DEMOGRAPHY AND SOCIAL STRUCTURE OF RESIDENT POPULATION OF BOTTLENOSE DOLPHIN *TURSIOPS TRUNCATUS* (MONTAGU, 1821) IN TUNISIAN NORTH-EASTERN COASTS

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ملخص

البنية الديمغرافية والاجتماعية للدلفين الكبير المتواجد بالسواحل الشمالية-الشرقية للبلاد التونسية : تعتبر دراسة العوامل الديموغرافية والبنية الاجتماعية للثدييات البحرية المعرضة للخطر أمرًا بالغ الأهمية لتقييم بيئتها واتخاذ التدابير المناسبة للحفاظ على ديمومتها لذلك يعتبر هذا العمل محاولة لفهم كيفية التنظم والانتماء الاجتماعي بالنسبة للدلفين الكبير (*Tursiops truncatus*) المتواجد بالسواحل الشرقية للبلاد التونسية.

خلال سنوات 2017/ 2018 تمكنا من انجاز 79 رحلة بحرية بمجهود رصد ومراقبة ميدانية في حدود 221.5 ساعة حيث تم رصد ومتابعة 45 مجموعة من الدلفين الكبير خلال 35 خرجة فقط. هذه المجموعات تمت ملاحظتها على طول السنة وهي تتكون في الاغلب من افراد بالغين وأحيانا مصحوبين بأفراد يافعين مع العلم ان حجم وتركيبة المجموعات يمكن ان يتغير من وقت الى اخر حسب نوعية النشاط، كميات الغذاء المتوفرة او حسب تواجد مراكب ومعدات الصيد بالمنطقة. كل هذه العوامل منفردة او مجتمعة يمكن ان تؤثر سلبا او ايجابا على قوة الترابط والانتماء الاجتماعي للدلفين الكبير.

الكلمات المفاتيح: الدلفين الكبير، حجم المجموعة، البنية الاجتماعية، السواحل الشمالية-الشرقية للبلاد التونسية

ABSTRACT

The study of demographic parameters and social structure of vulnerable marine mammal populations is critical to assess their ecology and take conservation measures. In Tunisia, Data of bottlenose dolphin (*Tursiops truncatus*, Montagu 1821) social structure is lacking. This study describes group organization and social affiliation of these species.

Surveys were assessed from 2017 to 2018 in the Tunisian North-eastern coasts. A total of 221.5 survey hours resulted from 79 surveys which only 35 surveys are on contact with 45 identified dolphins. Bottlenose dolphins were observed in all seasons. Seasonality was evident, with more encounters during the summer and fall. Groups encountered can include adults and immatures. Group size depend on group composition: groups with immature dolphins and groups formed only by adults were significantly different (Kruskal–Wallis test, $p < 0.001$). Encountered individuals are living in a fission-fusion society in which companionships are frequently change temporal analyses justify this observation with "casual acquaintance" as the best-fit model.

The variability of social affiliations seems to be related to changes in groups composition and especially to the presence of immatures. Similarly, these affiliations seem to be dependent on the availability of prey or the presence of purse seiners in the bottlenose dolphin distribution area.

Key words: *Tursiops truncatus*, group size, social structure, Tunisian North-eastern coasts.

RESUME

Démographie et structure sociale d'une population résidente de Grand Dauphin *Tursiops truncatus* (Montagu, 1821) des côtes Nord-Est de la Tunisie : L'étude des paramètres démographiques et de la structure sociale des populations vulnérables de mammifères marins est essentielle pour pouvoir dégager des mesures de conservation. En Tunisie, les données sur la structure sociale du Grand Dauphin (*Tursiops truncatus,* Montagu 1821) font défaut. Cette présente étude décrit l'organisation et la socialite des groupes de Grand Dauphin residents des côtes Nord-Est de la Tunisie.

