BOTTLENOSE DOLPHIN'S INTERACTIONS WITH AQUACULTURE FARM IN THE EASTERN OF TUNISIA: A PRELIMINARY STUDY

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ملخص

دراسة أولية حول تفاعلات الدلفين الكبير و مزارع تربية الأحياء المائية في شرق تونس : يعتبر هذا العمل مساهمة أولى لدراسة التفاعلات بين الدلافين ومزارع تربية الأسماك بالسواحل الشرقية للبلاد التونسية خلال الفترة الممتدة بداية من شهر مارس إلى موفى شهر أفريل 2015
خلال 58 عملية رصد ومشاهدة ميدانية تمكنا من تعداد 142 مجموعة من الدلافين، حيث كانت كل مجموعة تتكون في المتوسط من 1 إلى 8 أفراد كما أن جلّ المجموعات كانت تحتوي على أكبر عدد من صغار الدلافين مقارنة بالبالغين
تمّ فهرسة وتوثيق 43 فرد جديد وذلك من خلال مقارنة (Photo–identification) بالاعتماد على تقنية التعرف على الصور الكدمات والنّدوب الموجودة على مستوى الزعانف الظهرية، كما تمكنّا من تمييّز الأفراد المقيمين من الأفراد العابرين ومعرفة المزاج السلوكي للدلافين المتمثّل خاصة في الأنشطة الاجتماعية (16%)، السفر والترحال (18%) والانتهازية عند البحث عن الغذاء (61% من الدلافين التي وقعت معاينتها تفضل مهاجمة مزارع الأسماك لكي تقتات)
في الأخير تبيّن من خلال تحليل معامل الارتباط (association'Coefficient d) أن سلوك الدلافين ليس عشوائيا ولا اعتباطيا عند الارتباط بمجموعة معيّنة من الأفراد أو تجنّب مجموعة أخرى

الكلمات المفاتيح: الدلفين الكبير، تقنية التعرف على الصور، حجم المجموعات، المزاج السلوكي، البنية الإجتماعية، مزارع الأسماك، معامل الارتباط

ABSTRACT

The present work constitutes the first contribution to study the interactions between fish farm and Delphinidae, in the Tunisian coasts. From March to May 2015, 58 encounters of 142 groups of bottlenose dolphin (*Tursiops truncatus*) were recorded. The total time spent in the presence of dolphins was 1185 min, with a mean encounter duration of 18.29 ± 22.12 min. Group sizes was ranged from 1 to 8 with a mean of 2.39 ± 1.57 animals (median = 2.0). Schools containing calves were significantly larger than those containing only adults. Following the protocol of photo-identification, 43 dolphins were individually photo-identified based on the long-term natural marks on their dorsal fin. Considered the values of monthly sighting rate (SR), 60.47% (n=26) of individuals were considered as resident (SR>0.5) and the rest (n=17) as frequent (0.25≤SR≤0.5).

The behavioral budget for this species showed the predominance of activities characterized by opportunistic feeding (61.0%), not opportunistic feeding (4.0%), traveling (18.0%) and socializing activities (16.0%). A statistical difference was found between the budgets of groups with calves and those without calves.

Twenty-two photo-identified individuals which have been recaptured five or more times, were used to calculate the coefficients of association (CoAs) with maximum value ranged between 0.14 and 0.77 (mean = 0.09 ± 0.28). The results of permutation tests for non-random associations, indicate that dolphins associates preferentially with some individuals and avoids some others. Bottlenose dolphins show non-random social behavior in each reticles and depending on foraging categories

Keywords: *Tursiops truncatus*, photo-ID, group size, behavior, social structure, fish farm, habitat use.

