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RESEARCH ARTICLE

Abundance, activity and critical habitat of the striped dolphin *Stenella coeruleoalba* in the Gulf of Taranto (northern Ionian Sea, central Mediterranean Sea)

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Abstract

1. Abundance, density, daily variation in group size, activity and habitat use of the striped dolphin in the Gulf of Taranto (northern Ionian Sea, central Mediterranean Sea) were investigated using data from sightings collected between April 2009 and December 2016 during standardized vessel-based surveys. Density and abundance were estimated in the survey area by means of conventional distance sampling, resulting in 0.97 specimens/km^2 (CV = 5.77%; 95% CI = 0.86–1.08 specimens/km^2) and 615 specimens (CV = 5.77%; 95% CI = 549–689 specimens), respectively.
2. Group size data were analysed using multivariate methods. The changes in group size, depth and percentage occurrence of activity between daily periods were investigated with non-parametric tests. The spatio-temporal distribution of the striped dolphin in each predominant activity was investigated by means of the ordinary Kriging method.
3. Fifteen year-maps of spatial prediction were produced, allowing the identification of persistent areas. The results delineate a critical habitat of about 150 km^2 in the northernmost 'Taranto Valley' canyon system ranging between 140 and 910 m in depth. This critical habitat was persistently and regularly used by an important estimated population of striped dolphins for their day-to-day survival and maintenance in a healthy condition.
4. The intense human use occurring in the area highlights the need for local, national and EU management to set a comprehensive strategy.
5. The establishment of a SPAMI (Specially Protected Area of Mediterranean Importance) as an effective tool for the conservation of the species is suggested. The consequence of establishing a closed area could be reasonably accepted by local concurrent stakeholders. Indeed, limiting access through the establishment of this small closed area would result in the protection of a habitat acting as an ecological refuge for many other pelagic and demersal species of commercial interest, thus favouring their spill over.

KEYWORDS
coastal, conservation evaluation, habitat management, mammals, special protection area

1 | INTRODUCTION

Beyond the fact that cetaceans represent an iconic and charismatic flagship taxon, they assume a key ecological role as top predators in the marine food web, corresponding to most of the criteria defined within the EU Marine Strategy Framework Directive (MSFD) for selecting key species/groups to develop indicators (Azzellino et al., 2014). Indeed, the definition of a cetacean critical habitat as an area regularly used by a cetacean group, population or species to perform essential tasks for survival and equilibrium maintenance could be essential information to support the integrated management of human impacts (Halpern et al., 2008; Pauly, 1995) and a strategic milestone favouring their conservation (Ingram & Rogan, 2002). This is particularly true in both nearshore and pelagic domains of the Mediterranean Sea where changes made by man severely influence habitat suitability (Lusseau & Higham, 2004). Unfortunately, knowledge about the presence and distribution of cetaceans as well as their behaviour patterns in the Mediterranean Sea is still patchy, and that available refers mostly to the western regions (Notarbartolo di Sciara & Birkun, 2010; Pace, Tizzi, & Mussi, 2015). Concerning the striped dolphin *Stenella coeruleoalba* (Meyen, 1833), the available information reports the species as the most abundant cetacean distributed both inshore and offshore with a decreasing west to east trend in abundance (Aguilar, 2000; Cañadas, Sagarminaga, & García-Tiscar, 2002; Cotté, Guinet, Taupier-Letage, & Petiau, 2010; Forcada, Aguilar, Hammond, Pastor, & Aguilar, 1994; Gannier, 1999, 2005; Gaspari, Azzellino, Airoldi, & Hoelzel, 2007).

Concerning the Ionian Sea (central-eastern Mediterranean Sea), recent studies confirm that the striped dolphin regularly inhabits the Gulf of Taranto (northern Ionian Sea) (Carlucci et al., 2015; Dimatteo et al., 2011). Here, the species could be exposed to elevated levels of anthropogenic threats such as strikes from merchant traffic, disturbance from high intensity military sonar and exposure to chemical pollution from the nearby harbour of Taranto (Cardellicchio, Giandomenico, Ragone, & Di Leo, 2000; Dolman, Williams-Grey, Asmutis-Silvia, & Isaac, 2006; Gisiner, 1998; Marsili & Focardi, 1997; Notarbartolo di Sciara & Gordon, 1997; Parsons, 2017). These conditions represent a potential threat to the long-term survival of the species, reducing its habitat suitability as a behavioural response to local human-induced environmental changes (Carlucci et al., 2016).

In this study, conventional distance sampling was applied to sightings data recorded from 2009 to 2016 during standardized vessel-based surveys. An estimation of density and abundance of the striped dolphin in the Gulf of Taranto (northern Ionian Sea, Central Mediterranean Sea) is reported together with observations on daily variation in the group size of dolphins, their activity and habitat use. In addition, the critical habitat used by the species was identified by means of geostatistical techniques. Finally, the establishment of a Specially Protected Area of Mediterranean Importance (SPAMI) is suggested for the effective conservation of the species in the area.

2 | METHODS

2.1 | Study area

The Gulf of Taranto in the northern Ionian Sea (central Mediterranean Sea) covers an area of approximately 14 000 km^2 from Santa Maria di Leuca to Punta Alice showing a very complex topography (Figure 1). A narrow continental shelf with a steep slope and several channels characterize the western sector, while the eastern sector shows descending terraces toward the 'Taranto Valley', a NW–SE submarine canyon with no clear bathymetric connection to a major river system (Capezzuto et al., 2010; Harris & Whiteway, 2011; Pescatore & Senatore, 1986; Rossi & Gabbianelli, 1978). This singular morphology involves a complex distribution of water masses with a mixing of surface and dense bottom waters with the occurrence of high seasonal variability in upwelling currents (Bakun & Agostini, 2001; Carlucci,