Des observations en mer ont été menées durant l'année 2017 - 2018. Au total 79 sorties ont été realisées avec un effort d'observation égale à 221,5 heures. Seules 38 sorties ont été sujettes d'observation directe avec 45 groupes de Grand Dauphin. Cette espèce a été observée à longueur d'année. La saisonnalité était évidente, avec plus de rencontres durant les saisons estivales et automnales. Les groupes rencontrés peuvent inclure des adultes et des immatures ce qui influencaient la taille des groups. La taille des groupes incluant immatures et adultes se differenciait des groupes formés uniquement par des adultes (test de Kruskal – Wallis, $p < 0{,}001$). Les individus rencontrés suivaient une structure sociale de type fission-fusion avec changement frequent des compagnons. Les analyses temporelles justifient cette observation avec la «connaissance occasionnelle» comme modèle le mieux adapté.La variabilité des affiliations sociales semble être liée à des changements dans la composition des groupes et surtout à la présence d'immatures. De même, ces affiliations semblaient dépendre de la disponibilité de proies ou de la présence de senneurs dans l'aire de répartition de l'espèce étudiée.

***Mots clés** : Tursiops truncatus,* taille des groupes, structure sociale, côtes Nord-Est de la Tunisie.

INTRODOCTION

The small pelagic fishery is one of the main coastal activities in Tunisia; it employs 5708 fishermen and carries nearly 54.1% of the value related to the fishing activity (DGPA, 2018). In the early 90s, this sector had begun to suffer the negative effects of dolphin's attacks. Conflicts between delphinidae and fisheries have become a major concern at some Tunisian fisheries. Fishermen consider these small cetaceans as real competitors to be the origin of the deterioration of their fishing nets and causing heavy economic losses in fisheries production, repair costs and acquisition of new equipment (Ben Naceur, 2000; Lauriano *and al.,* 2004; Zahri *and al.,* 2004; Benmessaoud, 2008 and Benmessaoud *et al.,* 2011). Fishermen claims are increasing, seeking radical interventions to reduce the number of delphinidae that are considered a real obstacle to their fishing activity. However, Tunisia is a signatory of the most fauna protection conventions and is officially committed to avoid nuisance to cetacean population.

In order to avoid any ecological and economic flaws, fishery managers should present scenarios that respect ratified texts and take into account existing data. Various studies have been undertaken by the National Institut of Marine Sciences and Technologies (INSTM) to identify cetaceans and their areas of distribution along Tunisian coasts (Ben Naceur *et al.,* 2004). The Northern area of Tunisia has been subject of numerous prospecting campaigns which highlighting status of 4 delphinidae: *Tursiops truncatus*, *Delphinus delphis*, *Stenella coerualba*, *Grampus griseus*.

We propose in this study to focus on *Tursiops truncatus* population and to examine the size and composition of observed groups as well as the models of social structures linking by these individuals.

MATERIALS AND METHODS

Data collection

Data was collected in the coastal waters of Kélibia, around the Cap Bon Peninsula in Northeast of Tunisia (N 36°50', E 11°04'; Fig. 1). The study area is recognized by its openness to the two basins of the Mediterranean and hence the combination of oceanographic and ecological conditions conducive to the establishment of a diversified fauna (Benmessaoud, 2014). Moreover, this area is also known for its strong fishing potential and especially the importance of small pelagic landing (71.75% of total landing) (DGPA, 2018).