RESUME

Etude préliminaire des interactions entre le grand dauphin (*Tursiops truncatus*) et les fermes d'aquacultures de l'Est de la Tunisie : Le présent travail constitue une première contribution à l'étude des interactions entre pisciculture et delphinidés des côtes tunisiennes. Ce travail a eu lieu précisément dans une ferme aquacole sise à Teboulba durant la période allant de Mars à Mai 2015. Au total 58 observations ont été faites et ont permis le recensement de 142 groupes de grands dauphins (*Tursiops truncatus*). La durée totale des contacts avec *Tursiops* était de 1185 min, avec une durée moyenne de 18,29min (± 22,12 min). La taille des groupes variait de 1 à 8individus avec une moyenne de 2,39 ± 1,57 dauphins (médiane = 2,0). Les groupes

contenant des immatures (nouveau-nés ou/et juvéniles) étaient significativement plus larges que ceux contenant uniquement des adultes. Le protocole de photo-identification a permis d'identifier 43 dauphins sur la base des marques naturelles à long terme présentes au niveau de leurs nageoires dorsales. Le calcul du taux d'occurrence mensuel a permis d'identifier le modèle de résidence des individus observés. 60,47% (n = 26) des individus ont été considérés comme résidents et le reste sont considérés comme fréquents (n = 17).
L'analyse du budget comportemental a montré la dominance des activités relatives à l'alimentation opportuniste (61,0%), non alimentaire opportuniste (4,0%), les voyages (18,0%) et les activités socialisantes (16,0%). Une différence statistique a été mise en évidence entre les bilans comportementales des groupes incluant des immatures et ceux n'incluant que des adultes.
Vingt-deux individus photo-identifiés, recapturés cinq fois ou plus, ont été utilisés pour calculer les coefficients d'association (CoA) qui atteint une valeur comprise entre 0,14 et 0,77 (moyenne = 0,09 ± 0,28). Les résultats des tests de permutation pour les associations non aléatoires indiquent que les dauphins s'associent préférentiellement à certains individus et en évitent d'autres. Les grands dauphins montrent un comportement social non aléatoire dans chaque réticule et en fonction des catégories de recherche de nourriture
Mots clés : *Tursiops truncatus*, pisciculture photo-identification, taille du groupe, modèle de résidence, bilan comportemental, structure sociale.

INTRODUCTION

Bottlenose dolphin, *Tursiops truncatus*, considered as the most present dolphin in the Mediterranean Sea (Notarbartolo di Sciara 2002; Astruc 2005), is a coastal species protected under Habitat Directive (Annex II) (Dir. Habitat 92/43 CE) and classified in this region as vulnerable from the Red List IUCN (Bearzi et al. 2012).
This species is well known for its (i) foods-web effects on fishery yields also called prey depletion (Coll et al. 2007), (ii) interactions with fishing activities and depredation (Bearzi et al. 2001; Tringali et al. 2001) ; and (iii) interaction with aquaculture facilities (Diaz Lopez et al. 2001; Mitra et al. 2001;). Interactions between cetaceans and fisheries are probably as old as the first human attempts to catch fish with a net (Bearzi 2002). Fishery can affect negatively cetacean conservation in three ways: accidental mortality, direct killing, depletion of cetacean prey resources etc. On another side, cetacean can also affect heavily the fisheries through damage to fishing gear; reduction of the size or quality of the catch; reduction of the amount or value of the catch; lower income; a real or perceived ecological competition with cetaceans (Bearzi 2002).
Bottlenose dolphin visits to aquaculture facilities in the Mediterranean appear to be occurring with increasing frequency, probably owing to the rapid expansion of fish farming in coastal waters (Reeves et al. 2001; Karakassis, Pitta & Krom, 2005) and to the opportunistic behaviour of the dolphins. Increased nutrient levels, complex substrate and provision of fish-feed in the proximity of the cages trigger trophic enrichment and can attract potential bottlenose dolphin prey. Bottlenose dolphins have been regularly observed visiting fish farm cages in search of prey in several coastal areas in the Mediterranean such as in Cyprus waters (Bearzi 2002), around Lampedusa Island (Pace et al. 2006) and in the north of Sardinia (Díaz López 2006 a; Díaz López et al. 2001) . Many researches in the Mediterranean Sea have been leaning to study bottlenose dolphin behavior next to the off-shore cages (Kemper et al. 2003; Díaz López 2009; 2012). However, data remain fragmented and disparate for very limited areas. However, in Tunisian waters, this aspect remains untreated. The present work is the first contribution to study the interaction between bottlenose dolphin and fish farms in Tunisia.Thus, the goal of this investigation is to describe bottlenose dolphins behaviour and social dynamics near to fish farm based in group composition, habitat use, social structure and budget behaviour. The social dynamic of a population plays a key role in many aspects of its ecology and biology: it affects the genetic make-up, how diseases spread, and how animals benefit from their environment (Lusseau et al. 2005). Investigating the social dynamics, as well as behaviour, is an important factor for the management and the conservation of bottlenose dolphin (Sutherland 1998).