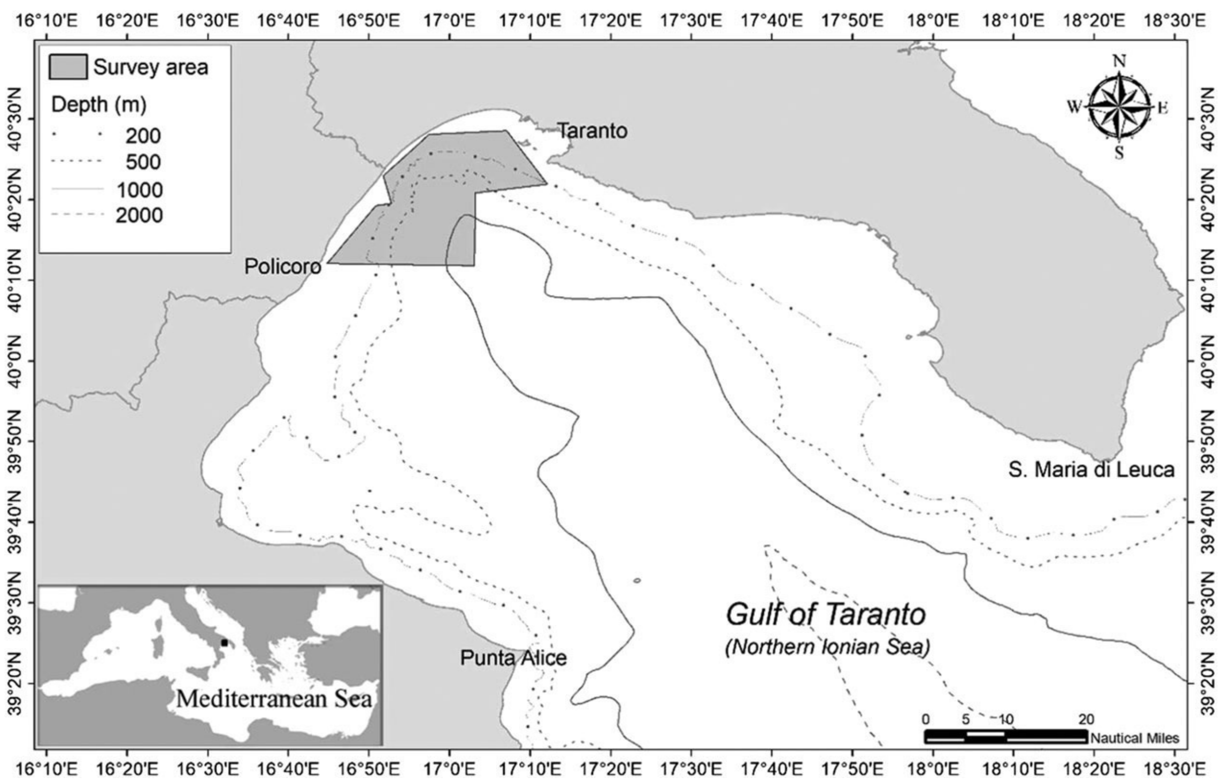


FIGURE 1 Map of the Gulf of Taranto (northern Ionian Sea, central-eastern Mediterranean Sea) with indication of the survey area investigated from 2009 to 2016.

Battista, Capezzuto, Serena, & Sion, 2014; Matarrese, Chiaradia, Tijani, Morea, & Carlucci, 2011).

2.2 | Sightings data

Sightings data for the striped dolphin were collected from April 2009 to December 2016 during standardized vessel-based surveys (Figure 2). Until 2012, surveys were carried out using a rib boat, replaced by a 12 m catamaran in the following years. The sampling effort was set at about 5 h/day along 35 nautical miles (nm) carried out from 07:00 to 18:30 (solar time). Speed was maintained between 7 and 8 knots and trips occurred only in favourable weather conditions (Douglas scale ≤ 3 and Beaufort scale ≤ 4). A line transect sampling approach was adopted according to Buckland et al. (2001) investigating a survey area of about 640 km^2 (Figure 3). Using the Distance 6.0 software the random equally spaced zigzag transects were generated daily with an angle of 45° to the x-axis (Thomas et al., 2010), this proved to be more efficient in terms of reducing effective costs and minimizing off-effort navigation time than the conventional parallel line transects (Strindberg & Buckland, 2004). Off-effort time was generally due to navigation from the harbours of Taranto or Policoro to the starting point of each random transect line.

The observer team on board consisted of at least three people rotating roles every 90 minutes. One observer searched for targets around 180° and counted the dolphins during each sighting, while the others supported the activities of the former observer, searching in a sector from the track-line to 90° on the starboard and port sides, respectively. The assumption required by distance sampling that all dolphins at a distance x on the line are detected (detection function $g(0) = 1$) was assured (Buckland et al., 2001; Thomas et al., 2002). Observations were made with the naked eye or 7×50 binoculars. The perpendicular distance was trigonometrically calculated, using the known track distance covered during the sighting. Once a target had been sighted the GPS position and the angle at the first contact were measured by an on-board compass assuming the dolphin position did not change during measurement. This measurement was validated by means of binoculars with internal reticules. The date, sea weather conditions, depth (m), time of first contact, group size (number of specimens) and the predominant activity state of the dolphins were recorded during sightings. In addition, the focal-group method with instantaneous scan sampling of the predominant behaviour was applied (Neumann, 2001). The focal group was scanned every 3 minutes recording the predominant behaviour during sessions of 15 minutes (Mann, 2000). The predominant behaviour was assigned when more than 50% of the dolphins within the group were involved at the time of sampling (Meissner et al., 2015). Four activity classes were identified according to Shane (1990): feeding, resting, socializing and travelling (Table 1). To avoid possible interference in dolphin behaviour due to the presence of the vessel, the sampling was interrupted when specimens were observed at less than about 50 m (Akkaya Baş, Öztürk, & Öztürk, 2015). Moreover, observers had to maintain a safe distance not less than 5 m from dolphins, lowering speed or interrupting navigation to prevent collisions or possible injuries (Carlson, 2008). Ten activity observations were discarded because behaviours were considered biased by dolphin response to boat proximity and data considered in the analysis only refers to sightings that occurred at a distance greater than about 200 m.

2.3 | Conventional distance sampling

Encounter rate, probability of detection, effective strip width (ESW), group size, density and abundance of striped dolphin as well as their coefficients of variation were estimated by year using conventional distance sampling (CDS). The effect of the change in the platform of observation on CDS outputs was tested by means of the non-parametric Kruskall–Wallis test (KW test, Sokal & Rohlf, 1995).

