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Social Structure and Temporal Distribution of *Tursiops truncatus* in the Gulf of Taranto (Central Mediterranean Sea)

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Abstract: This study aims to provide information on the site fidelity, residency patterns and the social structures of bottlenose dolphins occurring in the Gulf of Taranto in order to supply effective indications supporting the future management and conservation measures of the species. Out of 141 photo-identified individuals about 76% were re-sighted from 2 up to 31 times. The site fidelity analysis of photo-identified individuals highlighted the occurrence of 20 seasonal residents, 62 visitors and 59 transient individuals that were included in a local population in which emigration and reimmigration events occurred, as suggested by the residency-pattern analysis. The association pattern, performed using SOCPROG 2.9, highlighted a relatively low mean value of the overall half-weight association index (0.11 ± 0.04). However, the test for the null hypothesis of 'random association' was rejected and the temporal analysis made with SLAR suggested the presence of both extremely fluid and stable associations between individuals, describing a fission fusion social structure with a certain degree of social organization. Moreover, the cluster and social network analysis showed two geographically and socially segregated units. Thus, more investigations are needed and the development of a specific conservation plan for bottlenose dolphins in the whole area is required.

Keywords: common bottlenose dolphin; site fidelity; residency patterns; association pattern; social network analysis; cetaceans' conservation

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1. Introduction

Social behavior is a fundamental feature of many animal species, assuming an important role in the development of their behavior and fitness outcomes [1,2]). Among the distinctive characteristics of animal social groups there are complex, dynamic and non-random patterns of social interactions and relationships among members of society [3,4], resulting in a population's social structure. Studying the social structure of a population is one way to obtain useful information on its behavior and ecology and how that population will react to internal and external stimuli. It may affect population growth, genetic make-up, the way diseases spreads, pathways of information transfer and the way animals exploit their environment and move around [5–8]. Otherwise, the social structure can itself be influenced by intrinsic factors, such as the presence or absence of preferred associates, or by extrinsic habitat characteristics, such as prey availability, landscape complexity and anthropogenic disturbances [9–12]. Thus, incorporating social structure information results is a key determinant in population dynamics and may help to define management units of conservation of endangered species [13–15].

Since the 19th century the study of social structures has become widely diffused among the scientific community and behavioral researchers have begun to incorporate this aspect into robust models, developing tools and novel methodologies in order to better understand

and describe animal societies [16–23]. Initially, this approach was principally applied to primates (i.e., *Pan paniscus* [24], *Pan troglodytes* [25]) and then spread to other vertebrate species with high levels of social complexity, such as bat (i.e., *Thyroptera tricolor* [26]), giraffes (i.e., *Giraffa camelopardalis* [27]), elephants (i.e., *Loxodonta africana* [28]) and cetaceans (i.e., *Stenella frontalis* [29], *Sousa chinensis* [30] and *Grampus griseus* [31]). Concerning the methodologies applied over time to study social aspects it has developed from relationship-based approaches [32–34] to social-network analysis [16,35,36].

Among cetacean species, the common bottlenose dolphin *Tursiops truncatus* (Montagu, 1821) is the most studied species concerning aspects of their social structure [15] due to its wide distribution [37–39] especially in coastal areas that are relatively easy to access and monitor. In the Mediterranean Sea, the species is regularly present and is usually distributed within the limits of the continental shelf (<200 m) [40,41]. Common bottlenose dolphins have even been found above the shelf-break in the western Mediterranean Sea and in the Northern Ionian Sea, suggesting the possible occurrence of an offshore ecotype [42–44]. Due to its coastal habits, the common bottlenose dolphin is affected by several anthropogenic pressures [45,46]. Historical intentional killing, bycatch, habitat loss and degradation, prey depletion marine traffic and marine pollution are the main contributors to the decline in the Mediterranean sub-population of common bottlenose dolphins, resulting in a reduction of more than 30% over the last 60 years [47]. Even though the Mediterranean sub-population of the common bottlenose dolphin was assessed by the IUCN as Vulnerable in 2012, on the basis of the criterion A2cde, with evidence of a declining trend in its population [48], more recently its status has been downgraded to Least Concern [49,50]. Nevertheless, this evidence bodes well; however, many aspects need to be considered to assess an actual improvement in the welfare of this population, especially in a closed and strongly anthropized basin, such as the Mediterranean Sea. The occurrence of a genetically differentiated Mediterranean sub-population (i.e., the critically endangered common bottlenose dolphin found in the Ambracian Gulf and Greece [51]) shows the need to deepen the knowledge of the culture and the social tendencies of local units, which may not only lead to a differentiation into ecotypes but also into a haplotypic separation of putative metapopulations [41,52].

This study provides insight into both the social structure and the temporal distribution of the common bottlenose dolphin living in the Gulf of Taranto (Northern Ionian Sea and Central Mediterranean Sea), combining a social-network analysis (made with some of the most novel tools, such as the social network analysis [16,35,53]) with a more exhaustive analysis of site fidelity and residency patterns in the study area, in order to provide effective indications supporting the future management actions for the species and the mitigation of human impacts on the marine ecosystem. The characterization of bottlenose dolphin populations living in the Gulf of Taranto could prove to be highly relevant for the area, which is characterized by high levels of urbanization, intense fishing activity, commercial and cruise shipping traffic as well as the occurrence of heavy industries, naval exercises and offshore wind farm areas [54,55]. Over the past 15 years, common bottlenose dolphins were the focus of various studies in the Gulf of Taranto regarding their abundance and distribution [56–58], photo-identification [44,59], bioacoustics [60], evidence of interaction with sharks [61] and dolphin-fishery competition [54,62,63]. However, little is known about the social structures of the species in this area or its movement variability over space and time.

2. Materials and Methods

2.1. Study Area

The Gulf of Taranto is located in the Northern Ionian Sea (central-eastern Mediterranean Sea) and it extends from Punta Alice to Santa Maria di Leuca covering an area of approximately 14,000 km^2 (Figure 1). The basin is characterized by a complex morphology of seabed. A narrow continental shelf and a steep slope, engraved by several channels, characterize the western sector with terraces characterizing the eastern sector, both of which descend toward the NW-SE submarine canyon system in the 'Taranto Valley' [64–67]. This morphology involves a complex distribution of water masses with a mixing of surface and dense bottom waters and the occurrence of upwelling currents with a high seasonal variability [68–71]. Moreover, it makes the entire basin a hot spot of biodiversity, including valuable habitats, such as the Santa Maria di Leuca cold–water coral province, the Amendolara shoal [64,72–76] and several cetacean species [44,54,56,57,77–84], both worthy of conservation.