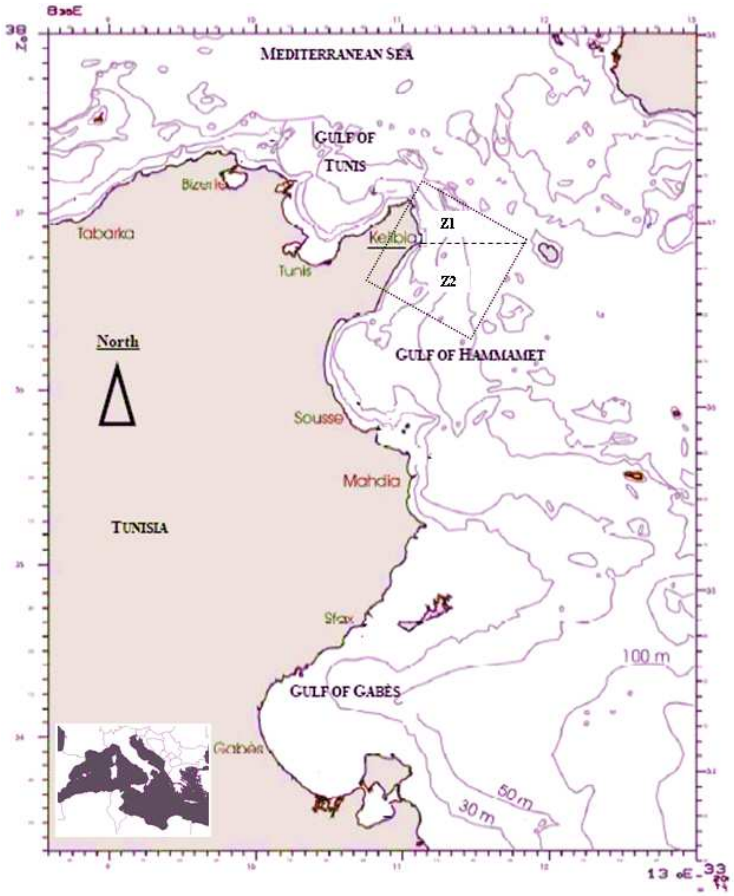

Figure 1: Study area (Z1: north, Z2: south).

This area supports a resident population of bottlenose dolphins (Benmessaoud, 2014). The dolphins consistently occupy the area and appear to have long-term site fidelity (Benmessaoud, 2014). This area was selected as an Important Marine Mammals Area (IMMA) in terms of distribution, foraging and reproduction of a small and resident community of bottlenose dolphin (IUCN, 2017).

Boat based, surveys were randomly, conducted monthly between January 2017 and January 2018, in board 16m charter vessel. The vessel was equipped with a Global Positioning System, (GPS). The observation height was 3m above sea level with an angle view of 360°, but observers mainly concentrate on 180°, to the sides and ahead of the boat. Sightings were considered satisfactory when the visibility was not reduced by rain or fog, and sea conditions were ≤3 Beaufort. Searching effort stopped at sighting, and restarted when the sighting was finished. The encounter continued until the group was lost (a group was considered lost after 15 min without a sighting).

Photo-identification

When sighted, dolphins were slowly approached in order to perform photo identification (Wursig and Jefferson 1990). A photo-identification form was filled in including the group size and composition, behaviour (travelling, feeding, depredation, resting, socializing and reaction to the boat) and direction of travel. Time spent photographing a dolphin was considered as an encounter (Díaz López, 2006a). Photographs were taken of dorsal fins animals, at a perpendicular angle. Attempts were made to photograph all animals, irrespective of group size. Individually marked animals were identified from photographs by matching marks and nicks on their dorsal fins with a photograph ID catalogue. Sightings of dolphins were included onto a database. Unmatched dolphins were considered as capture and given a new photo-ID catalogue number. Reseighted dolphins and which are identified and matched before were regarded as recapture and dolphin kept the same photo-id catalogue number.

Figure 2 : *Tursiops truncatus* dorsal fin photo-identification

Group Dynamics

Estimation of group size was based on the initial count of different individuals observed on the surface (Merriman *et al.,* 2009; Diaz Lopez *et al.,* 2013). The group size and age categories were assessed visually *in situ* and the data was later verified with photographs as mentioned by Díaz López and Shirai (2008). According to Bearzi and al. (2005), animals were categorised as belonging to one of two categories, adult and immature. Immature include (i) neonatal calves with a yellow/green tinge to their skin and (ii) younger animals with pale skin and visible foetal folds on their flank. Every dolphin estimated to be one half the lengths or less of an adult and at most time accompanied by an adult during the course of the observation was considered as immature. Adults were fully-grown dolphins, approximately 2.5–3.0 m long, with the darker skin colour.

The close proximity of a calf with an adult was used to predict a “probable female”, and if a dolphin was seen more than 2 times with an immature, it was designated as a definite female. A dolphin having a higher degree of scarring, through intraspecific interactions, was determined as “probable males” (Tolley *et al.,* 1995). If the genital area of a dolphin was seen, a definite distinction could be made for either sex (Díaz López and Shirai, 2008).