Right truncation was set at the largest observed distance. The fitting of the detection function model was based on the Akaike Information Criteria (AIC) (Akaike, 1979). Estimation of the encounter rate was assessed using the default option in CDS when a random design

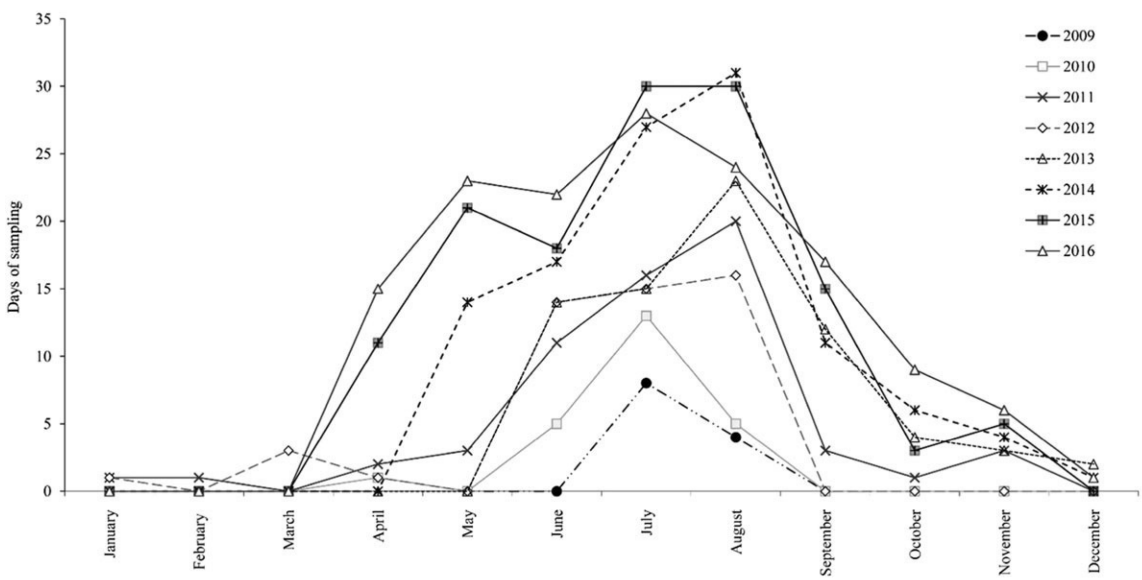


FIGURE 2 Monthly distribution of survey effort in terms of days of sampling throughout the investigated period.

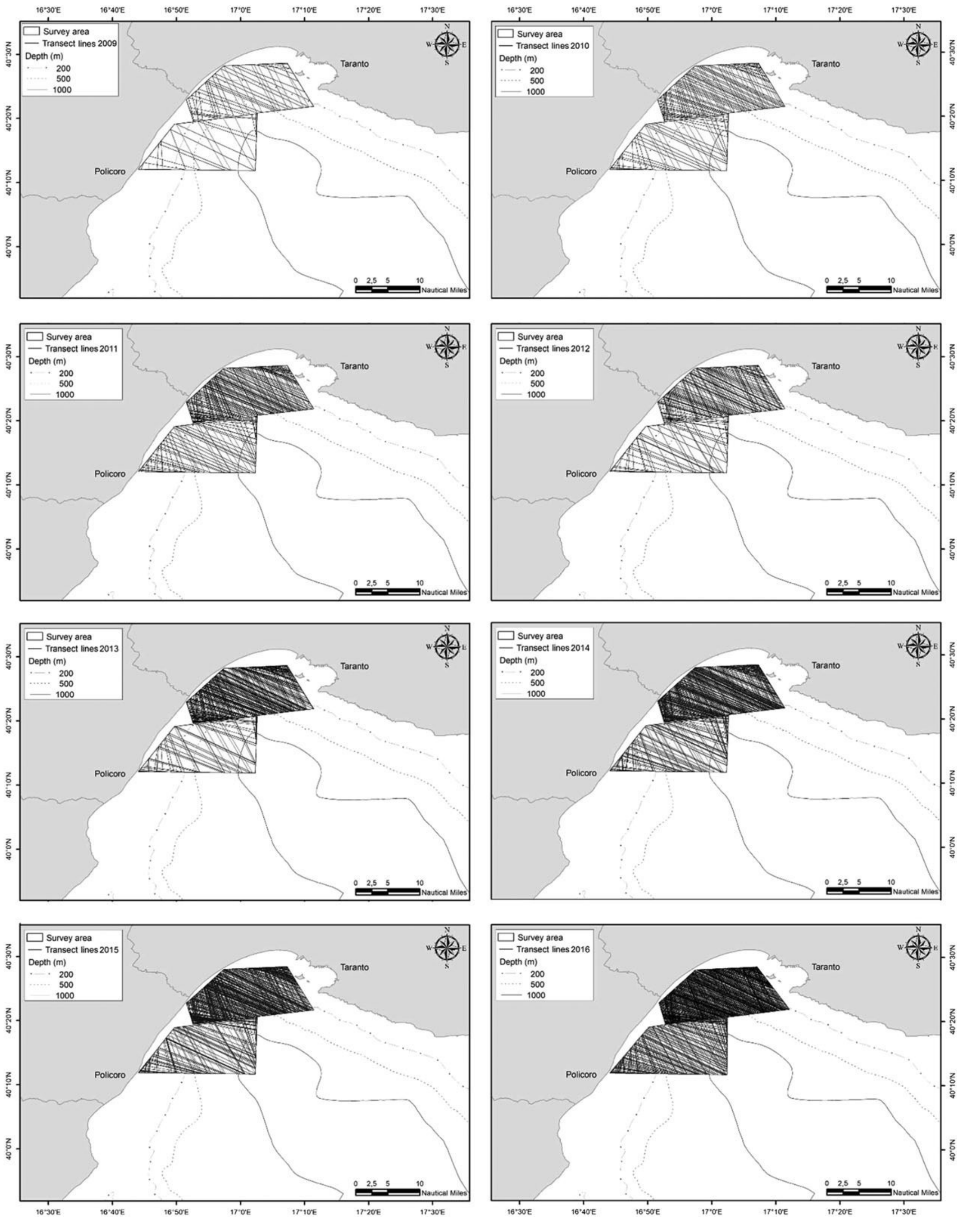


FIGURE 3 Sampling transect lines carried out from 2009 to 2016 in the survey area.

survey was applied (Fewster et al., 2009). The expected value of group size was assessed using a size-biased regression method.

