60) while 40 dolphins were seen only once. Eight dolphins were seen at least 30 times and one individual was seen 37 times, the highest rate of recapture recorded (Fig. 3).

Relative to the total number of seasons surveyed (11), from 2018 to 2020, most of the bottlenose dolphins were sighted occasionally, as confirmed by the mean seasonal occurrence rate SOR = 0.26 ± 0.23 and the mode 0.09.

Results showed that 19.5% of the dolphins (24 individuals) had a SOR higher than 0.5 and were seen regularly inside the study area; 16.3% (20 individuals) were considered frequent visitors with a SOR higher than 0.25; and the 64.2% (79 individuals) were rarely observed inside the study area and were considered sporadic visitors (SOR less than 0.25).

The Lagged Identification Rate (LIR) declined, after periods of 1 to 140 days (Fig. 4), decreasing constantly over time. This means that the probability of an individual being encountered in the population after the first
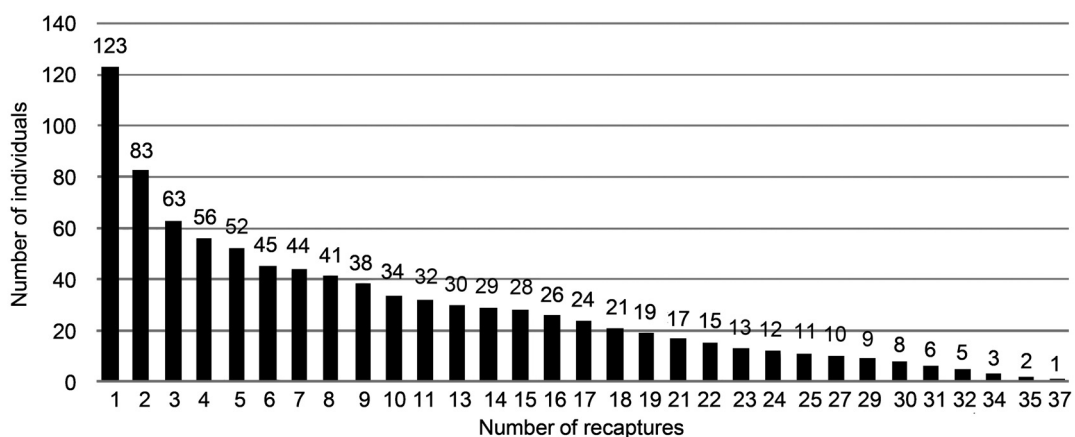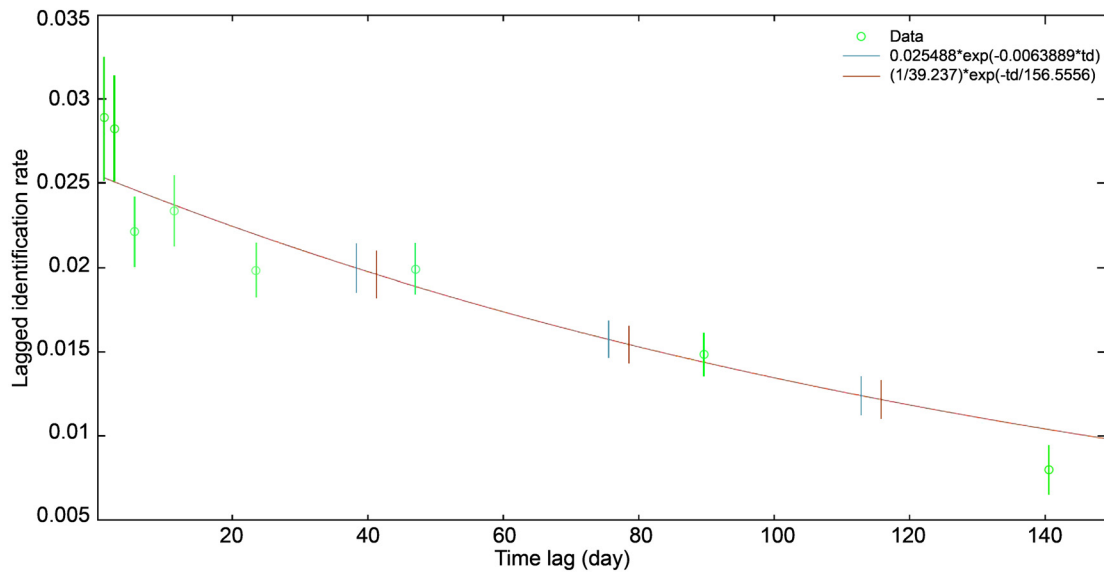

Fig. 3. Histogram of recaptures frequencies.

Fig. 4. Lagged identification rate (○) of bottlenose dolphins in the study area together with the best (emigration/mortality) fitting models of movements (black line) and estimated standard errors (bars).

Table 3

Models fitted to observed lagged identification rate (LIR) data of common bottlenose dolphin population in the study area. Explanation of each model refers to Whitehead (2001). The models that best fitted the data according to the lowest value of QAIC are shown in bold. For each model with a 'td' parameter, this refers to 'time lag'. Parameters a1, a2, a3 and a4 differ slightly amongst models and are therefore explained in the table. 'N' refers to the population size (at any one time) in the study area (Whitehead, 2001).