Seasonal and composition fluctuations in group size were tested using a Kruskal–Wallis test.

Social structure analysis

Bottlenose dolphin live in basic social unit, which provides for a cooperative, social way of life and

increases the chances for individual survival. Individuals of the same dyad or group were regarded as being associated or affiliated. Data on social structure was analysed using the SOCPROG 2.4 program (Whitehead, 2009). Coefficient of association (CoA) among dyads was calculated using the half-weight index (HWI). This index was defined with the following formula:

$$\mathbf{HWI = 2N_{ab} / (N_a+N_b)}$$

N_{ab}= the total sightings number of individuals *a* and *b* when they are seen together, N_a= the total sightings number of only individual *a*, N_b= the total sightings number of only individual *b*.

The HWI generally ranged from 0.0 (individuals *a* and *b* never seen together) to 1.0 (individuals *a* and *b* always seen together) and it can be grouped into five classes (Tab.I) as cited by Wells *et al.,* (1987) and Quintana-Rizzo and Wells (2001).

Table I. Different classes of HWI

HWI value	*classes*
< 0.20	Low
0.21 - 0.4	Moderate-low
0.41 - 0.6	Moderate
0.61 – 0.8	Moderate-high
> 0.81	high

To minimize the potential error of not identifying individuals when present within an observed group and to be able to compare results with published studies results, only associations of individuals seen five times or more were taken in consideration. Immatures were not included in the dataset for this analysis because it was expected that the allomothering affect the range and affiliation patterns of these immature, as described by Rossbach and Herzing (1999).

In order to determine the existence of preferred or avoided associations and differences in sociality of individuals, CoA values were compared to a random distribution by permuting the observed dataset 10000 times using the Manly/Bedjer procedure (Manly, 1995; Whitehead, 1999).

Social organisation based in the CoAs was graphically represented in a dendrogram, using the average linkage method of the hierarchical cluster analysis. Cophenetic correlation coefficient was determined in order to indicate how faithfully the dendrogram represented the dissimilarities among observations or data (Romesburg, 2004; Foley *et al.,* 2010). Newman (2006) and Whitehead (2009) noted that a cophenetic values above 0.8 indicate a good match and it is a recommended level of correlation for this type of analysis. Sociogram were used to assess the strength of association between individuals seen in study area (McSweeney *et al.,* 2008).

Long-term data of sightings contributing to association analyses is important. To examine the permanency of these associations, the time between dyad re-sightings should be considered. To measure the probability of two animals remaining associated after various time lags, we calculated the Lagged and Null association's rates using SOCPROG (LAR and NAR). The LAR was compared with models of social organization (Elliser and herzing, 2013a). Several standardized theoretical models representing different social structures were fit in order to determine which model had the best fit. To determine the best-fit model the Quasi Akaike's Information Criterion (QAIC) was calculated for each model (Ottensmeyer and Whitehead, 2003). The model with the lowest QAIC value was considered the best fit model.

RESULTS

A total of 79 surveys were conducted, with 221.5 hours spent of search effort (Tab.II). Survey effort differed between seasons due to changes of the weather condition. A total of 475 identifications were made, with a mean identification per sampling period equal to 13.57 and mean individuals identified per sampling period equal to 8.80.

Table II: Summary of research effort in Tunisian North-eastern coasts during study period

Seasons	*Winter*	*Spring*	*Summer*	*automn*	*Total*
Days at sea	24	16	23	16	79
Days with sightings	10	8	8	9	35
sightings per season	29	12	47	30	118

Photo-identification

842 photographs were taken, of which 527 were considered suitable for photo-identification analysis. Overall, 45 individuals (35 adults and 10 immature) were identified. Due to the quality of photographs, markings and age classes, only 34 individuals were used in the analysis (27 adults and 7 calves).

Group dynamics

Group size of bottlenose dolphin ranged from 1 to 16, with a mean of 4.69 individuals (median = 4, SD = 3.03). All types of group sizes were observed and in terms of group structure, groups composed by adults, juveniles and calves were the most observed. Groups of only adults were smallest than groups with immature which seem to be largest. Data suggested that there was an association between group

composition and group size (df = 1, F= 32.03, p < 0.00001). Our results revealed no seasonal variations in the group size (Kruskal–Wallis test, p = 0.38).