2.4 | Multivariate analysis

The group size changes were analysed by means of hierarchical cluster analysis (HCA) applied to sighting data recorded during the day in three periods 07:00–10.30 h (Morning-M), 10:31–14:30 h (Midday-MD) and 14:31–18:30 h (Afternoon-A). To reduce noise effects due to the extending of surveys into different seasons, the day time was expressed in solar-based time. The HCA was carried out on group size per daily period data after their square root transformation, applying the Bray–Curtis similarity measure and using the complete linkage method (PRIMER 6.1 Software) (Clarke & Gorley,

TABLE 1 Distribution in number and percentage occurrence (%) of activity classes with indication of the main behaviours observed during the sightings of striped dolphins recorded in the survey area from 2009 to 2016

Activity class	Description of observed behaviours	April-August 2009	April-August 2010	January-November 2011	January-August 2012	June-December 2013	May-December 2014	April-November 2015	April-December 2016
Feeding	Dolphin involved in chases or captures of prey items close to the surface, showing erratic movements at the surface, multidirectional diving and rapid circle swimming.	1 (9.1)	3 (11.1)	6 (11.1)	12 (29.3)	15 (23.4)	13 (15.9)	24 (19.5)	29 (17.3)
Resting	Dolphins observed in a tight group (<1 body length between individuals) stay close to the surface, emerging at regular intervals and swimming very slowly.	6 (54.5)	11 (40.7)	23 (42.6)	16 (39.0)	21 (32.8)	28 (34.1)	37 (30.1)	55 (32.7)
Socializing	Physical interactions ranging from chasing to body contact, such as rubbing and touching or copulation among dolphins. Aerial behaviours such as breaching frequently observed.	2 (18.2)	12 (44.4)	21 (38.9)	11 (26.8)	21 (32.8)	26 (31.7)	31 (25.2)	35 (20.8)
Travelling	Dolphins persistently swimming in the same direction at sustained speed and making noticeable headway.	2 (18.2)	1 (3.7)	4 (7.4)	2 (4.9)	7 (10.9)	15 (18.3)	31 (25.2)	49 (29.2)

2006). The group size data per daily period showed a non-normal distribution and the description of each category obtained was carried out providing the median value and interquartile range (IR) for both the dolphin group size and depth. Differences between categories in these variables were tested by means of the non-parametric KW test, and the multiple comparison Mann–Whitney test (U test with Bonferroni's correction) (PAST 3.05 Software) (Hammer, Harper, & Rayan, 2001).

The percentage of occurrence (PO) of activity was calculated on the total recordings. Possible differences in PO of activity states were tested by the chi-squared test (χ^2). However, aiming to also test differences between pairs of activity states in a multiple comparison within and between clusters (post hoc analysis), we applied an absence presence transformation (0 or 1 values, respectively) to the percentage of occurrence data and U test.

2.4.1 | *Geostatistical analysis*

The modelling of the spatial patterns of each predominant activity was investigated year by year using the Geostatistical Analyst Extension in the ArcGIS Desktop version 10.0 Software, according to methodology applied in similar studies (Alessi & Fiori, 2014; Cafaro et al., 2015; García & Dawson, 2003; Monestiez, Dubroca, Bonnin, Durbec, & Guinet, 2006). A preliminary analysis was carried out on the log-transformed group size data to verify spatial trends (Exploratory Spatial Data Analysis - e.g. Normal QQ Plot, Trend Analysis, Anisotropy Analysis and Semi-variogram in Supplementary materials). Then, the fitting of the semi-variograms was evaluated by means of cross-validation statistics, reporting the mean error (ME), root mean square error (RMSE), root mean square standardized error (RMSSE) and average standard error (Average SE) (Alessi & Fiori, 2014; Cafaro et al., 2015). The ordinary Kriging method was applied to provide prediction maps for each activity and year (Dubrule, 1983; Webster & Oliver, 2001). The ordinary Kriging maps were used to pinpoint the sites where the number of striped dolphin exceeded a cut-off threshold calculated as the median value of the group size within each activity (Carlucci et al., 2009; Colloca et al., 2015). Thus, the binary maps for each activity and year were elaborated showing areas where dolphin numbers were greater than or equal to their corresponding cut-off value. Finally, the binary maps were overlapped, only selecting persistent areas throughout the sampling period.

3 | RESULTS

3.1 | Conventional distance sampling

A total effort of 610 daily surveys was applied in the study area during the investigation period (2009–2016) (Table 2). Approximately 3050 hours of observations were carried out and 39 540 km covered, obtaining 580 sightings of striped dolphin. The frequency of occurrence calculated as the number of sightings per daily survey ranged from 0.74 (2014) to 1.17 (2016). Sightings occurred in water depths ranging between 8 and 1000 m with a mean of 435±179 m (Table 2).

Conventional distance sampling analysis was carried out with post-stratification by year due to the changes of effort which occurred throughout the sampling period (Table 3). Based on the lower AIC values, the half-normal function with no adjustment terms in CDS proved to be the best model fitting the detection functions and the longest perpendicular distance of observation was 1.1 km. The encounter rates ranged between 0.012 (CV = 6.42%) during 2014 and 0.017 specimens/km during 2010 (CV = 8.07%). The probability of detection and ESW ranged respectively from 0.37 and 0.41 km (CV = 23.12%) during 2009 to 0.66 and 0.74 km (CV = 7.07%) during 2016. The group size ranged from 29 (CV = 10.18%) during 2015 to 62 specimens (CV = 8.00%) during 2013. Density and abundance ranged respectively from 0.71 specimens/km^2 and 450 specimens (CV = 23.12%) during 2011 to 1.74 specimens/km^2 and 1110 specimens (CV = 20.07%) during 2010.

No significant differences were observed in any of the CDS outputs due to changes in the platform of observation.

The overall density and abundance of striped dolphin in the survey area were obtained by pooling data by year and averaging the possible effect of changes in the effort which occurred throughout the study period. The overall density and abundance were 0.97 specimens/km^2 (CV = 5.77%; 95% CI = 0.86–1.08 specimens/km^2) and 615 specimens (CV = 5.77%; 95% CI = 549–689 specimens), respectively.