	Model equation	Model explanation	QAIC	Model parameter
1	a1	Closed	37770.89	a1 = N
2	1/a1	Closed	37770.89	1/a1 = N
3	**a2*exp(− a1*td)**	**Emigration/mortality**	**37574.40**	**a1 = emigration rate; 1/a2 = N**
4	**(1/a1)*exp(− td/a2)**	**Emigration/mortality**	**37574.40**	**a1 = N; a2=mean residence time**
5	a2 + a3*exp(− a1*td)	Closed: Emigration + reimmigration	37746.86	a1 = emigration rate; a2/(a2 + a3) = proportion of population in study area at any time
6	a3*exp(− a1*td) + a4*exp(− a2*td)	Emigration + reimmigration + mortality	37576.12	a1 = N; a2 = mean time in study area; a3 = mean time out of study area; a4 = mortality rate
7	(1/a1)*((1/a3) + (1/a2)*exp(−(1/a3 + 1/a2)* td))/(1/a3 + 1/a2)	Emigration + reimmigration	37576.40	a1 = N; a2 = mean time in study area; a3 = mean time out of study area
8	(exp(− a4*td)/a1).* ((1/a3) + (1/a2)*exp (−(1/a3 + 1/a2)*td))/(1/a3 + 1/a2)	Emigration + reimmigration + mortality	37575,06	a1 = N; a2 = mean time in study area; a3 = mean time out of study area; a4 = mortality rate

sighting decreased with time. LIR in general levelled above zero indicating that a number of individuals subsequently re-immigrate to the study area and/or that some animals are residents The best fitted model (lowest QAIC value) described variations in LIR as the result of permanent emigration and/or mortality (Models 3,4; Table 3). These two models were equivalent, just parameterised differently and yielded identical QAIC values. The mean number of bottlenose dolphins in the study area at any one time derived from the models was 39 (CI 95% = 33–49) with an emigration rate of 0.0064 (CI 95% = 0.00454–0.00873). The mean residence time of individuals in the study area was 156 days (CI 95% = 114–220). The variance inflation factor (ĉ) was 1.40.

Abundance

A discovery curve of the number of individuals identified against the cumulative number of identifications, showed an increase over time, suggesting that new individuals were captured and/or unrecognizable animals acquired new marks during the study period (Fig. 5). In 2018 and 2019 the increase was even and constant, while in 2020 we observed again a rapid rise of the curve caused both by the identification of new marked animals and the acquisition of new marks by several previously unmarked juveniles. New recruits to the population may represent births, immigration into the population or captures in subsequent years of individuals which had been previously unphotographed.
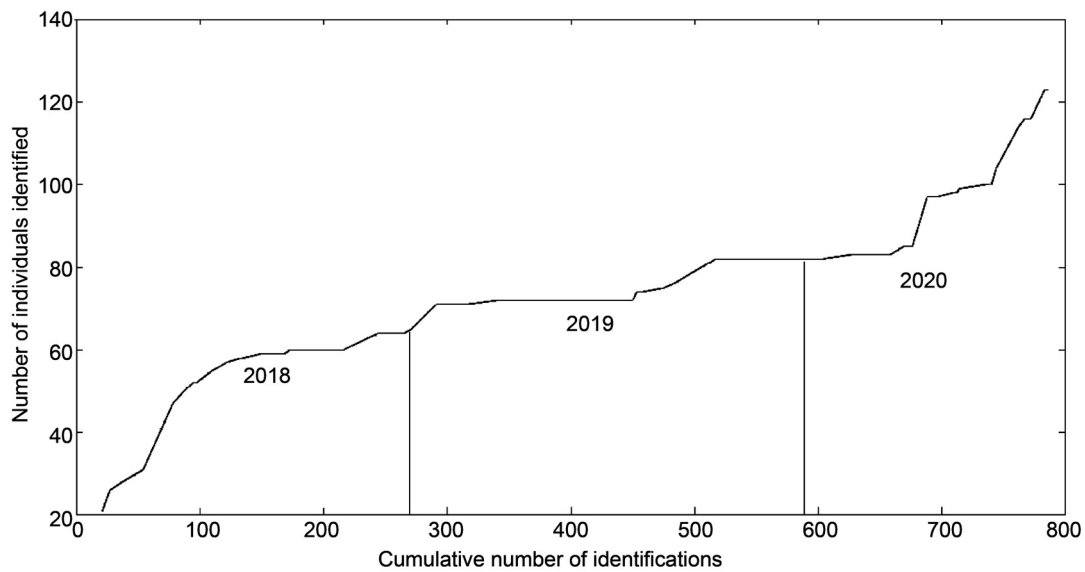
Fig. 5. Discovery curve showing the cumulative number of dolphins identified with increasing effort.

Table 4

List of the 8 Jolly-Seber mark–recapture models with POPAN parameterization ranked by quasi-likelihood Akaike Information Criteria (QAICc). The models that best fitted the data according to the lowest value of QAIC is shown in bold. *Phi* = survival probability; *p* = recapture probability; *pent* = probability of entering the study area. Each model incorporates either constant (.) or time-varying (*t*) parameters.

Model	QAICc	Delta QAICc	AICc Weights	Num. Par
{phi(.), p(.), pent(.)}	1426.932	0	0.96569	4
{phi(t), p(.), pent(.).}	1435.066	8.1341	0.01654	8
{phi(.), p(.), pent(t).}	1435.066	8.1341	0.01654	8
{p(.), phi(t), pent(t).}	1441.222	14.2899	0.00076	11
{pent(t), p(.), phi(t).}	1443.284	16.3524	0.00027	12
{phi(t), p(t), pent(.).}	1445.352	18.4202	0.0001	13
{phi(.), p(t), pent(t).}	1445.353	18.4205	0.0001	13
{p(t), phi(t), pent(t).}	1453.678	26.7456	0	17

Results of goodness-of-fit test (global test: TEST 2 + 3) was significant (χ^2 = 382.5221; p-value < 0.05, df = 164) and showed heterogeneity in capture probabilities between individuals due to the high proportion of transient animals, supported also by TEST T3.SR (χ^2 = 20.89; p-value < 0.05, df = 4). The variance inflation factor (c) was estimated as 2.33 indicating overdispersion of the data. The eight models providing the best fit in terms of QAICc score are reported in Table 4.