MATERIAL AND METHODS

FIELD METHODS
This study was carried out from March to May 2015 in the eastern coast of Monastir, Tunisia (**Figure 1**), near to the off-shore marine fish farm for rearing sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus aurata*). The area of fish farm was around 125 hecta containing 24 cages located at depth of 30 to 36 meters and have a diameter of 22 meters. The nets used are antifouling nets with a mesh size of 8, 12, 15, 18 and 20 mm depending of fish size. The cages are located in the same area and were part of the same reticle. Total cages were arranged in for reticules A, B, C and E (**Fig.1**).

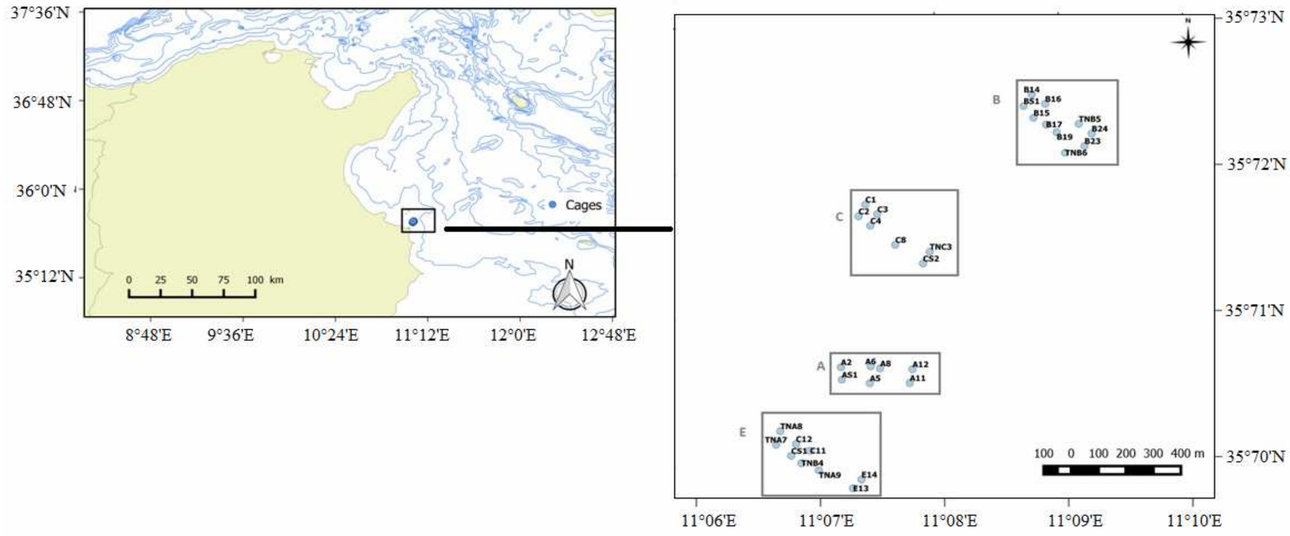

Figure 1: Map of the study area including the arrangement of cages

The feed distribution and maintenance operations of the cages are made daily depending on weather conditions. Hence the presence of the feed distribution boat and other facilities do not affect either the bottlenose dolphins group formation or their behavior. Dolphins were sampled from a boat during daily surveys (Blasi & Boitani 2012). Surveys were conducted in the morning in good light conditions and calm waters (sea state based on Beaufort scale less than 3).

GROUP FORMATION

We define a group as one or more dolphins observed in the study area at the same time and involved in the same activities, allowing us to detect social association. Group size and composition were assessed visually *in situ* and data were verified later with photographs and video taken during each sighting. Attempts were made to:

(i) photograph the dorsal fin with at least 5 pictures, in the same sighting, for each individual observed in the groups excluding unmarked individuals,

(ii) choose only good quality photographs with the dorsal fin perpendicular to the plane of the photograph and dorsal fin broad enough to identify surely the individual,

(iii) identify individual based on presence of marks and notches, location and size of these two type of marks on the trailing edge of the dorsal fin and directly behind the dorsal fin. Dolphins without marks are considered as unmarked individual and are excluded from the social analysis to minimize recognition bias.