TABLE 2 Sampling period, platform of observation, number of daily surveys, range time, depth range, effort (hours and kilometres), number of sightings, frequency of occurrence (number of sightings per daily survey) and mean depth with standard deviation for sightings of striped dolphin in the Gulf of Taranto from 2009 to 2016

Sampling period	Platform of observation	Daily surveys (n.)	Range time	Depth range (m)	Effort		Number of sightings	Frequency of occurrence	Mean depth (m)
					hours	kilometres			
April-August 2009	Rib boat	13	07:00-18:30	200-500	65	843	11	0.85	395±89
April-August 2010	Rib boat	24	07:00-18:30	200-636	120	1556	27	1.13	365±117
January-November 2011	Rib boat	61	07:00-18:30	15-665	305	3954	54	0.89	334±143
January-August 2012	Rib boat	50	07:00-18:30	35-694	250	3241	41	0.82	435±142
June-December 2013	Catamaran	73	07:00-18:30	117-882	365	4732	64	0.88	498±155
May-December 2014	Catamaran	111	07:00-18:30	144-1000	555	7195	82	0.74	458±174
April-November 2015	Catamaran	133	07:00-18:30	110-950	665	8621	131	0.98	416±166
April-December 2016	Catamaran	145	07:00-18:30	8-1000	725	9399	170	1.17	461±211
Total		610	07:00-18:30	8-1000	3050	39540	580	0.95	435±179

TABLE 3 Estimates of detection function model, AIC values, encounter rate, probability of detection, effective strip width (ESW), group size, density and abundance of striped dolphin obtained by CDS analysis carried out for each year and observation platform in the survey area

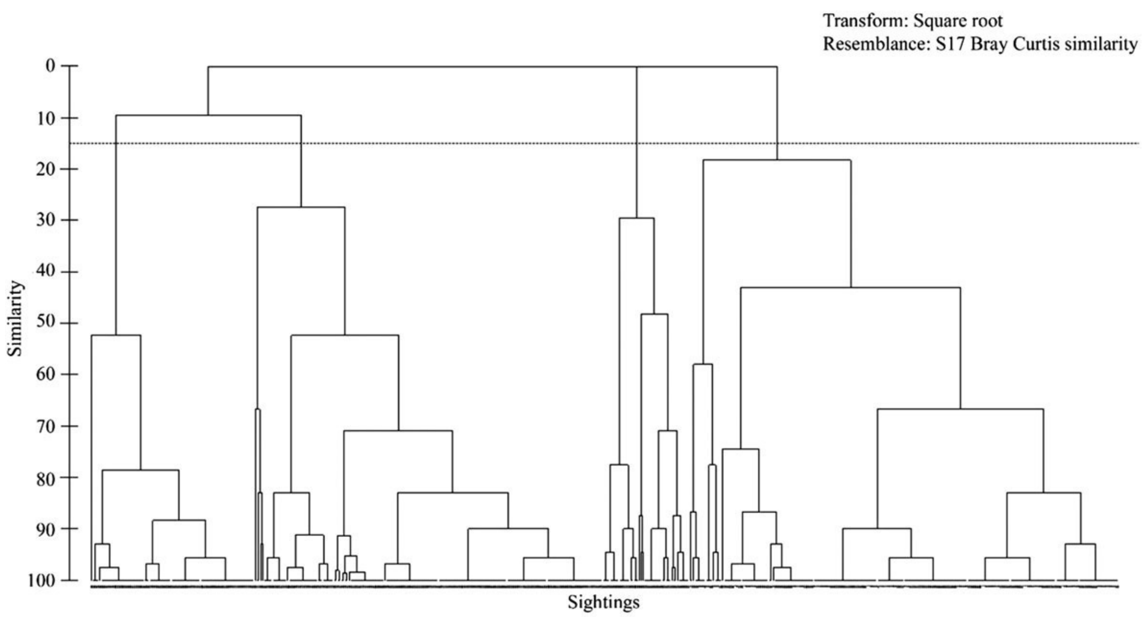
Year	Observation platform	Detection function model	AIC	Encounter rate	Probability of detection	ESW	Group size	Density	Abundance
2009	Rib boat	Half-normal key	-20.04	0.014 (12.27)	0.37 (23.12)	0.41 (23.12)	46 (19.36)	1.44 (32.56)	913 (32.56)
2010	Rib boat	Half-normal key	-41.73	0.017 (8.07)	0.46 (12.45)	0.52 (12.45)	49 (13.51)	1.74 (20.07)	1110 (20.07)
2011	Rib boat	Half-normal key	-65.37	0.015 (7.43)	0.62 (12.86)	0.69 (12.86)	34 (16.40)	0.71 (22.13)	450 (22.13)
2012	Rib boat	Half-normal key	-54.12	0.013 (8.92)	0.55 (13.09)	0.61 (13.09)	47 (11.34)	1.02 (19.48)	648 (19.48)
2013	Catamaran	Half-normal key	-89.92	0.014 (5.91)	0.52 (9.86)	0.57 (9.86)	62 (8.00)	1.38 (14.01)	878 (14.01)
2014	Catamaran	Half-normal key	-97.72	0.012 (6.42)	0.64 (9.91)	0.70 (9.91)	39 (13.37)	0.72 (17.84)	459 (17.84)
2015	Catamaran	Half-normal key	-161.06	0.016 (4.34)	0.62 (7.89)	0.69 (7.89)	29 (10.18)	0.72 (13.59)	457 (13.59)
2016	Catamaran	Half-normal key	-199.41	0.017 (5.43)	0.66 (7.07)	0.74 (7.07)	38 (5.72)	1.05 (10.59)	669 (10.59)

3.2 | Multivariate analysis

Sightings of the striped dolphin by daily period were grouped into four clusters corresponding to a percentage of similarity of 15% (Figure 4). The first cluster M-1 grouped 243 sightings (42.6% of total recordings) characterized by occurring in the morning with a median value of 40 specimens in the group size (IR = 35 specimens) and a median value of 359 m in depth (IR = 221 m). The second and third clusters MD-2 and MD-3, grouped 95 (16.7%) and 182 (31.9%) sightings clearly separated by the median value of group size equal to 60 (IR = 50 specimens) and 20 specimens (IR = 16 specimens), respectively. MD-2 and MD-3 showed the same median values of 500 m in depth (MD-2 IR = 228 m and MD-3 IR = 218 m, respectively). The last cluster A-4 grouped 50 sightings (8.8%) occurring in the afternoon with a median value of 25 specimens in group size (IR = 35 specimens) and a median value of 445 m in depth (IR = 162 m). The group size varied significantly between clusters (KW test, H = 219.9; df = 3; P<0.001). In fact, aggregations of dolphins observed in MD-2 showed significant difference in the median values of group size from both M-1, MD-3 and A-4 (U test, P<0.001). Similarly, the group size observed in MD-3 was significantly different from M-1 (U test, P<0.001) and A-4 (U test, P<0.05).