The most parsimonious POPAN model, based on QAICc values, assumed constant survival, constant capture probability, and a constant probability to enter the local population from the super-population. The superpopulation of bottlenose dolphins (N total), across the study period, estimated by the best fitted model for the mark rate (θ = 0.67) was 248 (SE = 24.5; CI 95% = 217–284) individuals. Average estimation of apparent survival (phi) was 0.96 (CI 95% = 0.83–98), average recapture probability (p) was 0.24 (CI 95% = 0.11–0.48), and the average probability of entry (pent) was 0.01 (CI 95% = 0.00–0.71).

DISCUSSION

Encounter rate and occurrence

In the Mediterranean Sea, bottlenose dolphin sightings usually occur within waters of < 200m depth on the continental shelf (Gnone *et al*., 2022). Despite the morphology of the seafloor of the study area, characterised by a very narrow continental shelf resulting in a limited habitat range for the species, the data collected in this study clearly show a regular presence of the species during all seasons. In almost three years of research, after 171 surveys, 94 groups of bottlenose dolphins were observed and photo-identified inside the study area. Contrary

to previous literature (Azzellino *et al.*, 2008; Bearzi *et al.*, 2008; Gnone *et al.*, 2011), the Western Ligurian Sea appears to be an important habitat for bottlenose dolphins.

The encounter rate recorded (0.0109) is higher than the one presented by Gnone *et al.* (2011) in the same area (ER = 0.0004) while it is very similar with values registered in the Eastern Ligurian Sea (ER = 0.0112) and the Tuscan Archipelagos (ER = 0.0127), two areas that showed a major density of *T. truncatus* due to their very wide continental shelf and shallow waters. This important difference with the study of Gnone *et al.* (2011) needs to be regarded with caution. From one side it might indicate that bottlenose dolphins started regularly using the study area only in recent years; on the other side, surveys in the present study focused specifically on bottlenose dolphins whereas in the past they were not the main target of research projects carried out in the same area.

Data from 2019 and 2020 show similar effort (3255.60 and 3151.62 km, respectively) and ER values (0.0120 and 0.0121), suggesting a constant presence of bottlenose dolphins while there was reduced survey effort in 2018. Despite the lower ER in Autumn compared to other seasons, the seasonal analysis showed no significant differences in ER values.

Site fidelity, residency and abundance

Results of this study show that the population of bottlenose dolphins inhabiting the Western Ligurian Sea is part of a larger population that frequents this area. The discovery curve showed an open population with an absence of plateau, suggesting that new individuals continued to be recruited to the population throughout the study period. This is further supported by the finding that most bottlenose dolphins (79) were rarely observed in the study area and only 24 individuals (19.5% of the total) were considered resident, with high site fidelity to the area. Moreover, the large proportion of dolphins observed only once (49%) indicated that there is a high number of individuals that spend most of their time outside the study area. Inside the Mediterranean Sea similar patterns are seen off the North-Western coast of Sardinia (Díaz López *et al.*, 2013), at the Tiber River Estuary, (Pace *et al.*, 2021), and the west coast of Istria (Ribaric, 2017), where a small portion of population shows high site fidelity while most dolphins are occasional visitors or transients.

Lagged identification rates (LIR) indicate that many animals leave the study area after a certain time period with some resident animals and/or re-immigration into the study area (Whitehead, 2001). Results from LIR analysis suggest further that this population is governed mainly by emigration and mortality with a small component of resident individuals.

The abundance estimate of the superpopulation was 248 (CI 95% = 217–284) individuals. This estimate needs to be interpreted with some caution, because goodness-of-fit results with the high variance inflation factor (ĉ) value of 2.33 suggested overdispersion in the mark-recapture data. The model estimated an average recapture probability of 0.24 (CI 95% = 0.11–0.48), suggesting individual heterogeneity in capture probabilities and the presence of transient animals (supported also by the residency results and global test: TEST 2 + 3 and TEST T3.SR), violating the model assumption of equal capture probability. Due to overdispersed data, the population size estimate presented here might be an underestimate (Reisinger and Karczmarski, 2010; Pledger *et al.*, 2003; Pollock and Alpizar-Jara, 2005). However, the lack of fit displayed by the ĉ value was limited (≤3) and might have resulted from extrabinomial noise rather than by the inappropriate model used (Lebreton *et al.*, 1992; Estrade and Dulau, 2020).

Overdispersion is a common observation with capture-recapture studies on species that aggregate in groups or form long-lasting social associations (Anderson *et al.*, 1994). Similar situations were found in the Tiber River Estuary ĉ = 2.65 (Pace *et al.*, 2021), Northwest Cape ĉ = 2.28 (Haughet *et al.*, 2020) and Algoa Bay Region, South Africa ĉ = 2.51 (Reisinger and Karczmarski, 2010).