Since that the exact age of individuals could not be determined, individuals were assigned according to their body size to one of two age classes: adults when individuals estimated to be longer than 2.5 m or calves when body size is less than the length of an adult (Díaz López 2006b). A dolphin having a higher degree of scarring, through intraspecific interactions, was determined as “probable males” (Tolley et al. 1995). If calf was sighted in close proximity of a particular adult more than twice, this adult was classified as a ‘probable female’ (Barnes 2011). If the dolphin genital area was seen, a definite distinction could be made. Under water observations help in sex determination by direct observation of the genital slits. According to Díaz López & Shirai (2008), males were identified by a gap between the uro-genital slit and the anus, lack of mammary slits, or observation of an erection. Females were identified by observation of mammary slits.

Individuals observed were photographed using a digital camera Canon EOS 70D equipped with 18-55 mm and 75-300 mm telephoto zoom lens. Video recordings were made *via* GoPro Hero4. Group sizes variation was tested using a non parametric Kruskal–Wallis-test to assess the monthly difference of group sizes. Composition fluctuations in-group size were tested using a non-parametric Mann-Whitney-U-test to evaluate the difference between group sizes in presence and absence of calves. Statistical significance was tested at the $p < 0.05$ level.

IDENTIFYING INDIVIDUAL DOLPHINS FROM PHOTOGRAPHS

Best photographs taken of every dolphin in each encounter were selected and matched with a catalogue of identified individuals. According to Wilson et al. (1999), all of the type’s marks are used to identify individuals. If a match was not found, the un-matched individual was given a unique identification code (T#) and added to the catalogue. Identifications and details relating to group companionship, such as sighting period, location and depth were recorded on a database.

BEHAVIORAL SAMPLING AND MEASURES

One of the main objectives of this study was the determination of the behavioral budgets of the bottlenose dolphins in order to assess the percent of time that animals spent in different behavioral states. According to (Weaver 1987) and (Bearzi 2005) a behavioral state is defined as a broad category of activities that integrates a number of individual behavior patterns into a recognizable pattern. We divided the observed behaviors into "Travelling", "Socializing", "Foraging" and "indeterminate" (Díaz López & Shirai 2010). According to Díaz López (2006a), we stratified the foraging groups into two exclusive categories: (i) opportunistic feeding when the dolphins were engaged in feeding activities from the fish farm, (ii) not opportunistic feeding when the dolphins were engaged in feeding activities far of the fish farm. In opportunistic feeding category six sub-feeding categories can be observed and are described in Díaz López (2006a). Behavioral data were collected using focal group continuous sampling (Mann 1999). As mentioned by Hanson & Defran (1993), the main activity of focal groups was recorded every 3 min intervals, which is considered as adequate time allowing both observation and recording of dolphin behavior. The frequency of sub-opportunistic foraging strategies observed was compared to that expected if they occurred randomly. A Chi-square test was used to test for equal distribution of sub-opportunistic foraging strategies between observed and expected values (Díaz López 2006a). The variation of group sizes was tested using a nonparametric Kruskal–Wallis-test to assess both the difference on group sizes.

SOCIAL ORGANIZATION

The animals photographed in the same group and having the same foraging category were considered associated. The Coefficient of Association (CoA) illustrate the thickness of the Coefficient of Association (CoA) between dolphins gathered in the same pod. We used the Half-Weight Index (HWI) as a measure of the CoA

$$\mathbf{HWI} = 2N / (Na + Nb)$$

Where N is the number of sightings that included both dolphins a and b, Na, is the number of sightings that included dolphin a but not dolphin b, and Nb is the number of sightings that included dolphin b but not dolphin a. The coefficients of association (COA) is ranging from zero to one, with zero representing two animals never seen together, and one representing two animals never seen apart. We plotted the HWI in the different feeding categories for each dyad against each other to determine whether strength of association differed between both feeding behavioral categories. We used a permutation test to test for nonrandom associations for all data combined against the null hypotheses that dolphins associate randomly with one another. The same test was used to test for nonrandom associations in each reticles and for nonrandom associations in each of the feeding activities. The observed association matrix was randomized 3,000 times with 1000 trials per permutation for each analysis. Associations were permuted within daily sampling intervals to remove possible demographic effects. The sociogram facilitated a presentation of individual association data such that it was possible to assess the social structure of dolphins identified during each year of study. In the sociogram, dolphins are represented by numbers around the perimeter of the diagram. The thickness of the adjoining lines within the diagram represents the strength of associations between individuals.