The depth significantly changed between clusters (KW test, H = 58.5; df = 3; P<0.001). In fact, the median value of depth in M-1 was significantly different from MD-2 and MD-3 (U test, P<0.001).

The percentage occurrence of activities varied significantly both between and within clusters (χ^2 = 208.0; df = 9; P<0.001) (Figure 5). In fact, resting in M-1 (PO = 23.2%) was significantly higher than in



Cluster	M-1	MD-2	MD-3	A-4
Number of sightings	243	95	182	50
Median value of group size (IR) (number of specimens)	40 (35)	60 (50)	20 (16)	25 (35)
Median value of depth (IR) (m)	359 (221)	500 (228)	500 (218)	445 (162)

FIGURE 4 Hierarchical cluster analysis (HCA) applied to sightings data recorded during morning (M-1), midday (MD-2 and MD-3) and afternoon (A-4). Dashed line indicates the percentage of similarity equal to 15% and IR indicates the interquartile range.

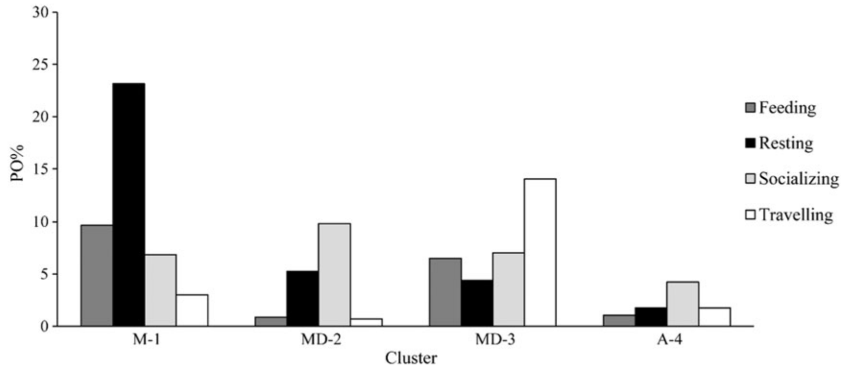


FIGURE 5 Percentage occurrence of each activity class (PO %) within each cluster.

other clusters (U test, P<0.001). Feeding in M-1 (PO = 9.6%) and MD-3 (PO = 6.5%) occurred with similar percentages, both being higher than in MD-2 and A-4 (U test, P<0.001). Lastly, travelling in MD-3 (PO = 14.0%) was significantly higher than in other clusters (U test, P<0.001).

Resting was found to be significantly more frequent than other activities within M-1 (U test, P<0.001). While both socializing (PO = 9.8%) and resting (PO = 5.3%) were significantly more frequent in MD-2 (U test, P<0.01). Lastly, travelling was significantly more frequent in MD-3 (U test, P<0.05).

3.3 | Geostatistical analysis

The preliminary analysis of group size data by activity recorded during sightings showed spatial autocorrelation. The semi-variograms fit for feeding, resting, socializing and travelling and the main statistics of the cross-validation analysis are shown in Table 4. The ordinary Kriging allows for estimation of a total of 15 prediction maps. The socializing and resting maps were predicted from 2012 to 2016 and from 2013 to 2016, respectively, while the feeding maps were predicted for 2012, 2013, 2015 and 2016 and the travelling maps for 2015 and 2016. The ordinary Kriging maps predicted for each activity were transformed into binary maps using the corresponding cut-off values (Table 5). Therefore, the binary maps generated within each activity were overlapped, showing persistent areas throughout the sampling period. The feeding showed eight persistent areas over 4 years, covering approximately 17 km^2 (3% of the total survey area) across a depth range from 230 to 810 m (Figure 6). The resting showed three persistent areas over 4 years, covering approximately 16 km^2 (3% of the total survey area) across a depth range from 140 to 750 m. The socializing recurred for 5 years in an area of about 37 km^2 (6% of the total survey area), across a depth range from 330 to 695 m. The travelling showed six persistent areas over 2 years, covering approximately 122 km^2 (19% of the total survey area) across a depth range from 160 to 910 m.

4 | DISCUSSION

This study reports data on the density and abundance of the striped dolphin in the Gulf of Taranto (northern Ionian Sea, central Mediterranean Sea) as well as daily changes in the group size and activity states,

TABLE 4 Cross-validation statistics indicating the adopted semi-variogram model, the presence of anisotropy and the prediction errors

Year	Semi-variogram model	Anisotropy	Mean Error	Root mean square error	Root mean square standardized error	Average standard error	Sample numbers
Feeding							
2012	Exponential	No	0.0057	0.3854	1.0003	0.3055	12
2013	Gaussian	No	0.0012	0.4877	1.0001	0.4687	15
2015	Spherical	No	0.0033	0.3085	1.0008	0.2629	24
2016	Circular	Yes	0.0025	0.5402	1.0040	0.5388	29
Resting							
2013	Spherical	No	0.0097	0.3270	1.8994	0.3257	21
2014	Circular	No	0.0033	0.4102	1.0001	0.3371	28
2015	Exponential	Yes	0.0001	0.4143	1.0006	0.3935	37
2016	Exponential	No	0.0010	0.3977	1.0002	0.3896	55
Socializing							
2012	Gaussian	No	0.0017	0.3664	1.0004	0.3258	11
2013	Gaussian	Yes	0.0015	0.3837	0.9995	0.3929	21
2014	Gaussian	No	0.0045	0.4744	0.9994	0.4714	26
2015	Gaussian	Yes	0.0006	0.4418	1.0003	0.4141	31
2016	Gaussian	No	0.0014	0.6281	1.0001	0.6214	35
Travelling							
2015	Circular	Yes	0.0086	0.4622	1.0009	0.4123	31
2016	Gaussian	No	0.0061	0.6040	1.0002	0.5224	49

TABLE 5 Cut-off values in number of specimens adopted for generating binary maps for each activity

Cut-off	Feeding	Resting	Socializing	Travelling
(n. specimens)	20	50	40	15

representing a baseline for the species long-term status and its preferential habitat use. Given the importance of these results, possible bias effects on estimates due to the changes of platform of observation and effort heterogeneities which occurred throughout the sampling period were considered. Thus, the overall density and abundance of striped dolphin in the survey area were obtained by pooling data by year averaging possible undesirable effects. The changes in the platform of observation proved not to affect results.