The annual apparent survival rate of bottlenose dolphins was 0.96 on average, a value relatively high but as expected for long-lived mammals with low reproductive rates (Connor *et al.*, 2000; Stolen and Barlow, 2003). Similarly, high values were found also in other locations as in Doubtful Sound, New Zealand (0.94) (Currey *et al.*, 2008); Sado Estuary, Portugal (0.96) (Gaspar, 2003); Charleston, NC (0.95) (Speakman *et al.* 2010); Little Bahama Bank, USA: (0.94) (Fearnbach *et al.*, 2012); Azores, Portugal (0.97) (Silva *et al.*, 2009). Such a high value might reflect the absence of predator pressure in the Mediterranean Sea (Bearzi *et al.*, 2009). Due to the high longevity

of bottlenose dolphins, we acknowledge that a 3-year study is a short time period and longer term monitoring is needed to better estimate apparent survival, mortality and emigration. Although the study area does not cover the entire Ligurian Sea, results indicate that bottlenose dolphins are abundant within these waters and should be included in the development of future conservation management programs. The occurrence of the species has increased in recent years (De Santis *et al*., 2018), in an area where human activities (fisheries, coastal development and marine traffic) and habitat degradation are present. Part of the data collected in this study has already been used to start the process of creating a Marine Protected Area (MPA), with proposals submitted to the administration of Santo Stefano al Mare.

The estimate of the local abundance of this population of dolphins is the first step to a long-term monitoring of bottlenose dolphins in the Western Ligurian Sea and constitutes a baseline upon which to assess future changes in their abundance inside the study area. New data could also be used to calculate a new abundance estimate of bottlenose dolphins in the entire Pelagos Area, to compare with previous studies (Gnone *et al*., 2011) in order to highlight long-term population trends and to provide valuable information for bottlenose dolphin conservation in the Mediterranean Sea.

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REFERENCES

Akaike, H. 1973. Maximum likelihood identification of Gaussian autoregressive moving average models. *Biometrika* 60 (2): 255–265. *https://doi.org/10.1093/biomet/60.2.255*

Akkaya Baş, A., Öztürk, B. and Öztürk, A.A. 2018. Encounter rate, residency pattern and site fidelity of bottlenose dolphins (*Tursiops truncatus*) within the Istanbul Strait, Turkey. *J. Mar. Biol. Assoc (UK)* 99 (4): 1009–1016. *https://doi.org/10.1017/S0025315418000577*

Amstrup, S.C., McDonald, T.L. and Manly, B.F. (Eds.). 2010. *Handbook of Capture-Recapture Analysis.* Princeton University Press, Princeton, New Jersey. 312pp. ISBN: 9780691089683. *https://doi.org/10.1515/9781400837717*

Anderson, D.R., Burnham, K.P. and White, G.C. 1994. AIC model selection in overdispersed capture-recapture data. *Ecology* 75 (6): 1780–1793. *https://doi.org/10.2307/1939637*

Alessi, J. and Fiori, C. 2014. From science to policy—a geostatistical approach to identifying potential areas for cetacean conservation: a case study of bottlenose dolphins in the Pelagos sanctuary (Mediterranean Sea). *J. Coastal Conservation* 18: 449–458. *https://doi.org/ 10.1007/s11852-014-0330-3*

Alessi, J., Mandich, A., Wurtz, M., Paoli, C., Bianchi, C. N., Morri, C., Povero, P., Brunoldi, M., Bozzini, G., Casale, A., Grosso, D., Cappanera, V., Fanciulli, G., Melchiorre, C., Viano, G., Bei, M., Taiuti, M. G. and Vassallo, P. 2019. Eavesdropping on dolphins: Investigating the habits of bottlenose dolphins (*Tursiops truncatus*) through fixed acoustic stations. *PLoS One* 14, e0226023. *https://doi.org/10.1371/ journal.pone.0226023*

Azzellino, A., Gaspari, S., Airoldi, S. and Nani, B. 2008. Habitat use and preferences of cetaceans along the continental slope and the adjacent pelagic waters in the western Ligurian Sea. *Deep Sea Research Part I: Oceanographic Research Papers* 55(3): 296–323. *https://doi.org/10.1016/j.dsr.2007.11.006*

Augusto, J.F., Rachinas-Lopes, P. and dos Santos, M.E. 2011. Social structure of the declining resident community of common bottlenose dolphins in the Sado Estuary, Portugal. *J. Mar. Biol. Assoc. (UK)* 92 (8): 1773–1782. *https://doi.org/10.1017/S0025315411000889*

Bearzi, G., Agazzi, S., Bonizzoni, S., Costa, M. and Azzellino, A. 2008. Dolphins in a bottle: Abundance, residency patterns and conservation of bottlenose dolphins *Tursiops truncatus* in the semi-closed eutrophic Amvrakikos Gulf Greece. *Aquatic Conservation: Marine and Freshwater Ecosystems* 18: 130–146. *https://doi.org/10.1002/aqc.843*

Bearzi, G., Fortuna, C., and Reeves, R. 2009. Ecology and conservation of common bottlenose dolphins *Tursiops truncatus* in the Mediterranean Sea. *Mammal Review* 39 (2): 92. *https://doi.org/10.1111/j.1365-2907.2008.00133.x*

Bearzi, G., Bonizzoni, S., Riley, M.A., and Santostasi, N.L. 2021. Bottlenose dolphins in the north-western Adriatic Sea: Abundance and management implications. *Aquatic Conservation: Marine and Freshwater Ecosystems* 31 (3): 651–664. *https://doi.org/10.1002/ aqc.3450*

Benmessaoud, R., Chérif, M. and Bejaoui, N. 2013. Baseline data on abundance, site fidelity and association patterns of common bottlenose dolphins (*Tursiops truncatus*) off the northeastern Tunisian coast (Mediterranean Sea). *J. Cetacean Res. Manage.* 13: 211–219.

Blasi, M. F., and Boitani, L. 2014. Complex social structure of an endangered population of bottlenose dolphins (*Tursiops truncatus*) in the Aeolian Archipelago (Italy). *PLoS One*, 9(12): e114849. *https://doi.org/10.1371/journal.pone.0114849*

Bouveroux, T., Tyson, R.B. and Nowacek, D.P. 2014. Abundance and site fidelity of bottlenose dolphins in coastal waters near Panama City, Florida. *J. Cetacean Res. Manage.* 14: 37–42.

