Abundance and distribution of bottlenose dolphins, *Tursiops truncatus*, in Panama City, Florida.

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ABSTRACT

The seaside resort of Panama City Beach, Florida, in the Gulf of Mexico, is famous for its population of bottlenose dolphins, *Tursiops truncatus*, living in the waters of St Andrew Bay. Although little is known about this dolphin population, it has become a major tourist attraction. A field survey was conducted in order to document the abundance as well as the distribution of bottlenose dolphins in this area. Photo-identification and mark-recapture techniques were used to conduct this survey. Our statistical model estimated a population range between 58 and 183 individuals, according to the season. During the studied period, 263 dolphins have been photo-identified. The common group size is five dolphins, but is modulated by zones and moment of the day. Groups size increase when new-borns or calves are present. Bottlenose dolphins are not equally distributed in the study area: probability of sightings is higher in the Gulf of Mexico than inside the St Andrew Bay. Tidal current influence also the presence of bottlenose dolphins in the study area.

Keywords: bottlenose dolphin, *Tursiops truncatus*, abundance, population size, photo-identification, Panama City, distribution, tidal current, size fidelity.

INTRODUCTION

Bottlenose dolphins are common in coastal waters around the world occupying a variety of marine habitats (Jefferson et al. 1993) and are therefore readily accessible to many people. A population of bottlenose dolphins, *Tursiops truncatus* (Montagu, 1821) lives in the seaside resort of Panama City, Florida, and the regular presence of these dolphins has been well known by local population. Therefore, this bottlenose dolphin population is increasingly becoming a popular tourist attraction.

Studies on dolphins have been conducted in several regions of the world; they focalize mainly on the following topics:

-population size estimation (Hammond, 1986; Hammond and Thompson, 1991; Wilson et al. 1999; Baird et al. 2001; Cañadas and Hammond, 2006; Bearzi, 2008);

-demographic parameters (survival rate, mortality and fecundity rate) (Wells and Scott, 1990; Kogi et al., 2004);

-social structure (Wells et al., 1987; Rossbach and Herzing, 1999; Connor et al. 2000; Quintana-Risso and Wells, 2001; Chilvers and Corkeron, 2002; Connor, 2007);

-distribution (Berrow et al., 1996, Wilson et al., 1997; Nojd, 2001; Baird et al., 2002; Griffin and Griffin, 2003; Stockin et al., 2006);

-behavioural study (Würsig and Würsig, 1979; Shane, 1990a, b; Dudzinski, 1996; Mann and Smuts, 1999; Acevedo and Parker, 2000 Bejder et al. 2006a);

-acoustic study (Acevedo- Guiterrez and Steinessen 2004; Hastie et al. 2006; Nowacek, 2005; Philpott et al. 2007);

-tourism effect on cetacean population (Acevedo, 1991a; Nowacek et al., 2001; Hale, 2002; Constantine et al., 2003; Glen, 2003; Hastie et al., 2003; Samuels and Bejder, 2004; Bejder et al. 2006b).

Studies of *Tursiops truncatus* habitats, daily movements and seasonal migrations, adaptations to human activities such as fishing and boating, relations with environment, studies of behavioral patterns in function to ecological factors such as prey distribution and tidal regime, all contribute to understand better the relationship between behavior and ecology in this species.

Several studies conducted in estuarine systems show that these habitats are regularly used by dolphins as feeding areas (Acevedo, 1991b). The particularity of Panama City is the presence of a bay, St Andrew-Bay, only connected to the Gulf of Mexico by the Channel entrance. This area is characterised by important water movements caused by the tides with as a result the presence of a lot of fish (Bouveroux, 2004).

The aims of this study are (i) to estimate the abundance of dolphins living in Panama City, and (ii) to know their distribution in the study area. Very little was known about this dolphin population before the present study; we therefore created a photo-identification catalogue, in order to recognise individuals. Indeed, previous researches on animal behavior and ecology recognized that aspects of their studies were enhanced by the recognition of individuals (Würsig and Jefferson, 1990).

A better knowledge of the population ecology will allow to improve the protection of this population regarding growing human pressure.

MATERIALS AND METHODS

Study area

Panama City (30°07'N, 85°43'O) is located on the north-west coast of Florida, in the area called the "panhandle" (Figure 1). 5000 years ago, a sand barrier created by the action of currents, tide and waves have given birth to the St Andrew Bay (Spinner, 1994). To facilitate the geographical location of dolphins, six zones of different size were delimited, based on the site topography:

- Zone 1: Grand Lagoon (13,73 km2);
- Zone 2: St Andrew Bay (109,26 km2);
- Zone 3: St Andrew Bay South East (76 km2);
- Zone 4: West Jetties (52,8 km2);
- Zone 5: East Jetties (70,96 km2);
- Zone 6: Channel Entrance (5,74km2).