Social structure

Of the 34 individuals, 28 individuals (82.35%) were sighted more than 5 times, with an average re-sighting frequency of 15.39 (SD = 7.14) and a median of 16 times.

Association matrix of individuals resulting from HWI ranged from 0 to 1 with an average of 0.425 (SD = 0.246, Fig. 3). Only 8% of total individual have a high coefficient of association and more than 50% of individuals have a coefficient of association value under 0.4.

There were differences in sociality of individuals given the high value of standard deviation of typical group size for the real dataset. Results of preferred/avoided associations test showed a higher value of the real standard deviation and coefficient of variation than the permuted data. This result suggest that companionships are preferred at long-term (Tab. III) but this does not negate the existence of temporary pod and dyads having short-term associations.

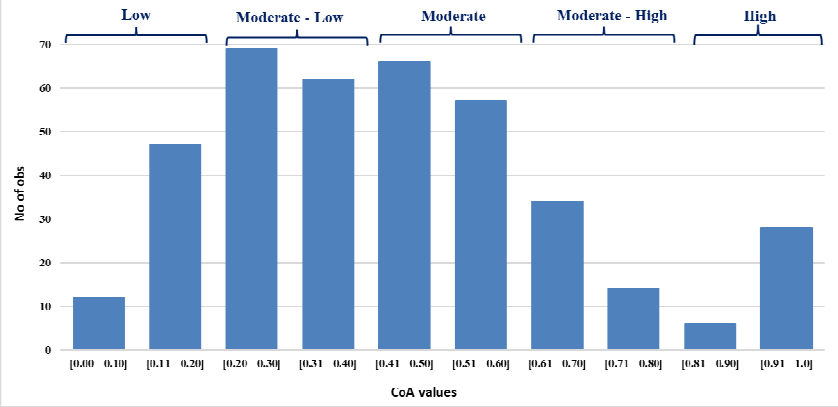

Figure 3: Distribution of coefficient of association (CoA) of bottlenose dolphins seen >5 times in Tunisian North-eastern coasts.

Table III: SOCPROG results for preferred/avoided associations test. Permuted data were calculated using 10.000 random permutations.

	Real	***Random***	***p-value***
Mean association index	0.38	0.00004	0.00000
Std. deviation	0.19	0.00002	0.00010
C. of variation	0.51	0.00005	0.00000
Std. deviation of typical group size	4.71	0.00004	0.00010

Sociogram and dendrogram facilitated the presentation of individual association data identified during the study period. Sociogram, in Figure 4, represent photo-identification numbers around the perimeter of the diagram. The thickness of the adjoining lines within the diagram represents the strength of associations between individuals during the study period.

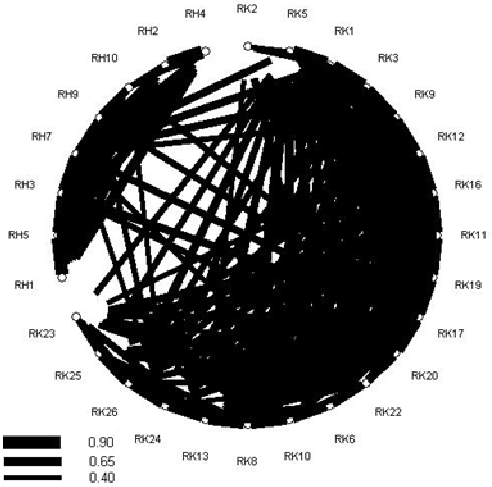

Figure 4: Sociogram of bottlenose dolphin seen > 5 times in Tunisian North-eastern coasts.

Cluster analysis of the associations is displayed in Figure 5. Hierarchical cluster analysis (average group linkage) was used to determine assemblages for study period data, which was found to not differ from the distribution of standard deviations produced from permutation test. However, a cophenetic correlation coefficient is equal to 0.863 and indicates a good match.