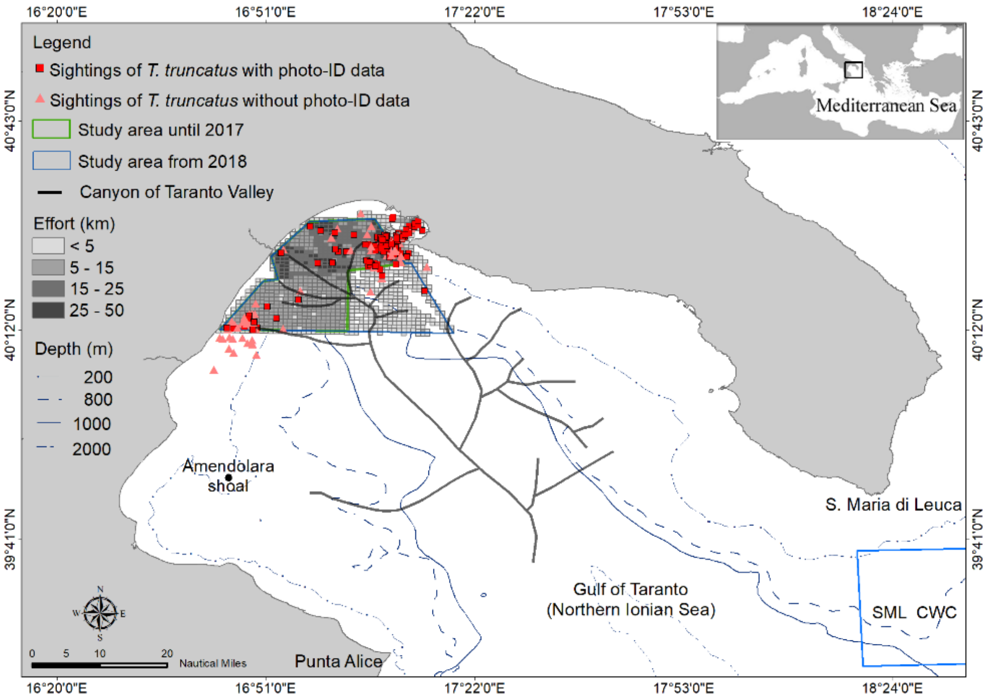

Figure 1. Map of the Gulf of Taranto with indication of its morphologic characters and evaluable habitats (Santa Maria di Luca cold–water coral, SML CWC and Amendolara shoal), surveyed areas and sightings carried out during this study period and the effort sustained (in term of km travelled) linked to sightings of *T. truncatus*.

2.2. Data Collection

Data were collected from July 2013 to September 2021 during standardized vessel-based surveys carried out on board a 12 m motorized catamaran whose cruising speed was maintained between 7 and 8 knots. Daily surveys were carried out only in favorable weather conditions (Douglas scale $\leq$ 3 and Beaufort scale $\leq$ 4) with a sampling effort set at about 5 h/day, covering 35 nautical miles, and applying the Distance Sampling approach [85]. In particular, random equally spaced zigzag transects were generated daily with an angle of 45° to the x-axis [86], to investigate a survey area of about 640 km^2 until 2017 and an area of about 960 km^2 from 2018. This sampling design proved to be more efficient in terms of the reducing effective costs and minimizing the off-effort navigation time than other sampling designs i.e., the conventional parallel line transects [87]. The off-effort time was generally due to navigation from the harbors of Taranto or Policoro to the starting point of each random transect line.

Observations were made with the naked eye and using 7×50 binoculars by three members of the scientific team on board. One observer searched for targets around 180° and counted the bottlenose dolphins during each sighting, while the others supported the activities of the former, searching in a sector from the track-line to 90° on the starboard and port sides, respectively. When a dolphin or a group of dolphins was sighted, the target was followed, switching to off-effort [88], and maintaining a minimum distance of about 50 m from the target to avoid crossing its path and altering its behavioral activity. When the dolphins approached more closely, the speed of the research vessel was reduced gradually until the engine was switched off. In several cases, dolphins were encountered also during off-effort navigation. In all cases, for each group observed the date, geographic coordinates, depth (m), time of first contact, group size and predominant behavioral state were recorded. A 'group' was defined as a collection of individuals observed within an area of less than 100 m radius, engaged in a similar behavior and moving in the same direction [89–91]. Moreover, photo-identification data were collected by a minimum of two photographers positioned on the bow of the research vessel, using a Nikon D3300 digital camera with a Nikon AF-P 70–300 mm, f 4,5–6,3G ED lens. In particular, several photographs of each individual in the group were taken, trying to collect images of both sides of the dorsal fin of each individual.

2.3. Data Analysis

2.3.1. Photo-Identification Process

Cetacean photo-identification (hereafter reported as photo-ID) is a non-invasive technique in which an individual is recognized based on the presence of natural marks on its body. For the photo-ID of the common bottlenose dolphin, the long-lasting marks which were considered were notches, cuts and deformities on the edges of their dorsal fin and depigmentation areas [92–94]. The photo-ID process consisted of three phases: (1) quality selection, (2) creation of a catalog and (3) comparison and matching [84,95–97]. In the first phase, to minimize misidentification, all images were processed and stored based on their quality rate, from 1 = good to 4 = no info, according to the sharpness and focus of the photo and the position of the dorsal fin relative to the frame [44,98]. Only images with a quality rate of 1 or 2 were used to create the digital catalog of photo-identified individuals. Then, each dorsal fin was classified into one of four categories of distinctiveness according to the presence/absence of recognizable features [44,98]. Calves and individuals classified in the 'Low' distinctiveness category were not included in the catalog. Finally, each photograph was compared and matched with existing images in the catalog. The whole photo-identification process was carried out by two observers to reduce the bias and the chance of false positives (different individuals identified as the same) or false negatives (the same individual classified as two different ones). Sex was determined, when possible, by visual inspection of the genital area (i.e., presence of mammary slits and an erect penis) during opportunistic surface observations, for example when dolphin came close to the boat, or during jumps and other social interactions. Moreover, any dolphin that was constantly accompanied and strictily associated with a calf was considered a mother and therefore a female [99]. In this work a female is defined if it was seen associated with a calf at least three times.

2.3.2. Site Fidelity

A hierarchical cluster analysis was performed to describe the tendency of photo-identified individuals to remain in, or return to, and reuse the study area (i.e., site-fidelity, [100]) considering their encounter histories. Clusters were characterized using four different composite indices [80,101] reported below (Appendix A):

1. The monthly sighting rate (MR), defined as the number of months a dolphin was identified as a proportion of the total number of months in which at least one survey was conducted;
2. The yearly sighting rate (YR), defined as the number of calendar years a dolphin was identified as a proportion of the total surveyed;
3. The seasonal sighting rates (SR), defined as the number of seasons a dolphin was identified as a proportion of the total number of seasons surveyed;
4. The relative span-time (RST), defined as the portion of the whole observation time elapsed between the first and last 'captures' of the individual.

The Gower's dissimilarity index was applied to calculate the dissimilarity between individuals. This index was chosen due to its broad applicability in most dissimilarity-based clustering with mixed-type variables [102]. Then Ward's method was applied as an agglomerative algorithm, based on a classical sum-of-squares criterion [103]. Finally, in order to determine the optimal number of clusters, the Elbow method was applied, and the elbow of the curve was used as the cut off point to define clusters [80,100,101,104]. All analyses were conducted with RStudio 4.2.0 software [105].

2.3.3. Residency Pattern

The amount of time identified individuals reside inside the study area was described through residency-pattern analysis [100,106]. The residency pattern of the photo-identified common bottlenose dolphins was determined using the lagged identification rate (LIR). LIR is the probability that if an individual is identified within the study area at any time, it will be identified in the study area some time lag later [107]. A hypothetical closed population (with no births, deaths, immigration, or emigration) should be described by a constant LIR at the inverse of the population size minus one, whereas a fall in LIR over time lag indicates that animals leave the population through emigration or mortality [16]. LIR values were only calculated for individuals observed on at least three occasions in order to ensure a reliable representation of the data. Different models, i.e., closed population, emigration/mortality, emigration + re-immigration and emigration + re-immigration + mortality [107] were fitted to the observed LIR data, and the selection of the best-fitting model was carried out according to the lowest values of the quasi-Akaike Information Criterion (QAIC), which tries to account for overdispersion of count data [17]. The LIR and fitting model were carried out using SOCPROG 2.9 software [18], setting as a sampling period the daily survey in which the photo-ID occurred.