RESULTS

SURVEY EFFORT

During three months of study, 58 sightings were recorded; 28 were surface encounters and 30 underwater. During these, 142 groups of bottlenose dolphins around the fish farm area were sighted. The total time spent in the presence of dolphins was 1185 min, with a mean sightings duration of 18.29 ± 22.12 min.

GROUP FORMATION

142 dolphins schools were photographed during the total encounters. The group sizes of bottlenose dolphins is ranged from 1 to 8, with a mean size of 2.39 ± 1.57, median = 2.0 (SE=0.13). The most frequently encountered group sizes contained a solitary individual in 35% of cases followed by dyads and triplets with 25% and 15% of encountered group sizes, respectively (**Fig. 2**).

The schools group sizes seemed to increase with the progression of the study period, but the Kruskal-Wallis-Test shows that no significant differences in group sizes between months (d.f. = 2; H = 1.69; p =

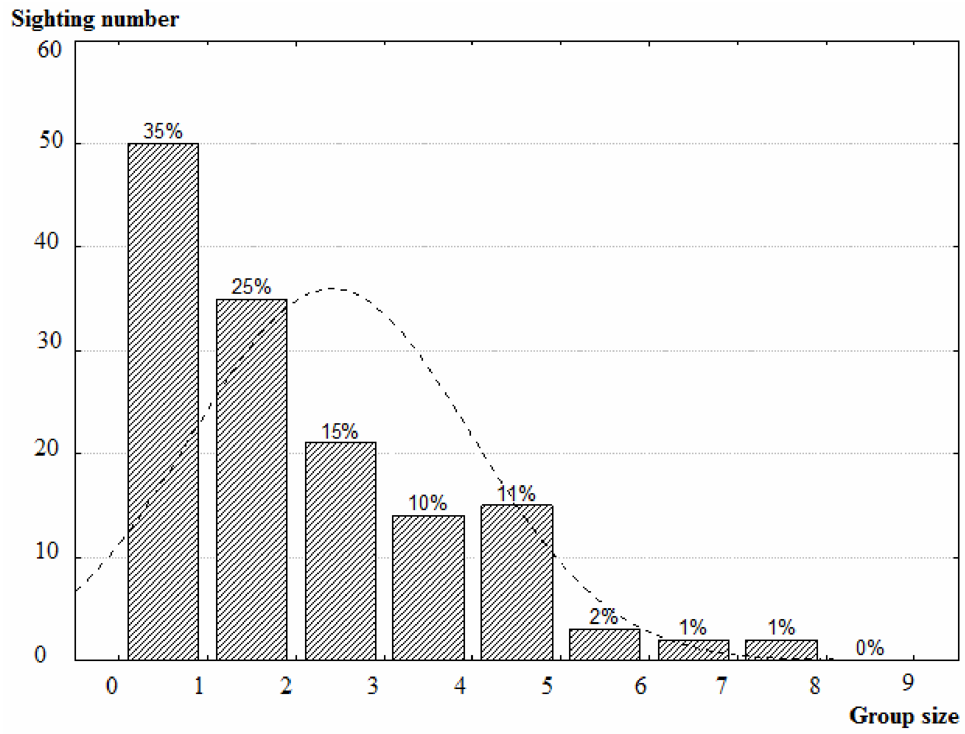

Figure 2: Frequency distribution graph of the bottlenose group sizes

0.443). From142 encounters recorded, 17.61% of the analyzed groups (n=25) have at least one immature. Calves were sighted in all survey months. Groups containing calves ($\bar{x}$=3.82± 1.60) were significantly larger than groups without calves ($\bar{x}$=2.08± 1.39) (Mann-Whitney-U-test, P <0.001).