Burnham, K., Anderson, D., White, G., Brownie, C. and Pollock, K. 1997. Design and analysis of fish survival experiments based on release-recapture data. American Fisheries Society Monograph 5. Bethesda, MD.437pp. ISBN 0-913235-41-5.

Burnham, K.P. and Anderson, D.R. 2002. *Model Selection and Inference: A Practical Information-Theoretic Approach.* 2nd Edition, Springer-Verlag, New York. *https://doi.org/10.1007/b97636*

Cooch, E. and White, G. 2012. *Program Mark – a gentle introduction*. 11th ed. [Available from *http://www.phidot.org*.; 2012]

Conn, P.B., Gorgone, A.M., Jugovich, A.R., Byrd, B.L. and Hansen, L.J. 2011. Accounting for transients when estimating abundance of bottlenose dolphins in Choctawhatchee Bay, Florida. *J. Wildl. Manage.* 75(3): 569–579. *https://doi.org/10.1002/jwmg.94*

Connor, R.C., Wells, R.S., Mann, J. and Read, A.J. 2000. The bottlenose dolphin. pp.91–126. *In*: J. Mann, R.C. Connor, P.L. Tyack and H. Whitehead (Eds) *Cetacean Societies: Field Studies of Dolphins and Whales*. Univ. of Chicago Press, Chicago. ISBN 0 226 50341.

Currey, R.J., Dawson, S.M., Slooten, E., Schneider, K., Lusseau, D., Boisseau, O.J., Haase, P. and Williams, J.A. 2009. Survival rates for a declining population of bottlenose dolphins in Doubtful Sound, New Zealand: an information theoretic approach to assessing the role of human impacts. Aquatic conservation: marine and freshwater ecosystems. *Aquatic Conservation: Marine and Freshwater Ecosystems* 19(6): 658–670. *https://doi.org/10.1002/aqc.1015*

Derraik, J.G. 2002. The pollution of the marine environment by plastic debris: a review. *Marine Poll. Bull.* 44: 842–852. *https://doi.org/10.1016/S0025-326X(02)00220-5*

De Santis, V., Azzellino, A., Lanfredi, C. and Airoldi, S. 2018. Are bottlenose dolphins (Tursiops truncatus) increasing in the North–Western part of the Pelagos Sanctuary (Mediterranean Sea)? Poster presented at the 32nd Conference of the European Cetacean Society, La Spezia, Italy, April 2018 (unpublished). [Available from *tethys@tethys.org*].

Díaz López, B. and Shirai, J.A.B. 2007. Bottlenose dolphin (*Tursiops truncatus*) presence and incidental capture in a marine fish farm on the north-eastern coast of Sardinia (Italy). *J. Mar. Biol. Assoc (UK)* 87(1): 113–117. *https://doi.org/10.1017/S0025315407054215*

Díaz López, B. 2012. Bottlenose dolphins and aquaculture: interaction and site fidelity on the north-eastern coast of Sardinia (Italy). *Mar. Biol.* 159: 2161–2172. *https://doi.org/10.1007/s00227-012-2002-x*

Díaz López, B., Addis, A. and Fabiano, F. 2013. Ecology of common bottlenose dolphins along the North-western Sardinian coastal waters (Italy). *Thalassas* 29(2): 35–44.

Díaz López, B. and Methion, S. 2017. The impact of shellfish farming on common bottlenose dolphins' use of habitat. *Mar. Biol.* 164(4): 1–10. *https://doi.org/10.1007/s00227-017-3125-x*

Dinis, A., Alves, F., Nicolau, C., Ribeiro, C., Kaufmann, M., Cañadas, A. and Freitas, L. 2016. Bottlenose dolphin *Tursiops truncatus* group dynamics, site fidelity, residency and movement patterns in the Madeira Archipelago (North-East Atlantic). *Afr. J. Mar. Sci.* 38(2): 151–160. *https://doi.org/10.2989/1814232X.2016.1167780*

Di-Méglio, N., Roul, M., David, L., Gimenez, O., Azzinari, C., Jourdan, J., Barbier, M. and Labach, H. 2015. Abondance et répartition spatio-temporelle et fonctionnelle du grand dauphin dans le Golfe du Lion. Étude et gestion en Méditerranée 2013–2015. Rapport GIS3M. Projet GDeGEM grand dauphin. 79pp. [In French; available from: *https://www.gdegem.org/rapports*]

Dhermain, F. and Césarini, C. 2007. Suivi des populations de Grands Dauphins sur les zones d'application du programme Life LINDA. Rapport final de l'Action A1, Life LINDA, GECEM, 121pp. [In French]

Estrade, V. and Dulau, V. 2020. Abundance and site fidelity of bottlenose dolphins off a remote oceanic island (Reunion Island, southwest Indian Ocean). *Mar. Mamm. Sci.* 36(3): 871–896. *https://doi.org/10.1111/mms.12693*

Fearnbach, H., Durban, J., Parsons, K. and Claridge, D. 2012. Photographic mark–recapture analysis of local dynamics within an open population of dolphins. *Ecological Applications* 22 (5): 1689–1700. *https://doi.org/10.1890/12-0021.1*

Félix, F., Calderón, A., Vintimilla, M. and Bayas-Rea, R.A. 2017. Decreasing population trend in coastal bottlenose dolphin (*Tursiops truncatus*) from the Gulf of Guayaquil, Ecuador. *Aquatic Conservation: Marine and Freshwater Ecosystems* 27(4): 856–866. *https//doi.org/10.1002/aqc.2763*

Fozzi, A., Aplington, G., Pisu, D., Castiglioni, D., Galante, I. and Plastina, G. 2001. Status and conservation of the bottlenose dolphin (*Tursiops truncatus*) population in the Maddalena Archipelago National Park (Sardinia, Italy). *Eur. Res. Cetaceans* 15: 420.