2.3.4. Association Pattern and Social Structure

The association index, defined as the proportion of time that a pair of individuals spends in association, was evaluated for every individual calculating the Half-Weight Association Index (HWI), as it accounts for observer biases during the photo-identification process [16,19]. In detail, in order to reduce bias and make the social organization analysis representative of the real society, only daily surveys with more than 50% of identified individuals out of the total number of sighted individuals were considered. Indeed, according to Whitehead [16] the quality of a dataset could be described considering the percentage of photo-identified individuals: defining the dataset as 'sparse' if in each daily surveys less than 10% of individuals were identified; 'intermediate' if a percentage between 10% and 80% of individuals were identified; and 'complete,' if more than 80% of individuals were identified. Moreover, the association analysis was performed using as selection criterion, i.e., the number of times that an animal was sighted. Only individuals re-sighted at least three times were used for the analysis, in order to ensure the data were representative and reliable as suggested by Chilvers and Corkeron [108]. Furthermore, both the social differentiation (S) i.e., the coefficient of variation in the true association indices and the correlation coefficient between the real and the estimated association indices were estimated using the maximum likelihood method [16]. The former indicates the variability of the association indices within the population describing how varied the social system is ($S < 0.3$ relationships within population are homogeneous, $S > 0.5$ they are well differentiated, and $S > 2.0$ extremely differentiated). The latter is an indicator of the power of the analysis to detect the true social system (1.0 indicates a perfect job and 0.0 a useless one). The presence of preferred (non-random) associations among dolphins was tested through a permutation test against the null hypothesis that the dolphins were randomly associated. The observed association matrix of HWIs was randomly permutated 10,000 times with 1000 flips per permutation [109]. The hypothesis of non-random associations (i.e., preferred companionships in the population) in the observed matrix was accepted if the value of the standard deviation (SD) and the coefficient of variation (CV) were significantly higher than those computed from the randomly permuted data. Hierarchical cluster analysis was used to identify relationships between individual dolphins. A cophenetic correlation coefficient (CCC) greater than approximately 0.80 and a modularity greater than approximately 0.30 indicated that the division into clusters is sensitive [18,20]. Data were analyzed using the compiled version of SOCPROG 2.9 software [18].

To determine the stability over time of associations among individuals the Standardized Lagged Association Rate (SLAR) was calculated. The SLAR estimates the probability of resighting two individuals in association at t(x), after having observed them associated at t(0) [21]. If there is no preferred association among individuals the SLAR equals the null association rate that indicates independent association over the time [21,22]. Different models, such as preferred companions (Pref. comps.), casual acquaintances (casual acqs.), preferred companions + casual acquaintances (Pref. comps. + casual acqs.) and two levels of casual acquaintances [107] were fitted to the observed SLAR data and the selection of the best-fitting model was carried out according to the lowest QAIC [17].

Finally, a social network analysis was performed providing information about the role of individuals within the network through five parameters estimated using SOCPROG 2.9 [23]. The strength, which is the sum of association indices of any individual with all other individuals [110] indicates the bonding degree (gregariousness), so larger values suggest a broad preference for larger groups. The affinity, which is the weighted mean strength of neighboring individuals; therefore, an individual with a high affinity has relatively high associations with individuals that have high strength. The eigenvector centrality, which is given by the first eigenvector of the matrix of association indices and measures how well an individual is associated to other individuals and also how well they are associated. In other words, higher values of eigenvector centrality indicate that individuals generally have high gregariousness and/or are connected to individuals with high gregariousness. The reach, which is a measure of indirect connectedness, so a high value indicates that individuals are indirectly linked to many others in the population. The clustering coefficient, which is calculated as the likelihood that an individual's associates are associated with each other. It indicates how well the associates of an individual are themselves associated, so a value of 0 indicates none of an individual's associates are associated with each other, and a value of 1 indicates that they are all associates of each other with equal weight [16,111].

A social network diagram was drawn in NetDraw using HWI values to graphically display network relationships and to illustrate the structure of the network [112].

3. Results

3.1. Data Collection

From July 2013 to September 2021, a survey effort of 1055 h of observation and 7385 nm of navigation was performed providing 216 sightings of bottlenose dolphin (details of effort distribution over the years are reported in Table 1). Surveys were carried out during the whole year but the effort was differently distributed over the seasons: 65% of surveys in summer, 19.5% in spring, 14% in autumn and 1.5% in winter. The sightings occurred in a depth range from 2 to 900 m with a mean value of 125 $\pm$ 147 m, and the group size ranged between 2 to 25 individuals with a mean group size value of 8 $\pm$ 5 specimens. Moreover, twelve sightings of a single individual occurred during the study period.

3.2. Photo-Identification

Photo-ID data were collected in 130 daily surveys. The number of sightings with photo-ID data increased during the year as shown in Table 1, allowing for the identification of more than 60% of the encountered animals in each sighting from 2016. The cumulative number of identified individuals from 2013 to 2021 is shown in Figure 2. The curve obtained grows sharply over the study period without reaching a plateau.

Table 1. Number of daily surveys, seasons and months sampled with indication of effort (in hours and nm), group size (range and mean values) and depth values (range and mean values) recorded during the sightings of bottlenose dolphins in the Gulf of Taranto.

Year	Daily Surveys (n days)	No. Sightings	Sightings with Photo-ID (n days)	Effort (h)	Effort (nm)	Season	Month	Group Size (range)	Group Size (mean ± SD)	Depth Range (m)	Mean Depth (m)
2013	5	5	3	25	175	1	2	2–15	6 ± 5	20–421	169 ± 166
2014	15	16	5	75	525	4	6	1–22	8 ± 6	2–423	98 ± 136
2015	19	19	1	95	665	3	6	1–25	9 ± 5	13–500	103 ± 107
2016	22	23	10	110	770	3	8	1–20	8 ± 5	11–277	71 ± 66
2017	29	29	13	145	1015	3	6	2–20	7 ± 5	13–441	103 ± 93
2018	49	50	36	245	1715	3	9	1–20	8 ± 5	15–900	196 ± 217
2019	37	39	30	185	1295	4	8	1–25	9 ± 6	15–470	132 ± 145
2020	14	14	11	70	490	2	3	1–12	5 ± 2	20–500	114 ± 142
2021	21	21	21	105	735	3	5	1–20	8 ±4	10–180	79 ± 87
Overall	211	216	130	1055	7385	18	33	1–25	8 ± 5	2–900	125 ± 147

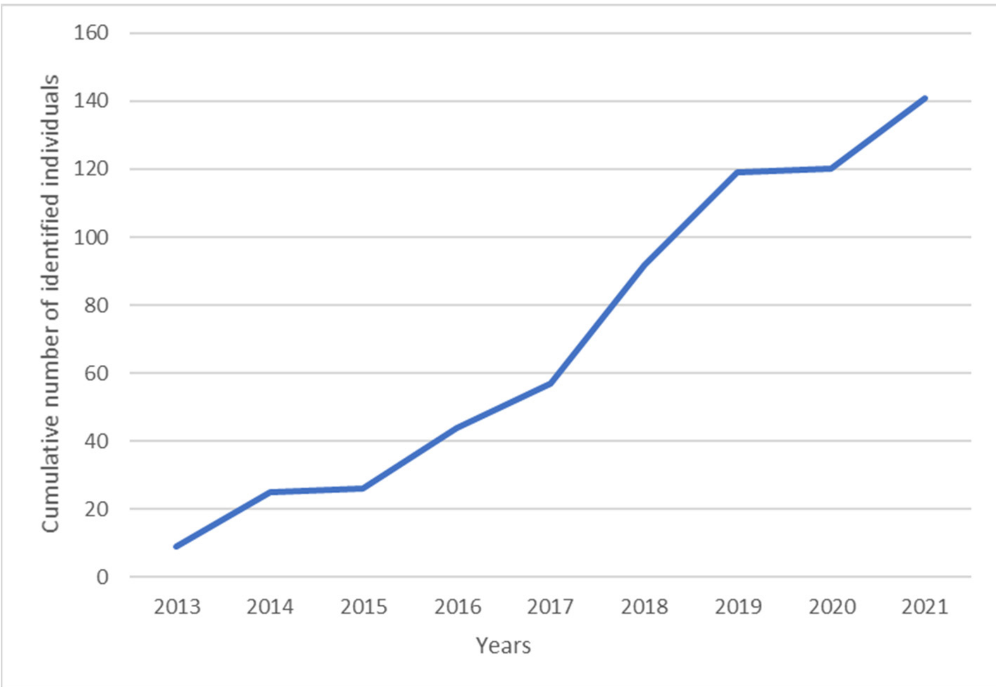

Figure 2. Cumulative number of identified individuals from 2013 to 2021 in the Gulf of Taranto.