In applying the variable stopping rule at 0.4 HWI in the dendrogram as recommended by Rogan *et al.,* (2000), there is a rapid agglomeration of observed dyads and triads from which it becomes impossible to distinguish separate groups. This dendrogram shows 2 major agglomerations. The first one (G1) regroup all individuals seen in the north of the study area, which the average CoA value was under 0.4, showing a moderate-low and low association value. The second group (G2) was composed by individuals seen in the south of study area and which average CoA value was classified as moderate and moderate to high. Despite this distinct agglomeration, individuals of (G1) and (G2) were observed either side of the northern and southern borders.

Temporal stability was weak with rapid decrease in dyads seen together after a few days. The best model that interpolates the pattern of associations, for the values of QAIC, is the “Casual acquaintances” (lower QAIK= 1101.76).

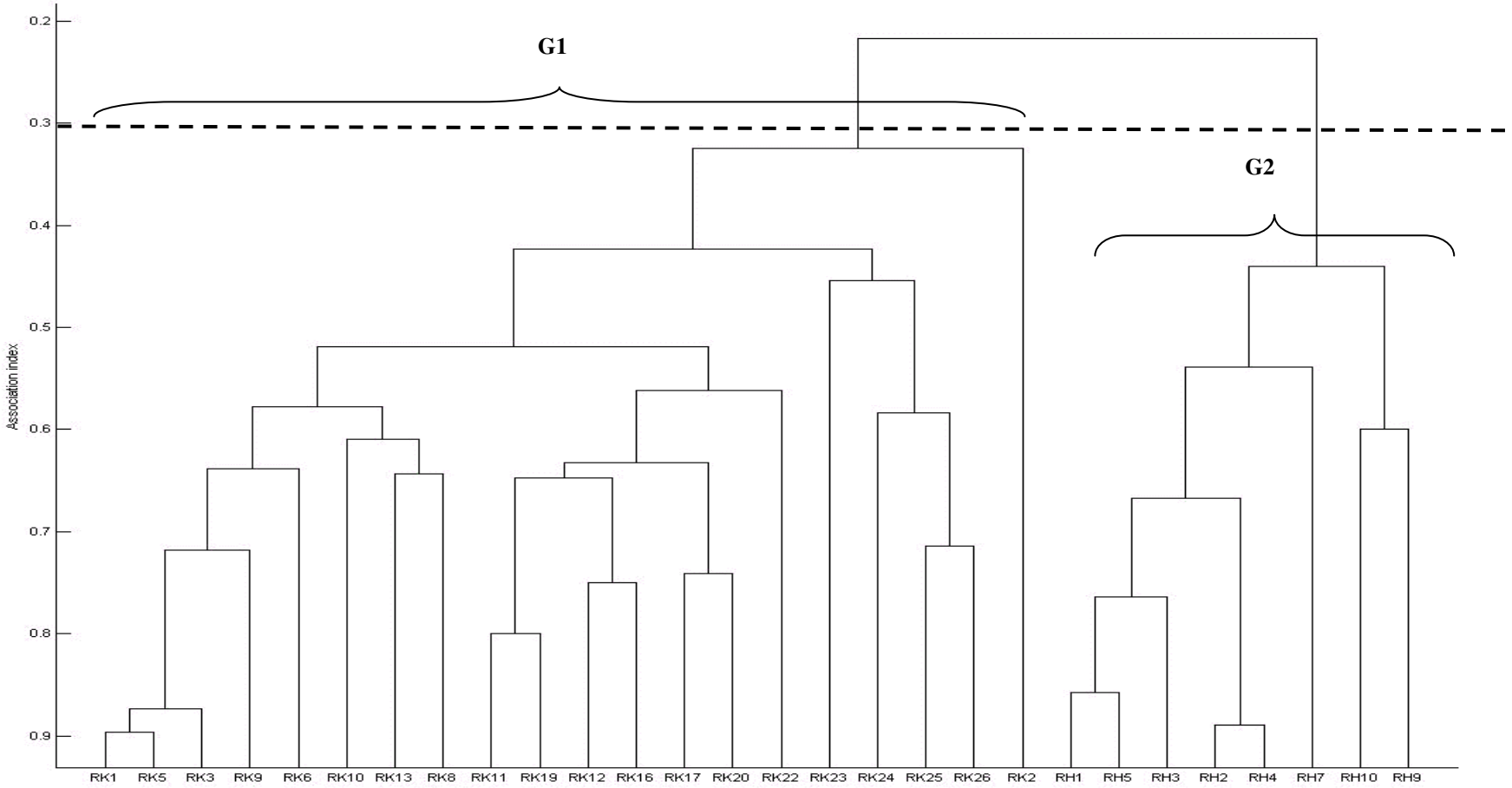

Figure 5: Dendogram showing the average-linkage cluster analysis of associations between bottlenose dolphins *Tursiops truncatus* seen >5 times in Tunisian North-eastern coasts.

This model describes those associations in which individuals are associated to a given period, dissociate and return to re-associate (Fig. 6). This dynamic association is described as fission-fusion society.

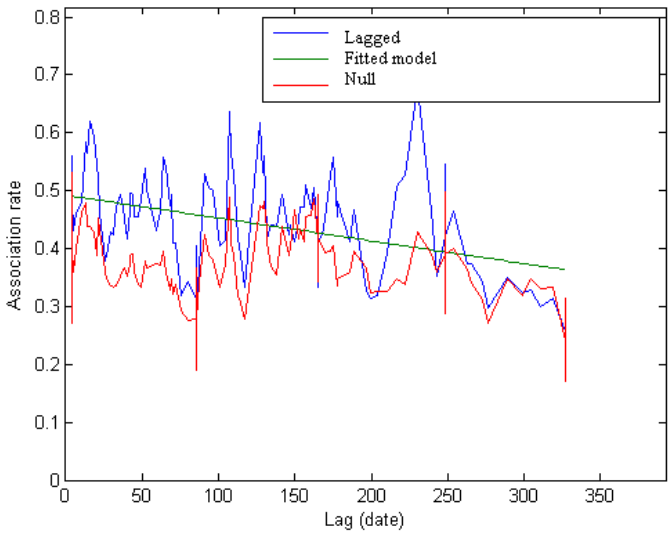

Figure 6: Curves of LAR, best model and NAR of bottlenose dolphins *Tursiops truncatus* seen >5 times in Kelibia with a moving average of 1400 associations. Error bars were calculated using the jackknife technique.

DISCUSSION

This study contributes to filling the knowledge gaps on cetaceans in Tunisia through the study of demography and social structure of the bottlenose dolphins in the Tunisian North-eastern coasts.