The overall density value estimated for *S. coeruleoalba* in the present study (0.97 specimens/km^2) is the highest among those reported for both the eastern (Bearzi, Bonizzoni, Agazzi, & Gonzalvo, 2011; Panigada et al., 2017; Santostasi, Bonizzoni, Bearzi, Lavinia, & Olivier, 2016) and western Mediterranean regions (Cotté et al., 2010; Forcada et al., 1994; Forcada & Hammond, 1998; Forcada, Notarbartolo di Sciara, & Fabbri, 1995; Gannier, 1998; Gómez de Segura, Crespo, Pedraza, Hammond, & Raga, 2006; Gómez de Segura, Hammond, Cañadas, & Raga, 2007; Lauriano, Panigada, Cannieri, Zeichen, & Notarbartolo di Sciara, 2010; Panigada et al., 2017; Panigada, Burt, Lauriano, Pierantonio, & Donovan, 2009; Panigada, Lauriano, Burt, Pierantonio, & Donovan, 2011). However, in these latter studies, much larger areas were considered and different observation platforms and estimation methods were used, thus caution is required in any further comparative considerations.

Understanding spatial and temporal fluctuations in behaviour is necessary to understand how a population uses its environment, and in turn how to effectively manage it (Stockin, Binedell, Wiseman, Brunton, & Orams, 2009). As reported in several studies, the dynamics of cohesion or dispersal influencing grouping patterns in dolphin species is mainly shaped by food availability (Benoit-Bird & Au, 2009; Heithaus & Dill, 2002; Karczmarski, Würsig, Gailey, Larson, & Vanderlip, 2005; Miyazaki, Kasuya, & Nishiwaki, 1973; Pearson, 2009), predation risks or human disturbances (Dolman, Evans, Notarbartolo di Sciara, & Frisch, 2010; Fossi & Lauriano, 2008; Gowans, Würsig, & Karczmarski, 2008; Hildebrand, 2005), intra-sexual competition and inter-sexual conflicts (Clutton-Brock, 2007), as well as habitat heterogeneity (Azzellino, Airoldi, Gaspari, & Nani, 2008; Tyne, Johnston, Rankin, Loneragan, & Bejder, 2015). Concerning the geomorphological complexity, the hydrographic characteristics and the anthropogenic disturbances in the northern Ionian Sea seem to drive not only the habitat suitability for the striped dolphin (Carlucci et al., 2016), but also its daily variations in group size through changes in aggregation patterns, depths and activity states. In particular, as observed in the north-western Ligurian Sea (Gannier, 1999; Gannier & Laran, 1999), the results suggested a cyclical activity pattern coupled to the dynamics of cohesion and dispersal of dolphins, as well as shifts in their spatial distribution. In fact, the cohesive activities of *S. coeruleoalba* occurred in the morning and at midday when the largest group size (median values of 40 and 60 animals repectively) were observed, when dolphins were mostly engaged in resting or feeding on the upper slope and socializing on meso-bathyal grounds. This aggregation pattern is probably adopted to reduce predation risks (Cipriano, 1992; Pearson, 2009; Pryor & Shallenberger, 1991; Würsig

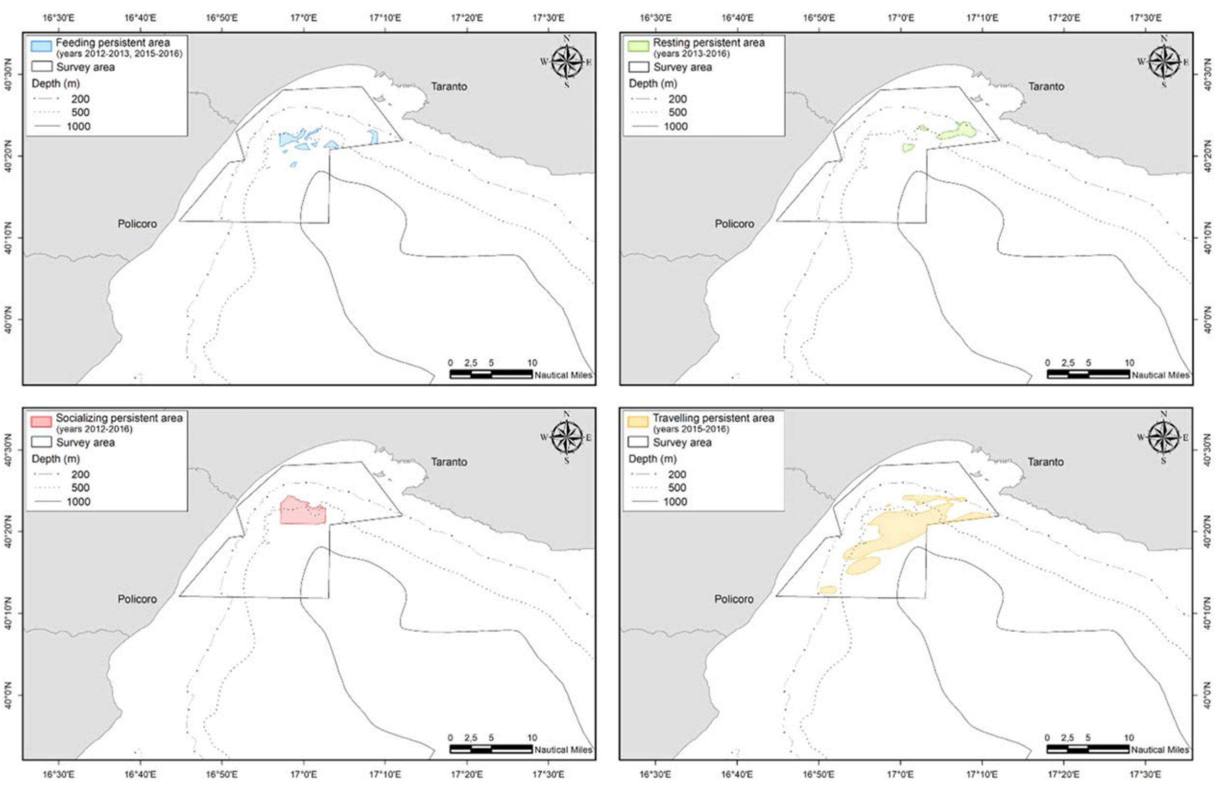


FIGURE 6 Map of persistent areas by activity estimated for the striped dolphin from 2009 to 2016 in the Gulf of Taranto.