Once the quality and distinctiveness criteria were applied, it was possible to identify and catalog 141 specimens thanks to the natural marks and cuts or deformities on the edges of the dorsal fin. Among them, 34 individuals were sighted only once and 107 were re-sighted from 2 up to 31 times, with a mean value of re-sightings of 5 ± 5 times. In detail, 25 bottlenose dolphins were re-sighted in one year, 31 were observed in two or more consecutive years and 51 in two or more non-consecutive years. Sixteen dolphins were unequivocally sexed as female and none as male.

3.3. Site Fidelity

The monthly sighting rate of bottlenose dolphins varied between 0.026 (sighted only in 1 month) and 0.410 (sighted up to 39 months), with a mean value of 0.087 ± 0.078. The yearly sighting rate varied between 0.111 (sighted in 1 year) and 0.778 (sighted up to

9 years), with a mean value of 0.247 ± 0.161. The seasonal rate ranged from 0.048 (sighted during 1 season) to 0.476 (sighted in up to 21 seasons), with a mean value of 0.138 ± 0.107. Values of the relative span time index ranged from 0.000 (sighted only once) and 0.990, with a mean value of 0.254 ± 0.279.

The Elbow method identified three as the optimal number of clusters in which to group individuals (Figure 3). The dendrogram provided by the application of the agglomerative hierarchical cluster analysis clearly highlighted three well defined clusters, including 59, 20 and 62 individuals, respectively (Figure 4, Table 2). Cluster 1 included dolphins never re-sighted, or only re-sighted in one year with a low mean value of monthly (0.032 ± 0.012), yearly (0.111 ± 0.000) and seasonal (0.055 ± 0.017) rate and a low mean value of the relative span time index (0.003 ± 0.006), resulting in transient individuals. Cluster 2 included dolphins re-sighted from one year up to 9 years, with relatively high mean values of monthly (0.242 ± 0.066), yearly (0.556 ± 0.088) and seasonal (0.359 ± 0.057) rate and a high mean value of relative span time index (0.634 ± 0.160), resulting in seasonal resident individuals. Cluster 3 included all dolphins with intermediate mean values of monthly (0.088 ± 0.037), yearly (0.278 ± 0.077) and seasonal rate (0.145 ± 0.047) and an intermediate mean value of relative span time index (0.370 ± 0.220), resulting in visitor individuals

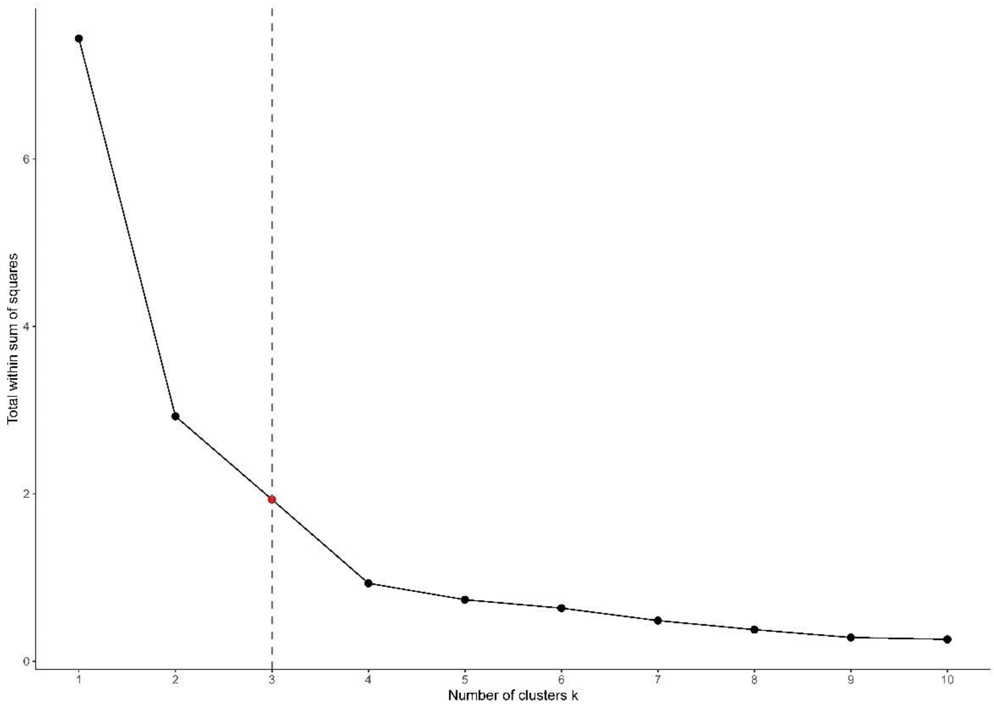

Figure 3. Elbow method plot used in determining the number of clusters in a data set. The elbow of the curve is used as a cutoff point of the dendrogram.

Table 2. Mean, standard deviation (Sd), minimum (Min) and maximum (Max) values of the monthly, seasonal, annual sighting rate and the relative span time index estimated for the individuals of bottlenose dolphin included in the agglomerative hierarchical cluster analysis.

	Monthly Sighting Rate				**Yearly Sighting Rate**				**Seasonal Sighting Rate**				**Relative Span Time**			
	Mean	**Sd**	**Min**	**Max**	**Mean**	**Sd**	**Min**	**Max**	**Mean**	**Sd**	**Min**	**Max**	**Mean**	**Sd**	**Min**	**Max**
Cluster 1 (59 individuals)	0.0322	0.0122	0.0256	0.0769	0.1111	0.0000	0.1111	0.1111	0.0549	0.0173	0.0476	0.0952	0.0034	0.0062	0.0000	0.0285
Cluster 2 (20 individuals)	0.2423	0.0663	0.1795	0.4103	0.5556	0.0883	0.4444	0.7778	0.3595	0.0567	0.2857	0.4762	0.6341	0.1596	0.3952	0.9903
Cluster 3 (62 individuals)	0.0877	0.0367	0.0513	0.1795	0.2778	0.0773	0.2222	0.4444	0.1452	0.0476	0.0952	0.2857	0.3696	0.2211	0.0901	0.8664