Group size of bottlenose dolphins in study area seems to be influenced by group composition. Therefore, group size was influenced by the presence of juveniles and calves, with groups tending to be larger when individuals of these age classes were present. The influence of immatures in group size was reported in several areas, as North-western coastal waters of Sardinia, Italy (Diaz Lopez *et al.,* 2013), Marlborough Sounds in New Zealand (Merriman, 2007), Southeastern Australia (Môller *et al.,* 2002), Adriatic Sea (Bearzi *et al.,* 1997) and Sarasota Bay, Florida (Wells *et al.,* 1987). In larger groups, the enhanced assistance of the immature by other members allows reducing maternal investment (Bearzi *et al.,* 1997).

The HWI is the index, the most commonly used in Cetacean's social structure analysis because it is the less biased index which takes into consideration the case of unrecognition of all associates (Cairns and Schwager, 1987) and since it is the most used it allows for comparisons between other studies. The group of bottlenose dolphins in the study area demonstrated low to moderate association values. Low association coefficients values are characteristic of the fission-fusion society of bottlenose dolphins, with highly fluid groups varying membership within a very small-time frame (Connor *et al.,* 2000). Preferred companionships were present in study zone and there were differences in gregariousness in which certain individuals are seen in large groups and others in small groups. Association patterns are commonly influenced by factors such as the age and sex of the individuals. The previous association between group size and group composition may be reflected in this association patterns as well, as females with immature may prefer larger groups for the benefits mentioned. It reported that males might also form small groups by response to aggression of adult male individuals when attempting to copulate with females (Norris, 1967) and adults for cooperation to maintain female consorts (Connor *et al.,* 1992). Thus, it may be possible that group size is influencing social structure of bottlenose dolphins in study area.