& Würsig, 1980) through increased vigilance and protection against predators and the cooperative protection of calves (Möller, 2012; Möller & Harcourt, 2008). Dispersal of the striped dolphins was observed exclusively around midday, characterized by small groups engaged in travelling towards other not investigated offshore areas or within the survey area. Although the reasons are unclear, the dispersal pattern seems very similar to that observed for the striped dolphin in the north-western Mediterranean Sea (Bauer et al., 2015; Gannier, 1999).

Feeding was more frequently observed during the morning on the upper slope, probably representing the tail end of a main nocturnal activity. This is consistent with results documented for the striped dolphins in the north-western Ligurian Sea (Gannier, 1999), where striped dolphins feed exploiting mesopelagic prey during their daily vertical migrations (Bello, 1993; Blanco, Anzar, & Raga, 1995; Öztürk, Salman, Öztürk, & Tonay, 2007; Spitz, Richard, Meynier, Pusineri, & Ridoux, 2006; Würtz & Marrale, 1993). In this light, an important meso- and bathypelagic community has been described in the area due to the presence of a narrow continental shelf and steep slope (Capezzuto et al., 2010), the canyon system in the "Taranto Valley" (Pescatore & Senatore, 1986) as well as the mixing of surface and dense bottom waters (Sellschopp & Álvarez, 2003) with the occurrence of upwelling currents (Bakun & Agostini, 2001; Carlucci et al., 2014; Matarrese et al., 2011; Milligan & Cattaneo, 2007).

Changes in the group size were recorded during the day. Large groups of striped dolphins occurred in the morning, while the coexistence of large and small groups was observed at midday. No clear pattern was detected in the afternoon. However, different activities seem to occur, with dolphins aggregating on the upper slope probably to exploit near shore resources during their nocturnal feeding (Gannier, 1999).

The spatio-temporal distribution of the striped dolphin in each activity was investigated allowing the identification of persistent overlapping areas preferentially used by the species for different activities covering an area of about 150 km^2 in the northernmost 'Taranto Valley' canyon system ranging between 140 and 910 m in depth (Figure 7). This area could be considered a Cetaceans Critical Habitat (CCH), persistently and regularly used by an important population of striped dolphins for their day-to-day survival and maintenance in a healthy condition, according to the ACCOBAMS definition (ACCOBAMS-ECS-WK Threats, 2017). In addition, significant interactions between striped dolphins and human activities occur in the Gulf of Taranto, where shipping navigation, naval exercises, chemical pollution from nearby industrial areas and authorized seismic surveys represent potential threats to the species (Carlucci et al., 2016). This intense human use of coastal and offshore areas in the northern Ionian Sea highlights the urgent need for the involvement of local, national and EU management systems in the setting of a comprehensive strategy maintaining potentially harmful activities within acceptable levels according to the EU MSDF and Maritime Spatial Planning Directive (MSPD). Moreover, specific conservation measures are necessary for the effective protection of the striped dolphin in the Gulf of Taranto (northern Ionian Sea, central-eastern Mediterranean Sea), where the species occurs together with the common bottlenose dolphin *Tursiops truncatus*, the Risso's dolphin *Grampus griseus* and the fin whale *Balaenoptera physalus* (Dimatteo et al., 2011; Fanizza, Dimatteo, Pollazzon, Prunella, & Carlucci, 2014). We consider the CCH identified in this study to be primarily eligible for the establishment of a SPAMI according to the SPA/BD Protocol. The consequence of establishing a SPAMI limiting spatial access to local fishermn could be reasonably accepted. In fact, there is evidence that the main fishing fleets in the neighbouring areas mainly operate close to the harbours of Gallipoli, Taranto and Corigliano Calabro, exploiting fishing grounds distributed on the shelf and the nearest portion of the slope, avoiding the 'Taranto Valley' canyon system (Russo et al., 2017). Moreover, limiting access to this small closed area would result in the protection of habitat

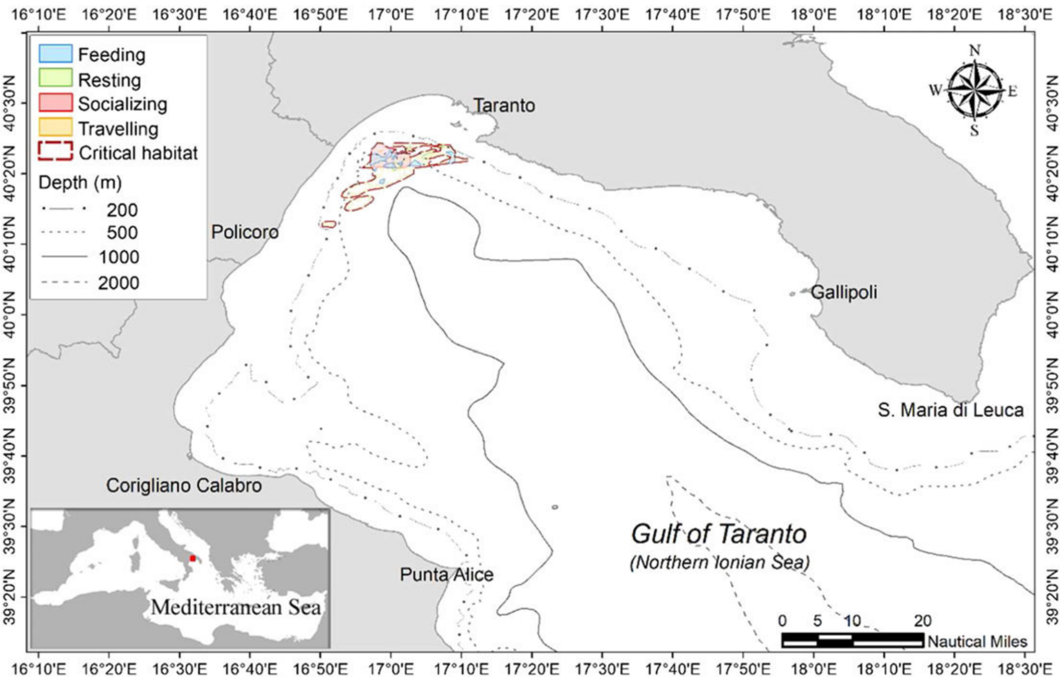


FIGURE 7 Map of the critical habitat identified for the striped dolphin in the Gulf of Taranto.

important as a refuge for many other pelagic and demersal species of commercial interest, thus favouring their spill over with benefits in terms of productivity and economic income.

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