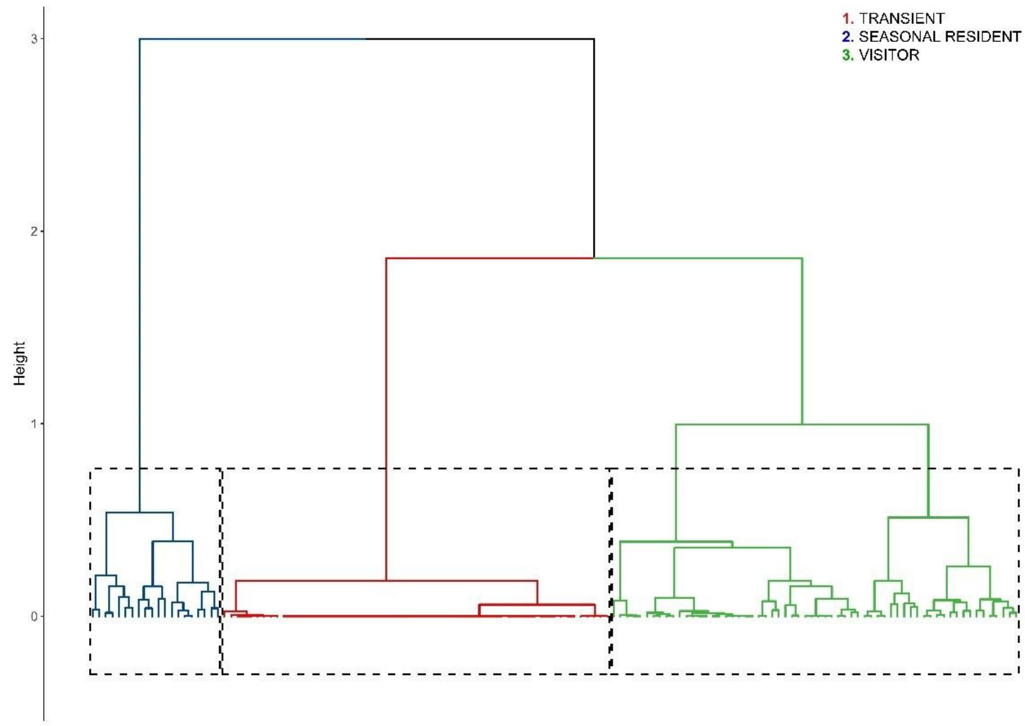

Figure 4. The dendrogram of the agglomerative hierarchical cluster analysis performed to identify the different degree of site fidelity of photo-identified individuals in the Gulf of Taranto. Cluster 1 (transient) is shown in red, cluster 2 (seasonal resident) in blue and cluster 3 (visitor) in green.

3.4. Residency Pattern

For the residency-pattern analysis, only individuals re-sighted at least three times were considered, resulting in 114 sampling periods out of 130 and 55 identified individuals out of 141. The lagged identification rates began to fall within 10 days, suggesting that the common bottlenose dolphin population of the Gulf of Taranto is characterized by some emigration or mortality events (Figure 5). Following the fall, LIR started to level off again and stabilize after 100 days, indicating emigration from and re-immigration events into the study area. Indeed, the most parsimonious model representing the population, according to QAIC, is the emigration + reimmigration model (Table 3). This result suggested a mixed population of resident and transient individuals.

Table 3. Models fitted to LIR data from the Gulf of Taranto. The model that best fit the data according to QAIC is shown in bold. ΔQAIC indicates how well the data support the less favored model (Burham and Anderson 2002).

Function Type	Explanation	QAIC	ΔQAIC
a1	Closed	9451.8	64.3
a2*exp(−a1*td)	Emigration/mortality	9411.0	23.5
a2 + a3*exp(−a1*td)	**Emigration + reimmigration**	**9387.5**	
a3*exp(−a1*td) + a4*exp(−a2*td)	Emigration + reimmigration + mortality	9399.7	12.2

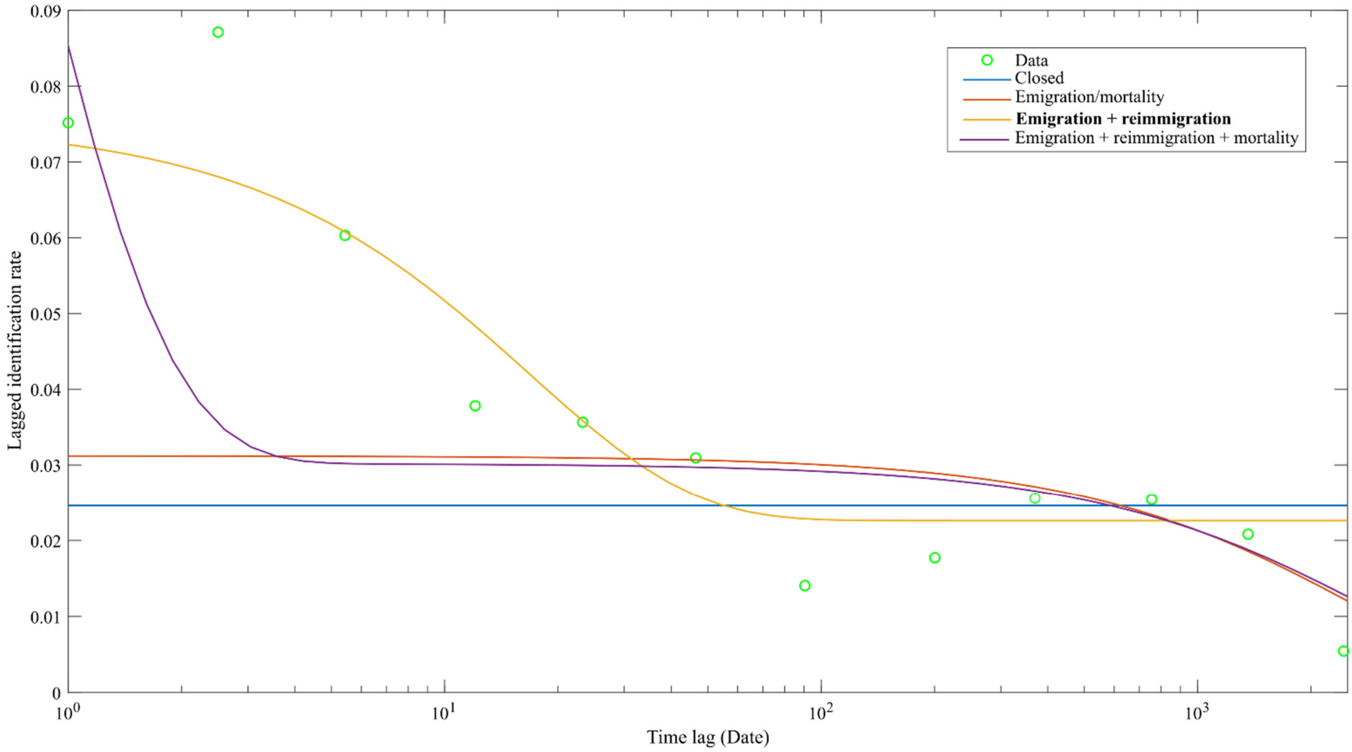

Figure 5. Lagged identification rate (LIR) of bottlenose dolphins sighted at least three times in the Gulf of Taranto. Data are represented by green circles, models tested are represented by different colored curves according to the legend. In bold the best model selected by QAIC.

3.5. Association Pattern and Social Structure

For the association pattern and the social-structure analysis, only surveys with more than 50% of identified individuals out of the total number of sighted individuals were considered, resulting in 95 sampling periods out of 130 and 133 identified individuals out of 141. The second selection criteria applied (i.e., number of re-sightings > 3) resulted in 89 sampling periods and 48 individuals used for this analysis. The mean value of half-weight association index ranged from 0.06 to 0.21, with an overall mean value of 0.11 ± 0.04. The individual labeled as Tt 41 showed the highest mean value of the HWI (mean HWI = 0.21), followed by Tt 113 (mean HWI = 0.19), Tt 117 (mean HWI = 0.18) and Tt 118 (mean HWI = 0.17). The estimate of social differentiation suggested a differentiated society (S = 1.030) and the correlation coefficient between the real and the estimated association was 0.641, indicating a good power of the analysis. The results of the permutation tests on possible preferred or avoided associations in the population show a significantly higher value of SD (SD 0.18231, random SD 0.00018, $p > 0.9999$) and CV of association indices (CV 1.6060, random CV 0.00161, $p > 0.9999$), indicating that occurrence of long-term preferred companionship is present in the population.