Fury, C.A. and Harrison, P. L. 2008. Abundance, site fidelity and range patterns of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in two Australian subtropical estuaries. *Marine and Freshwater Research* 59(11): 1015–1027. *https://doi.org/10.1071/MF08109*

Gannier, A. 2005. Summer distribution and relative abundance of delphinids in the Mediterranean Sea. *Revue d'Ecologie (Terre et Vie)* 60(3): 223–238 [Available at: *https://hal.archives-ouvertes.fr/hal-03530129*]

Gaspar, R. 2003. Status of the resident bottlenose dolphin population in the Sado estuary: past, present and future. PhD thesis, University of St Andrews, Scotland. [Available at: *https://research-repository.st-andrews.ac.uk/handle/10023/10974*]

Genov, T., Centrih, T., Kotnjek, P. and Hace, A. 2019. Behavioural and temporal partitioning of dolphin social groups in the northern Adriatic Sea. *J. Mar. Biol.* 166(1): 1–14. *https://doi.org/10.1007/s00227-018-3450-8*

Gnone, G., Nuti, S., Bellingeri, M., Pannoncini, R., and Bedocchi, D. 2006. Comportamento spaziale di *Tursiops truncatus* lungo la costa del Mar Ligure: risultati preliminari. *Biol. Mar. Medit.* 13(2): 272–273. [In Italian]

Gnone, G., Bellingeri, M., Dhermain, F., Dupraz, F., Nuti, S., Bedocchi, D., Moulins, A., Rosso, M., Alessi, J., McCrea, R.S., Azzellino, A., Airoldi, S., Portunato, N., Laran, S., David, L., Di Meglio, N., Bonelli, P., Montesi, G., Trucchi, R., Fossa, F. and Wurtz, M. 2011. Distribution, abundance, and movements of the bottlenose dolphin (*Tursiops truncatus*) in the Pelagos Sanctuary MPA (north-west Mediterranean Sea). *Aquatic Conservation: Marine and Freshwater Ecosystems* 21(4): 372–388. *http://dx.doi.org/10.1002/aqc.1191*

Gnone, G., Bellingeri, M., Molinari, Y., Dhermain, F., Labach, H., Díaz López, B., David, L., Di Meglio, N., Azzinari, G., Azzinari, C., Airoldi, S., Lanfredi, C., Gonzalvo, J., De Santis, V., Nuti, S., Chicote, C., A., Gazo, M., Mandich, A., Alessi, J., Azzellino, A., Tomasi, N., Santoni, M.-C., Mancusi, C., Falabrino, M. and Cañadas, A.M. 2022. The seabed makes the dolphins: Physiographic features shape the size and structure of the bottlenose dolphin geographical units. *Journal of Marine Science and Engineering* 10(8), 1036. *https://doi.org/10.3390/jmse10081036*

Gonzalvo, J., Forcada, J., Grau, E. and Aguilar, A. 2014. Strong site-fidelity increases vulnerability of common bottlenose dolphins *Tursiops truncatus* in a mass tourism destination in the western Mediterranean Sea. *J. Mar. Biol. Assoc. (UK)* 94(6), 1227–1235. *https://doi.org/ 10.1017/S0025315413000866*

Haughey, R., Hunt, T., Hanf, D., Rankin, R.W. and Parra, G.J. 2020. Photographic capture-recapture analysis reveals a large population of indo-pacific bottlenose Dolphins (*Tursiops aduncus*) with low site fidelity off the north west cape, Western Australia. *Frontiers in Marine Science* 6, 781. 14pp. *https://doi.org/10.3389/fmars.2019.00781*

Labach, H., Azzinari, C., Barbier, M., Cesarini, C., Daniel, B., David, L., Dhermain, F., Di-Méglio, N., Guichard, B., Jourdan, J., Robert, N., Roul, M., Tomasi, N. and Gimenez, O. 2019. Distribution and abundance of bottlenose dolphin (*Tursiops truncatus*) over the French Mediterranean continental shelf. BioRxiv pre-print, 723569. [Published in 2021, *Mar. Mamm. Sci.* 38(2), 12874. *https://doi.org/ 10.1111/mms.12874*]

Lauriano G., Mackelworth P. and Fortuna C.M. 2003. Densità e abbondanza relativa del tursiope (*Tursiops truncatus*) nel parco nazionale dell'Asinara, Sardegna. *Biol. Mar. Medit.* 10(2):717–720. [In Italian]

La Manna, G., Ronchetti, F. and Sarà, G. 2016. Predicting common bottlenose dolphin habitat preference to dynamically adapt management measures from a Marine Spatial Planning perspective. *Ocean and Coastal Management* 130: 317–327. *https://doi.org/10.1016/ j.ocecoaman.2016.07.004*

Lebreton, J.D., Burnham, K.P., Clobert, J. and Anderson, D.R. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. *Ecological Monographs* 62(1): 67–118. *https://doi.org/10.2307/2937171*

Louis, M., Gally, F., Barbraud, C., Béesau, J., Tixier, P., Simon-Bouhet, B., Le Rest, K. and Guinet, C. 2015. Social structure and abundance of coastal bottlenose dolphins, *Tursiops truncatus*, in the Normano-Breton Gulf, English Channel. *J. Mammal.* 96(3): 481–493. *https://doi.org/10.1093/jmammal/gyv053*

Lusseau, D., Wilson, B., Hammond, P.S., Grellier, K., Durban, J.W., Parsons, K.M., Barton, T.R. and Thompson, P.M. 2006. Quantifying the influence of sociality on population structure in bottlenose dolphins. *J. Animal Ecology* 75: 14–24. *https://doi.org/10.1111/j.1365-2656.2005.01013.x*

Menchaca, C., Laporta, P. and Tassino, B. 2019. Social structure of Lahille's bottlenose dolphin, *Tursiops truncatus gephyreus* (Cetacea: Delphinidae) off the Uruguayan marine coast. *Mastozoología Neotropical* 26: 410–419.