BOTTLENOSE DOLPHINS FISH FARM FIDELITY AND HABITAT USE

Forty-three bottlenose dolphins including adults and calves were photographically identified during the study period. Each of them was seen at varying frequencies up to a maximum of 31 times ($\bar{x}$= 8.28±5:89). We succeed to determine the age of 36 adults and 4 calves, whereas 3 individuals are remained with indeterminate age. 9 dolphins were positively identified as males by lack of association with a calf or observation of their genital slits. Only one dolphin was identified as female based on the observation of genital and mammary slits. 36 individuals (83.72%) of the animals archived exhibited dorsal marks and are archived in photo-identification catalog.

BEHAVIOURAL SAMPLING AND MESURES

In order to being able to analyze how bottlenose dolphin use the fish farm over time, the overall behavioral budget was represented in **Figure 3**. The encountered bottlenose dolphins observed sharing its time between socializing (16%; $\bar{x}$= 18:05±11:34min) and traveling (18%; $\bar{x}$=15:40±13:07min) activities. The remain of behavior budget is dedicated to foraging activities (65%; $\bar{x}$= 15:04±12:24min) where feeding on fish farm is predominant (61%; $\bar{x}$= 14:19±12:17min) and only 4% of its time are devoted to *not opportunistic* activities ($\bar{x}$= 21:17±13:33min). A Kruskal-Wallis-Test showed a significant differences in feeding activities (d.f. = 1; H = 12.22; p < 0.001). In *opportunistic feeding* activities, 4 sub-categories were mostly noted (**Fig. 4**). Some sub-categories are seen more than others are: "*Encircling cage*" are mostly sub-*opportunistic feeding* categories observed (44%) followed by "feeding rush"(25%). "Feeding during fish farm operations" (13%) and "carrousel swimming" (19%) are less observed. The frequency of the different sub-feeding strategies was not expected by chance or random (Chi-Square test=689.76, df = 5, *p*< 0.01).

The mean group size of dolphin encountered near to fish farm is compared with group size of bottlenose dolphin inhabiting far from the fish farm. 92 groups encountered are involved in feeding activities with 15 groups foraging near the fish farm ($\bar{x}$=3.08± 1.2) and the rest foraging in offshore ($\bar{x}$=2.10±1.57). A Kruskal-Wallis-Test showed a significant differences in group sizes foraging categories (d.f. = 1; H = 3.77; p = 0.05).

SOCIAL ORGANISATION

The coefficient of association index was calculated only for the adult dolphins seen more than five times. 3000 random permutations were run and compared to

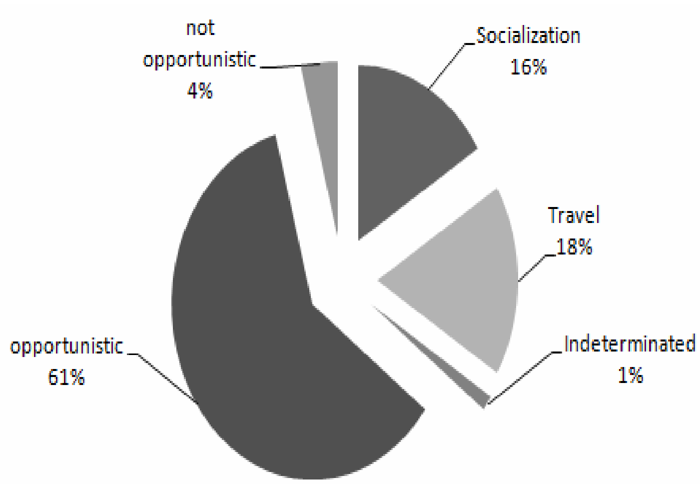

Figure 3: Frequency of behavioral patterns seen in bottlenose dolphin in study area