The hierarchical cluster analysis highlighted the occurrence of four clusters consisting, respectively, of 3 (cluster 1), 16 (cluster 2), 21 (cluster 3) and 8 individuals (cluster 4) (Figure 6). The mean values of HWI within each cluster are shown in Table 4. Within clusters 1, 2 and 3 a certain degree of association was shown, whereas cluster 4 was completely independent from the others, as highlighted by the estimation of mean value of HWI between different clusters (Figure 6, Table 4). The maximum modularity was 0.489 at HWI 0.158 and the cophenetic correlation coefficient was 0.897, indicating a good representation of bottlenose dolphin society in clusters.

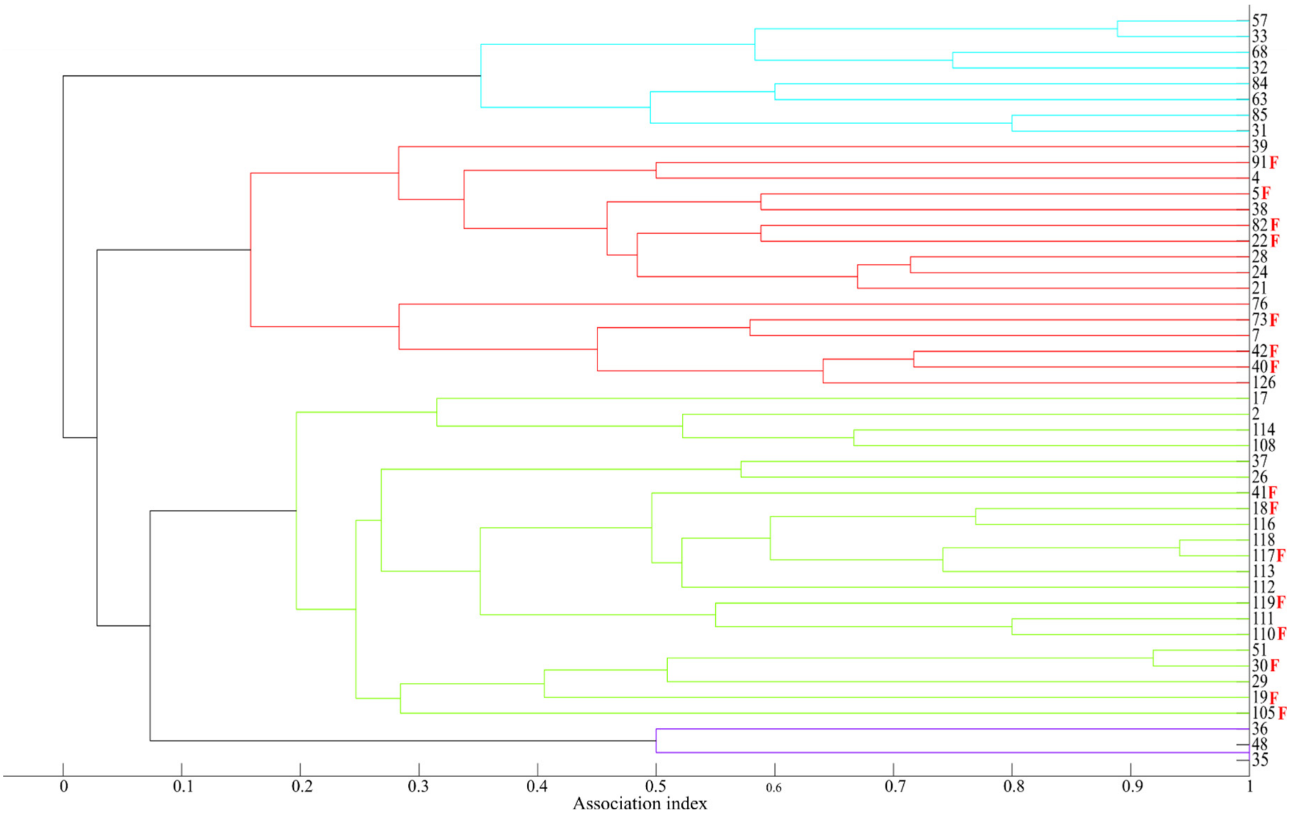

Figure 6. The dendrogram of the agglomerative hierarchical cluster analysis performed to identify different degrees of association of 48 bottlenose dolphins re-sighted at least three times in the Gulf of Taranto. The letter 'F' indicates the individuals sexed as females. Cluster 1 is shown in purple, cluster 2 in red, cluster 3 in green and cluster 4 in light blue.

Table 4. Mean values of half-weight association index within and between clusters. Null values of half-weight association index were reported in bold.

	Mean HWI
Cluster 1	0.06 ± 0.01
Cluster 2	0.11 ± 0.02
Cluster 3	0.14 ± 0.03
Cluster 4	0.07 ± 0.01
	Mean HWI
Cluster 1/Cluster 2	0.01 ± 0.03
Cluster 1/Cluster 3	0.07 ± 0.03
Cluster 1/Cluster 4	$\mathbf{0.00 \pm 0.00}$
Cluster 2/Cluster 3	0.03 ± 0.03
Cluster 2/Cluster 4	$\mathbf{0.00 \pm 0.00}$
Cluster 3/Cluster4	$\mathbf{0.00 \pm 0.00}$

The SLAR indicated that the most parsimonious model was that of preferred companions plus casual acquaintances among dolphins (Figure 7, Table 5). Indeed, the SLAR falls but stabilizes above the null association rate over the period, suggesting a situation in which units have a permanent core membership but there are also floaters who move between units.

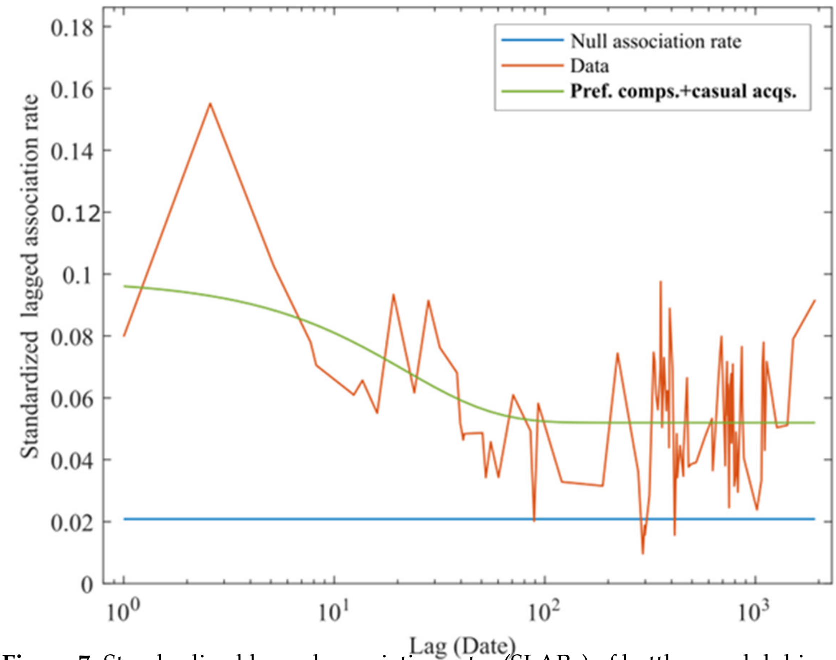

Figure 7. Standardized lagged association rates (SLARs) of bottlenose dolphins sighted at least three times in the Gulf of Taranto. The observed SLAR is represented by the dark orange line, the null association rate is the blue line.