Methion, S. and Díaz López, B. 2018. Abundance and demographic parameters of bottlenose dolphins in a highly affected coastal ecosystem. *Marine and Freshwater Research* 69: 1355–1364. https://doi.org/10.1071/MF17346

Migeon, S., Cattaneo, A., Hassoun, V., Larroque, C., Corradi, N., Fanucci, F., Dano, A., Mercier de Lepinay, B., Sage, F. and Gorini, C. 2011. Morphology, distribution and origin of recent submarine landslides of the Ligurian Margin (North-western Mediterranean): some insights into geohazard assessment. *Marine Geophysical Research* 32: 225–243. *https://doi.org/10.1007/s11001-011-9123-3*

Natoli, A., Peddemors, V.M. and Rus Hoelzel, A. 2004. Population structure and speciation in the genus *Tursiops* based on microsatellite and mitochondrial DNA analyses. *J. Evolutionary Biology* 17(2): 363–375. *https://doi.org/10.1046/j.1420-9101.2003.00672.x*

Natoli, A., Genov, T., Kerem, D., Gonzalvo, J., Holcer, D., Labach, H., Marsili, L., Mazzariol, S., Moura, A.E., Öztürk, A.A., Pardalou, A., Tonay, A.M., Verborgh, P. and Fortuna, C. 2021. *Tursiops truncatus* (Mediterranean subpopulation). IUCN Red List Threatened Species 2021, E.T16369383A50285287. [Available online: *https://www.iucnredlist.org/species/16369383/215248781*]

Nicholson, K., Bejder, L., Allen, S.J., Krützen, M. and Pollock, K.H. 2012. Abundance, survival and temporary emigration of bottlenose dolphins (Tursiops sp.) off Useless Loop in the western gulf of Shark Bay, Western Australia. *Marine and Freshwater Research* 63(11): 1059–1068. *http://dx.doi.org/10.1071/MF12210*

Notarbartolo Di Sciara, G., Agardy, T., Hyrenbach, D., Scovazzi, T. and Van Klaveren, P. 2008. The Pelagos Sanctuary for Mediterranean Marine Mammals. *Aquatic Conservation: Marine and Freshwater Ecosystems* 18(4): 367–391. *https://doi.org/10.1002/aqc.855*

Notarbartolo Di Sciara, G. and Birkun, A. 2010. Conserving whales, dolphins and porpoises in the Mediterranean and Black Sea: an ACCOBAMS status report, ACCOBAMS, Monaco. 212pp.

Notarbartolo Di Sciara, G. and Tonay, A.M. 2021. Conserving whales, dolphins and porpoises in the Mediterranean, Black Seas and adjacent areas: an ACCOBAMS status report. ACCOBAMS, Monaco. 160pp.

Nuti, S., Giorli, G. and Bedocchi, D. 2006. Range analysis of *Tursiops truncatus* along the north-Tuscany coast by means of GIS system. *Biologia Marina Mediterranea* 13: 281–282.

Pace, D.S., Di Marco, C., Giacomini, G., Ferri, S., Silvestri, M., Papale, E., Casoli, E., Ventura, D., Mingione, M., Alaimo Di Loro, P., Lasinio, G.J. and Ardizzone, G. 2021. Capitoline dolphins: residency patterns and abundance estimate of *Tursiops truncatus* at the Tiber River Estuary (Mediterranean Sea). *Biology* 10(4), 275. *https://doi.org/10.3390/biology10040275*

Panigada S., Boisseau O., Canadas A., Lambert C., Laran S., McLanaghan R. and Moscrop, A. 2021. Estimates of abundance and distribution of cetaceans, marine mega-fauna and marine litter in the Mediterranean Sea from 2018–2019 surveys. ACCOBAMS – ACCOBAMS Survey Initiative Project, Monaco. 177pp. [Available for download at: *https://accobams.org/wp-content/uploads/2021/11/ASI-Med-Report-updated.pdf*]

Papale, E., Ceraulo, M., Giardino, G., Buffa, G., Filiciotto, F., Grammauta, R., Maccarone, V., Mazzola, S. and Buscaino, G. 2017. Association patterns and population dynamics of bottlenose dolphins in the Strait of Sicily (Central Mediterranean Sea): implication for management. *Population Ecology* 59 (1): 55–64. *https://doi.org/10.1007/s10144-016-0566-x*

Parra, G.J., Corkeron, P.J. and Marsh, H. 2006. Population sizes, site fidelity and residence patterns of Australian snubfin and Indo-Pacific humpback dolphins: Implications for conservation. *Biol. Cons.* 129(2): 167–180. *https://doi.org/10.1016/j.biocon.2005.10.031*

Pledger, S., Pollock, K.H. and Norris, J. L. 2003. Open capture-recapture models with heterogeneity: I. Cormack-Jolly-Seber model. *Biometrics* 59 (4): 786–794. *https://doi.org/10.1111/j.0006-341X.2003.00092.x*

Pollock, K.H., and Alpizar-Jara, R. 2005. Classical open-population capture-recapture models. pp.36–57. *In*: Amstrup, S.C., McDonald T. and Manly, B. (eds.) *Handbook of Capture-Recapture Methods*. Princeton University Press, Princeton, New Jersey. 312pp.