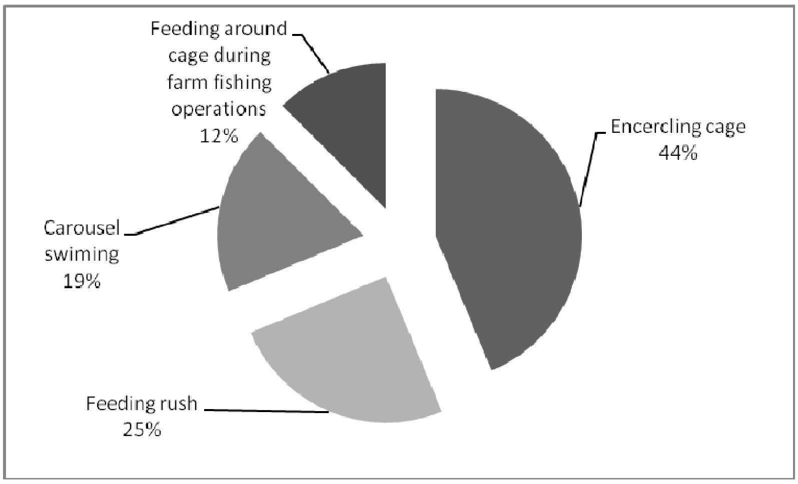

Figure 4: Distribution of bottlenose dolphin sub-opportunistic strategies observed during the study period

the real data, the *p* value of the SD was 0.99, indicating that the real data were significantly different from random. The mean coefficient of association was found to be significantly higher than the observed mean (random permuted $_{mean}$ = 0.00006, real $_{mean}$ = 0.18), this suggest that the observed individuals show preference or avoidance associations tendency. In addition, the reel standard deviation was found to be higher than the random one (SD_{real} = 0.21 versus SD_{random} = 0.00007). The distribution of CoAs for all individuals was clearly skewed towards lower values with many of the sampled animals showing no association at all. Coefficients of association index was ranged from 0 to 1.00, with mean of 0.09 (± 0.28). The maximum CoAs was ranged from 0.14 to 0.77.

Associations analysis of individuals, observed per reticles, showed that individuals choose their companionships to be preferred or avoided, and it is not in any case haphazard (Tab. I). Likewise the association analysis per feeding categories is differed from random. The standard deviations of the real association indexes were significantly larger than for the random permuted data ($p<0.001$, Tab. II). All associations depending on feeding categories can be seen in the sociogram (Fig. 5). It showed individuals seen together and having the same feeding categories. In terms of feeding aggregations; non opportunistic Individuals (n=12) seem to have a stronger association than their opportunistic equals (n=22). In addition the 12 aforementioned individuals (those of opportunistic feeding) have also been seen aggregated for opportunistic feeding behavior. These results could explain the fusion-fission structure in this bottlenose dolphin population, which is also influenced by prey abundance around the fish farm.

Table I: Individuals associations analysis per reticles

Reticles	Reticle A		Reticle B		Reticle C		Reticle E	
	Real	Random	Real	Random	Real	Random	Real	Random
Mean	0.09797	0.00003	0.08881	0.00003	0.08881	0.00003	0.08881	0.00003
S.D	0.21316	0.00007	0.22672	0.00008	0.22672	0.00008	0.22672	0.00008
C.V	2.17569	0.00073	2.55284	0.00085	2.55284	0.00085	2.55284	0.00085

Table II: Real and random data of half-weight indexes (HWIs) across the two feeding categories

Feeding categories	Real		Random		P value
	Mean	SD	Mean	SD	
Opportunistic	0.07099	0.12449	0.00002	0.00004	< 0.0001
Not opportunistic	0.22172	0.32271	0.00007	0.00011	< 0.0001

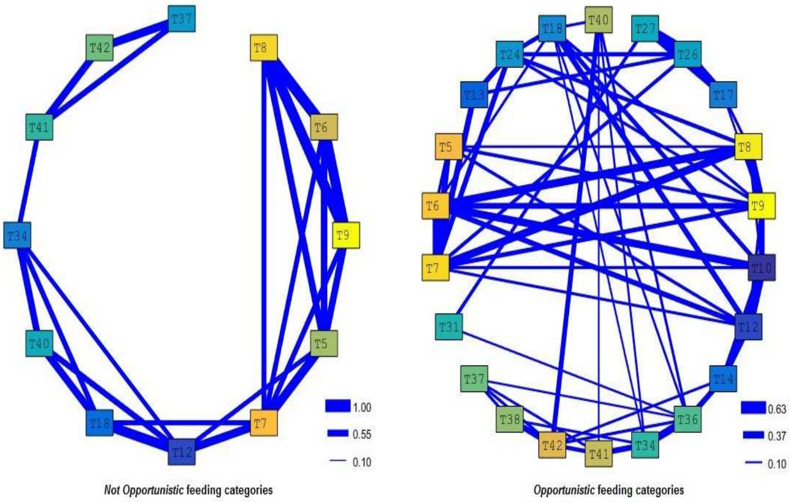

Figure 5: Sociogram of bottlenose dolphins off Northeastern of Tunisia during *opportunistic* and *not opportunistic* feeding activities.