Table 5. Models fitted to LIR data of Gulf of Taranto. The model that best fit the data according to QAIC is shown in bold. ΔQAIC indicates how well the data supports the less favored models [17].

Function Type	Explanation	QAIC	ΔQAIC
a1	Pref. comps.	6879.7	33.3
a2*exp(−a1*td)	Casual acqs.	6874.0	27.6
a2 + a3*exp(−a1*td)	**Pref. comps. + Casual acqs.**	**6846.4**	
a3*exp(−a1*td) + a4*exp(−a2*td)	Two levels of casual acqs.	6874.7	28.3

The social network analysis highlighted the occurrence of 4 clusters (Figure 8, Table 6). Clusters 2 and 3 showed high values of strength, reach, eigenvector centrality and affinity, highlighting how well individuals within these clusters are connected with the others, playing a key role in the society. In Cluster 4, the eigenvector centrality was zero, confirming the poor connection of individuals in this cluster with the others. In particular, the social network graph clearly shows two different social groups in which the strength is represented by the size of each node. Tt 41 was the individual with the highest strength (9.73) and reach (63.35), followed by Tt 1139.09 and 62.51, respectively, Tt 117 8.39 and 58.21, respectively and Tt 118 8.13 and 57.52, respectively. Tt 113 was the individual with the highest eigenvector centrality, Tt57 had the highest clustering coefficient, and finally Tt 119 was the one with the highest affinity. Moreover, in Figure 8 each individual is characterized by a different shape according to the site fidelity group division, showing the key role of Tt41 as a resident of the area and of Tt 113, Tt 117 and Tt 118 as visitors.

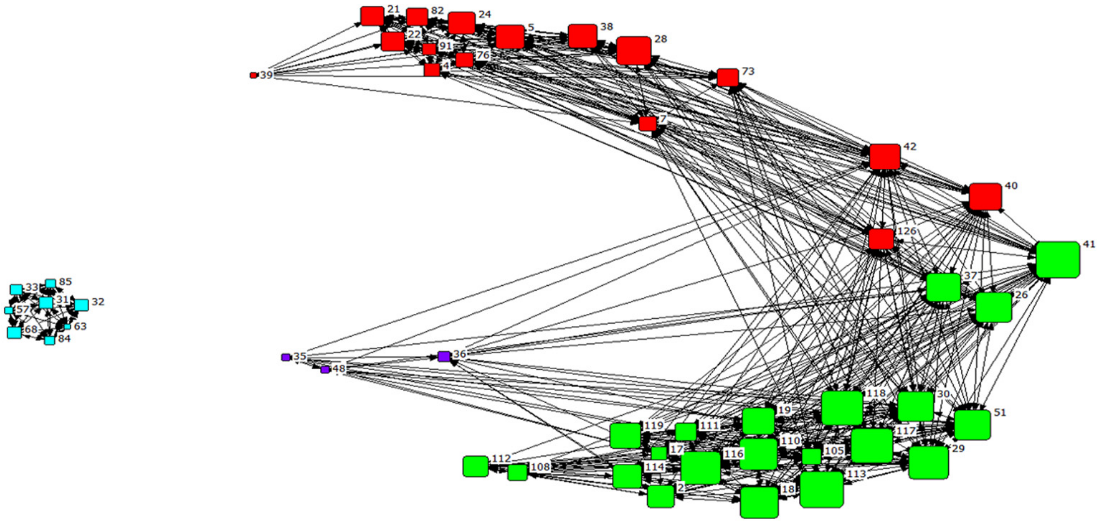

Figure 8. Social network diagram. Nodes represent different individuals, each node is characterized by a different color linked to the cluster division (purple for cluster 1, red for cluster 2, green for cluster 3, light blue for cluster 4), by a different size, proportional to its strength value, and by a different shape, related to the site fidelity group division: circular for transient, square for resident, triangular for visitor.

Table 6. Mean values of strength, eigenvector centrality, reach, clustering coefficient and affinity resulting from the social network analysis and considering all 48 individuals included in the analysis (overall values) and individuals in each cluster (within cluster values).

	Strength	Eigenvector Centrality	Reach	Clustering Coefficient	Affinity
Overall	5.33 ± 1.83	0.11 ± 0.09	31.74 ± 15.67	0.32 ± 0.09	5.64 ± 1.28
Whitin clusters					
Cluster 1 (n = 3)	3.01 ± 0.45	0.06 ± 0.02	15.04 ± 4.75	0.27 ± 0.02	4.92 ± 0.78
Cluster 2 (n = 16)	5.02 ±1.03	0.06 ± 0.03	27.49 ± 5.86	0.29 ± 0.06	5.47± 0.32
Cluster 3 (n = 21)	6.70 ± 1.54	0.20 ± 0.05	45.36 ±11.00	0.30 ± 0.06	6.76 ± 0.37
Cluster 4 (n = 8)	3.25 ± 0.46	0.00± 0.00	10.72± 1.34	0.48 ± 0.02	0.06

4. Discussion

This study provides valuable information about the temporal ranging pattern of the common bottlenose dolphin occurring in the Gulf of Taranto and its social structure, which is investigated through an integrated approach that includes the analysis of site fidelity indexes and the analysis of the social structure. In detail, this study tries to integrate the information obtained from individual analyzes to increase our knowledge on their use of habitats and their habits in the Gulf; enabling a better understanding into whether individuals sighted in the surveyed area live there permanently, or if they have selected the area as a habitat to return to assiduously over time, during one or more specific seasons. Moreover, social-structure analysis allows us to better understand the occurrence of social units and how they interact with each other. This information is crucial to address specific measures for their protection, especially in a basin affected by several anthropogenic pressures [54,55].

The sightings of the common bottlenose dolphin in the study area were distributed over a depth range from 2 to 900 m. According to [40], the Mediterranean population of bottlenose dolphins is often considered as a 'coastal' species, mostly encountered in the continental shelf and shallower waters. However, in some areas of the Mediterranean Sea, such as the Alboran and Balearic seas or the Strait of Gibraltar, they can occur on the continental slope and in productive waters ranging from 200 to 600 m deep, i.e., [113,114]. In the Gulf of Taranto, as already reported by Santacesaria et al. [44], common bottlenose dolphins are also found over the steep slope in the deep waters of the 'Taranto valley'. Moreover, photo-identification data previously analyzed (until 2018 by Santacesaria et al. [44] and here updated, suggested the presence of two groups of bottlenose dolphins geographically separated: A "coastal" group distributed in a depth range from 2 to 277 m, and a "pelagic" group in a depth range from 375 to 900 m. In particular, these two groups are separated not only geographically but also socially, as highlighted by the social-network analysis, enforcing the assumption of a different ecotype, even if specific genetic analysis have to be performed to make this assumption official. Some studies have reported cases of spatial or temporal segregation of bottlenose dolphin populations within the Mediterranean Sea, suggesting ecological specialization as one of the main drivers in the foraging activity, possibly including opportunistic feeding on the discards from different fishing activities [41,115]. Other factors, such as habitat productivity, predation risk and human activities could also be considered responsible for the differences seen in the social segregation and the organization of bottlenose dolphins [30,115,116]. In the Gulf of Taranto, one of the main drivers of this separation could be the presence of several maritime and land-based human activities. For instance, the intense fishing exploitation recorded within this area, from the coastal waters to about 800 m in depth, could influence the occurrence and the distribution of common bottlenose dolphins; when considering that this species shows a consistent food resource overlap with passive nets and longlines that are used to catch sparids, mullet, European hake, red mullet and small pelagic fishes [62]. However, results of several studies carried out to assess dolphins-fishery interactions indicate a condition of low competition in the Gulf of Taranto [54,63]. Thus, further, and specific studies are needed in order to evaluate the diverse factors of this separation.