Cluster analysis and associate data support the hypothesis that dolphins in North-eastern coasts of Tunisia comprise two distinct sub-populations. These two sub-populations corresponded to the two of home range overlap reported by Benmessaoud (2014). Overlapping or adjacent range of social sub-populations of *Tursiops truncatus* was documented in many others area as Bahamas (Rossbach and Herzing, 1999), Sarasota (Well and *al.,* 1987) and South Carolina estuary (Gubbins, 2002). It was the first proof of this social pattern in the South of the Mediterranean.

Temporal analysis showed that long-term associations of bottlenose dolphins in study zone lasted few days and the pattern found was best fitted in a model composed by casual acquaintances. The same case was reported by Alessi (2013) and Lusseau

et al., (2006) for bottlenose dolphins seen respectively in Ligurian Sea and Northern Tyrrhenian Sea and in Moray Firth and adjacent coastal waters of eastern Scotland. Although this model is characteristic of a fission-fusion society (Augusto and *al.,* 2011; Pereira, 2012). As long-lived animals, bottlenose dolphins' benefit of these associations passing on knowledge and developing social skills that may be vital to a successful function in their biotope (Lusseau and *al.,* 2003; Rendell and Whitehead, 2001).

Lusseau *et al.,* (2003) reported that temporal stability of a relationship is also an important factor to consider, as it estimates the probability that two individuals interacting will still be interacting in a future time period. According to the literature, we can find a variety of temporal analysis in the same study area (Foley *et al.,* 2010). Associations vary from one season to another and from one year to another and especially related to the composition of the groups studied. Over time individuals, pattern's association can vary considerably within the same population or between populations (Aureli *et al.,* 2008). According to Pace *et al.,* (2011), certain environmental factors may influence the type of social structure such as the acquisition of resources (Wrangham and Rubenstein, 1986), caring for newborns (Pace *et al.,* 2011) and population density (Connor *et al.,* 2000; Wiszniewski *et al.,* 2009). For example, fish farms, trawlers and purse seine are an anthropological food source where preys are concentrated (Díaz López, 2006, 2012; Benmessaoud *et al.,* 2013) and will easily be captured by bottlenose dolphins, saving them unnecessary energy expenditure (Fertl and Leatherwood, 1997; Karpouzli and Leaper, 2004).

The study area, as mentioned in the introduction, is known by the important fishing potential and especially fishing of small pelagic fish. A study made by Benmessaoud *et al.,* (2013), showed that bottlenose dolphin interacts with purse seiners gears. Depredation rate was estimated to 34.1% whither different group size and composition were seen trying to take fishing school concentrate under the light or encircled by purse seine. They are also seen waiting for discards. This new adaptation to the abundance of prey can affect the *Tursiops* habitat use, behaviour and the social pattern of this species (Fertl and Leatherwood, 1997; Chilvers and Corkeron, 2001, 2002; Díaz López and Shirai, 2008). In this context, the opportunity to examine patterns of association of bottlenose dolphin populations affected by human activities is required. In addition, factors that could engender depredation should be definite.

CONCLUSION

Findings from the present study indicate that the social structure of some bottlenose dolphins in study area was revealed to be fluid in the short term where some individuals were continually coalescing and fragmenting. However, the majority of individuals exhibited stronger relationships with preferred companions which showed consistency over the longer term. This changeability of groups was directly related to the differences in occurrence patterns observed and the different patterns movements of this species. Groups with immature were found to be typically larger than those without. The benefits of alloparental care and implications for the survivorship of immature are further discussed. The findings presented here serve to further our understanding of the factors influencing distribution patterns and sociality of this coastal cetacean in North-eastern of Tunisian waters. Along these coasts bottlenose dolphin population is living in fragile coastal areas which can be considered as Cetaceans Critical Habitat (CCH) due to the presence of all type of human activities causing a deterioration of the biotope where individuals are concentrated. In this respect, the results of the present studies will be extremely important in the development and implementation of effective management policies for the protection of this species.

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