DISCUSSION

Interactions between fisheries and bottlenose dolphins have been frequently reported and involved for almost all existing fishing gears, but their interaction with marine fish farm have never been studied in Tunisia. This study contributes to improve the knowledge on the bottlenose dolphin's interaction with marine fish farm, in the eastern Tunisian coasts by studying demography, behaviour and social structure pattern. Owing that this is the first results on the interactions between bottlenose dolphins and aquaculture activities in Tunisia, we will compare our results with other site case studies.

By examining the results of this study, it is clear that the presence of bottlenose dolphins is regular in the fish farm area during the study period. Some individuals interacted with the fish farm on a regular basis, while others were presented less often. The repeated observations of marked and unmarked individuals around cages suggest individual habitat use and preference for this area. The knowledge of habitat use is necessary for defining boundaries to such areas and for understanding how these areas are used by the bottlenose dolphins.

Group size of bottlenose dolphins encountered in the study area is smaller than those observed during the prospecting survey of the National Institute of Sciences and Technologies of the Sea in 2003, where the group size was constituted by groups of 1 to 8 with an average group size equal to 5 individuals (Ben Naceur et al. 2004). The smaller mean group size was also observed in the North-eastern of Sardinia (Díaz López, 2006b; 2008; 2012) where the main average group size was recorded in 2006 ($\bar{x}$=4.35±0.37, Median=4). Therefore, group size was influenced by the presence of calves, in fact groups tending to be larger when individuals of this age classes were present. The influence of calves in group size have been reported for several areas, as the North-western coastal of Sardinia, Italy (Díaz López 2012).

The finding that bottlenose dolphin spend more time in the study area mainly in the vicinity of the cages seems to confirm the hypothesis that this species is an opportunistic predator manifesting ethological plasticity in response to the variety and the availability of prey (Diáz López 2006a). It is also probable that bottlenose dolphins easily benefit from existing resources when it is available in benches or concentrated in the nets (Benmessaoud et al. 2013) or under fish farm cages, which increase their predation rates while decreasing energy expenditure related to catching prey (Díaz López 2008). In this study, bottlenose dolphin budget behavior was shared between foraging, travelling and socializing. The same finding was advanced by Diaz López (2012) in the North-eastern part of Sardinia, Italy, which indicated that bottlenose dolphins are engaged for foraging activities (78%) followed by travelling (16%), socializing (5%) and resting (1%). Dolphins are seen feeding both individually and cooperatively around the fish farm cages, or in offshore, the same behavior was observed in Sardinia (Díaz López 2006b). However, there are a few detailed on different categories of opportunistic feeding because it need an underwater observations. We had the opportunity to make these kind of observations due to the daily scuba-divers presence. Four sub-opportunistic feeding activities (Encircling cages, feeding rush, Feeding during fish farm operations and carrousel swimming) are reported and described by Bel'Kovish et al. (1991), Connor (2000) and Díaz López (2006b). Scuba divers confirm that bottlenose dolphins exploit easily the concentrated feed, which reduce the competition between individuals, as observed in the Sardinian fish farm (Díaz Lopez 2006a; b). We noticed during the underwater-observations, that when the dolphins are present near the caged sea bass, fish stops feeding and plunges to the bottom of the close to gilthead sea bream cage, which induces a stress that manifested by a shock propagating in the cage. However, no direct damage was observed by divers, contrary to many fish farms of Italy, Spain, Greece, Israel and Malta where bottlenose dolphins are causing physical and economical damages related to the depredation and stress they cause to the fish (Díaz López 2012).

Acknowledgements

This study would have not been possible without the willingness of many fisherman's to be interviewed. I also thank numerous colleagues and volunteers for their assistance and support with data collection. Anonymous reviewers and the editor made valuable comments, allowing me to improve the text, I thank them all.

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