Concerning the photo-ID data, a total of 141 individuals were uniquely identified and cataloged thanks to the presence of natural marks, cuts or deformities on the edges of their dorsal fin. About 76% of the identified individuals were re-sighted from 2 up to 31 times and among them about 77% were re-sighted in different years, suggesting a certain degree of stability in the use of this habitat. According to the site fidelity analysis, 20 individuals are seasonal residents within the study area. Despite these individuals showing the highest value of monthly and seasonal sighting rates, they never reach the maximum value of 1 due to the reduction in the survey effort during the colder months. Therefore, these individuals are considered seasonal residents. However, the presence of individuals who reside for part of the year and return in this area confirms that the Gulf of Taranto is a critical habitat for the species, as already suggested for other cetacean species, such as striped dolphin *Stenella coeruleoalba* (Mayen, 1833), Risso's dolphin *Grampus griseus* (Cuvier, 1812) and sperm whale *Physeter macrocephalus* (Linnaeus, 1758) [54]. The presence of 121 individuals, including transients and visitors as well as the results obtained from the residency-pattern analysis, suggest classifying the local population as an open population this is characterized by emigration and reimmigration events. In addition, the presence of visitors and transient dolphins also highlights that the Northern part of the Gulf of Taranto might only be part of their distributional range.

For the social-structure analysis, only 48 individuals were used in order to ensure its robustness. Despite the relatively low value of the overall mean half-weight association index (0.11 ± 0.04), the rejection of the null hypothesis, indicating non-random associations and the temporal analysis made with SLAR suggest the presence of both extremely fluid and stable associations between individuals. This outcome is in accordance with the results of the residency-pattern analysis, which suggests a mixed population of resident and transient individuals. In fact, longer-lasting associations can also be explained by the distribution pattern of individuals. According to [116], all populations of bottlenose dolphin have a fission-fusion grouping pattern in which individuals are associated in small groups that change in composition on a daily basis. Our findings confirm that the Gulf of Taranto bottlenose dolphin population is also represented by a fission–fusion social structure and, as reported for other areas within the Mediterranean Sea [12,111,117–120], a certain degree of social organization based on sex-specific bonds should be considered

The association pattern and the social-network analysis highlight the occurrence of 4 social units, of which three (clusters 1, 2 and 3) are connected to each other in different degrees and one (cluster 4) that is completely separated. In particular, clusters 1 and 3 are characterized mostly by visitors (3/3 individuals and 11/21 individuals, respectively). Cluster 2 is characterized mostly by resident individuals (11/16) (Figure 6). These three clusters include individuals distributed at a mean depth of 81 m, suggesting a coastal habitus, whereas eight visitor individuals belonging to cluster 4 were sighted at a mean depth of 450 m, suggesting a preference for the pelagic group. In addition, Tt57, a member of the 'pelagic group', is the individual with the highest clustering coefficient, suggesting its membership to a tight, closed and homogeneous social unit. These data highlighted a separation of the 'pelagic' group not only from a geographical but also a social point of view.

Among individuals belonging to the connected social units, Tt 41 and Tt 117 with its juvenile Tt 118, have the highest values of mean half-weight association index, strength, eigenvector centrality and reach. The tendency of these two females and of the juvenile to form several and/or stronger associations with other individuals emphasizes their role as bridge nodes between three social units, which interact with each other thanks to a few individuals, both of which are seasonal residents and visitors. According to Connor et al. [116], all populations of bottlenose dolphin have a fission-fusion society where individuals join and leave groups in a flexible manner, such that group size and composition change frequently on small spatial and temporal scales to rapidly respond to the interaction with ecological variables. These findings confirm that bottlenose dolphins occurring in the Gulf of Taranto is also represented by a fission–fusion social structure, but further study must be conducted in order to investigate whether there is a certain degree of social organization based on sex-specific bonds.

5. Conclusions

According to the Habitats Directive, for species listed in Annex II, such as the bottlenose dolphin, it is required to create SAC (Special Areas of Conservation), sites of Community importance that 'contribute significantly to the maintenance or restoration at a favorable conservation status, of the habitats or populations of the species for which the site is designated'. Considering our results, the Northern part of the Gulf of Taranto, in both coastal and pelagic areas, should be considered as a critical habitat for this species and therefore a SAC should be designed. However, the institution of a SAC only in the study area could be insufficient for the conservation of the species. Indeed, the population studied is characterized by several emigration and immigration events and the waters within the study area seem to represent only a portion of a wider range used by these animals. Moreover, since data suggest a fission-fusion social structure, the local population of the bottlenose dolphin is not isolated or socially segregated, thus the potential gene flow from individuals entering the area is pivotal to maintaining variation and enhancing its conservation.

Thus, more investigations are needed and the development of a specific conservation plan for the species in the whole Gulf of Taranto is required as well as further studies aimed to better characterize two geographically and socially segregated units.

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Appendix A

This Appendix reports an insight into the mathematical formule of indices used in the hierarchical cluster analysis to describe the presence of dolphin groups according to their site-fidelity pattern in the surveyed area.

In order to calculate different indices, it was necessary to assign a number occasion, $occ_{k,}$ ranging from with $k = 1, \ldots, n$ (i.e., in this study $occ_n = 130$ daily survey), to each daily survey in order to calculate the total capture occasions for each photo-identified individual. To each of occ_k corresponds the time Δt_k with $k = 1, \ldots, n$, which is the time in days elapsing between the first occasion and occ_k (i.e., for the first daily survey ($\Delta t_k = 0$), for the last daily survey ($\Delta t_n = 2986$ days)). Successively, the sets of capture occasions belonging to the k-th month, year, or season, respectively, has been labelled as M_k, $k = 1, \ldots, n_m$, Y_k, $k = 1, \ldots, n_y$ and Sn_k, $k = 1, \ldots, n_{sn}$. Finally, n_d has been defined as the number of identified dolphins and $\{Cij\}_{j=1}^{Occ_n}$ as the encounter history associated with dolphin $i = 1, \ldots, n_d$, where $Cij = 1$ if dolphin i was observed only once. Then, we calculated the times (days) of the first (Δt^{f}) and last (Δt^{l}) captures of each dolphin as:

$$\Delta t_i^f = min\left\{t_j,\ j = 1,\ \ldots, n_{occ}\ :\ C_{ij} = 1\right\}, \Delta t_i^l = max\left\{t_j,\ j = 1,\ \ldots, n_{occ}\ :\ C_{ij} = 1\right\},$$

for $i = 1, \ldots, n_d$, respectively.

Mathematical formulas of four indices used as monthly sighting rate, yearly sighting rate, seasonal sighting rate and relative span time index are reported below:

Monthly sighting rate—MR

$$\mathrm{MR}_i = \frac{\sum_{k=1}^{n_m} I_{M_k}\left(\sum_{\Delta tj\epsilon M_k} C_{ij} > 0\right)}{n_m} \tag{A1}$$

Yearly sighting rate—YR

$$\mathrm{YR}_i = \frac{\sum_{k=1}^{n_m} I_{Y_k}\left(\sum_{\Delta tj\epsilon Y_k} C_{ij} > 0\right)}{n_y} \tag{A2}$$

Seasonal sighting rate—SR

$$Sn_i = \frac{\sum_{k=1}^{n_m} I_{Sn_k}\left(\sum_{\Delta tj\epsilon Sn_k} C_{ij} > 0\right)}{n_{Sn}} \tag{A3}$$

Relative span-time—RST

$$\mathrm{RST}_i = \left(\frac{\Delta t_i^l - \Delta t_i^f}{\Delta tn - \Delta t1}\right) \tag{A4}$$

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