Read, A.J., Urian, K.W., Wilson, B. and Waples, D.M. 2003. Abundance of bottlenose dolphins in the bays, sounds, and estuaries of North Carolina. *Mar. Mamm. Sci.* 19: 59–73. *https://doi.org/10.1111/j.1748-7692.2003.tb01092.x.*

Read, A.J., Drinker, P. and Northridge, S. 2006. Bycatch of marine mammals in US and global fisheries. *Cons. Biol.* 20: 163–169. *https://doi.org/10.1111/j.1523-1739.2006.00338.x*

Reeves, R.R., Smith, B.D., Crespo, E.A. and Notarbartolo di Sciara, G. (compilers). 2003. *Dolphins, Whales and Porpoises: 2002–2010 Conservation Action Plan for the World's Cetaceans*. IUCN/SSC Cetacean Specialist Group, IUCN, Gland, Switzerland and Cambridge, UK. 139pp.

Reisinger, R.R. and Kaczmarski, L. 2010. Population size estimate of Indo-Pacific bottlenose dolphins in the Algoa Bay region, South Africa. *Mar. Mamm. Sci.* 26(1): 86–97. *https://doi.org/10.1111/j.1748-7692.2009.00324.x*

Reynolds, J.E., Wells, R.S. and Eide, S.D. 2000. *The Bottlenose Dolphin: Biology and Conservation*. University Press of Florida, Gainesville. 289pp.

Ribarič, D. 2017. First report on abundance and distribution of common bottlenose dolphins (*Tursiops truncatus*) in the NATURA 2000 area, Istria, North-eastern Adriatic Sea. *J. Mar. Biol. Assoc. (UK)* 98 (5): 1039–1053. *https://doi.org/10.1017/S0025315417001424*

Rondinini, C., Battistoni, A., Peronace, V. and Teofili, C. 2013. *Lista Rossa IUCN dei Vertebrati italiani.* Comitato Italiano IUCN e Ministero Dell'Ambiente e Della Tutela Del Territorio e Del Mare, Roma. 56pp. [In Italian; Available at: *http://www.iucn.it/pdf/Comitato_IUCN _Lista_Rossa_dei_vertebrati_italiani.pdf*]

RStudio Team. 2015. RStudio: Integrated Development for R. RStudio, Inc., Boston, MA. [Available from: *http://www.rstudio.com*]

Schwarz, C.J. and Arnason, A.N. 1996. A general methodology for the analysis of capture-recapture experiments in open populations. *Biometrics* 860–873. *https://doi.org/10.2307/2533048*

Silva, M.A., Magalhães, S., Prieto, R., Santos, R.S. and Hammond, P.S. 2009. Estimating survival and abundance in a bottlenose dolphin population taking into account transience and temporary emigration. *Mar. Ecol. Prog. Ser.* 392: 263–276. *https://doi.org/10.3354/ meps08233*

Speakman, T.R., Lane, S.M., Schwacke, L.H., Fair, P.A. and Zolman, E.S. 2010. Mark-recapture estimates of seasonal abundance and survivorship for bottlenose dolphins (*Tursiops truncatus*) near Charleston, South Carolina, USA. *J. Cetacean Res. Manage.* 11(2): 153–162.

Stolen, M.K. and Barlow, J. 2003. A model life table for bottlenose dolphins (*Tursiops truncatus*) from the Indian River Lagoon System, Florida, USA. *Mar. Mamm. Sci.* 19 (4): 630–649. *https://doi.org/10.1111/j.1748-7692.2003.tb01121.x*

White, G.C. and Burnham, K.P. 1999. Program MARK: survival estimation from populations of marked animals. *Bird Study* 46(sup1): S120–S139. *https://doi.org/10.1080/00063659909477239*

Whitehead, H. 2001. Analysis of animal movement using opportunistic individual identifications: application to sperm whales. *Ecology* 82(5): 1417–1432. *http://dx.doi.org/10.2307/2679999*

Whitehead, H. 2009. SOCPROG programs: Analysing animal social structures. *Behavioral Ecology and Sociobiology* 63(5): 765–778. *https://doi.org/10.1007/s00265-008-0697-y*

Williams, B.K., Nichols, J.D. and Conroy, M.J. (eds.). 2002. *Analysis and Management of Animal Populations*. Academic Press, San Diego. 818pp.

Wilson, D.R.B. 1995. The ecology of bottlenose dolphins in the Moray Firth, Scotland: a population at the northern extreme of the species range. PhD thesis, Aberdeen University, Aberdeen, Scotland.

Wilson, B., Hammond, P.S. and Thompson, P.M. 1999. Estimating size and assessing trends in a coastal bottlenose dolphin population. *Ecological Applications* 9(1): 288–300. *https://doi.org/10.2307/2641186*

Würsig, B. and Jefferson, T.A. 1990. Methods of photo-identification for small cetaceans. *Rep. int. Whal. Comm.* (Special Issue) 12: 42–43.

Würsig, B. and Würsig, M. 1977. The photographic determination of group size, composition, and stability of coastal porpoises (*Tursiops truncatus*). *Science* 198(4318): 755–756. *https://doi.org/10.1126/science.198.4318.755*

Würtz, M. (ed.). 2012. *Mediterranean Submarine Canyons: Ecology and Governance.* IUCN, Gland, Switzerland and Malaga, Spain. 216pp.