We have also defined two majors sectors:

1. Interior Sector (INT): St Andrew Bay waters, composed by zones 1, 2 and 3
2. Exterior Sector (EXT): The Mexico Gulf waters, composed by zones 4 and 5

Three different time periods were also determined:

-AM: 08h00-11h59 hours

-PM1: 12h00-15h59 hours

-PM2: 16h00-20h00 hours.

Sighting records

The surveys were conducted using different boats, smaller than five meters with powered between 55 and 85 HP outboard engine. Fieldwork was shared out in four stays:

-20st March to 31st May 2004;

-28st September to 31st November 2005;

-20st July to 21st August 2006;

-1st June to 25st July 2007;

During those four field periods, 162 survey days (49 days in 2004; 53 days in 2005 and 25 days in 2006; 35 days in 2007) were carried out and a total of 835h51 were spent searching for and observing dolphins in the waters of Panama City Beach. Observations could only be carried out in a Beaufort sea state of three or less to optimise sightability. A dolphin sighting was recorded when any dolphin was encountered during a survey.

Photo-identification study

Photo-identification technique was used to estimate the abundance of bottlenose dolphins living in the St Andrew Bay area. To avoid problems associated with pseudo-replication, the photo-identification survey was not carried out all days (Hammond and Thompson, 1991). Therefore, we have divided each fields work into several sessions of photo-identification, evenly distributed over the whole stay. Within the studied period in 2004, 12 days were devoted to photo-identification. Those 12 days were gathered together into four sessions of three days. In 2005, six photo-identification sessions of five days, each five days, were realised; in 2006, three sessions of five days were achieved. Finally, in 2007, four sessions of five days were accomplished. So, a total of 77 sighting occasions have been conducted.

Surveys followed a predetermined routes (Figure 3) until a school of dolphins was encountered, whereupon the survey vessel slowly approached the group of dolphins and ran parallel to its course.

Group size was assessed several times during the encounter, including neonates. Geographical position were recorded using a GPS (Garmin GPSMAP 76S), and photo-identification pictures taken using a Canon EOS 350D camera equipped with 18-55 mm (f 3.5-5.6), 35-80 mm (f4.5-6) or 90–300 mm (f4.5-5.6) zoom lenses. A school was defined as “all animals within 100 m of each other engaged in similar activities” (Wells et al., 1987). Individuals were identified from photographs using unique natural markings such as nicks and notches in the dorsal fin and toothrake marks, scratches, scars, and skin lesions on the dorsal fin and back (Würsig and Würsig, 1977; Wells and Scott, 1990; Wilson et al., 1999). Neonates were distinguished from other age classes by their small size, sunk skin, and the presence of foetal bands (vertical light lines on the sides of the body). Calves differed from neonates because foetal bands were no longer present (Grellier et al., 2003) nor they were observed to swim in echelon position with their mothers. Juveniles were characterised by a body size up to 2/3 the size of an adult (Wells et al. 1987). Photo-identification still remains one of the best and non-invasive method used for gathering information about cetacean societies in the wild (Culloch, 2004).

Dolphins harbouring sufficient markings were identified from a high-quality picture. Only good quality photographs (in focus, not fuzzy, un-obscured, with the dorsal fin relatively perpendicular to the plane of the photograph and without spray) were used in the analyses (Baird et al., 2001). A photo-identification catalogue was created, indexing all recognised individual.

When a dolphin was identified, we gave it an identification code XYZ:

X, the age class: *A= adult; J= juvenile or C= calf*
Y, the sex: *M= male; F= female or X= unknown*
Z, the individual number

Such a codification allows faster identification. For instance, AF30 is the thirtieth identified dolphin, and it is a female adult. Finally, in order to facilitate the comparison of dorsal fins in the photo-identification catalog, we used the classification system of dorsal fins designed by Urian (Urian et al. 1999).

Estimation of population size

Population size, based on the number of marked and recaptured individuals, was carried out using robust design model (Pollock, 1982). The robust design model uses characteristics of closed population abundance estimates and open population estimates. Moreover, the abundance will be determined during multiple short term periods with closed population models combined to the Jolly-Seber open population model to estimate survivorship and emigration rates.

The robust design model was preferred to close population models for two reasons:

(i) Evidence of dolphins' migrations in the population living in Panama City: close to Panama City, another bottlenose dolphins population lives in St Joe Bay, a large bay at approximately 30 nM from the Channel entrance of Panama City. A scientific research is also conducted on this dolphins' population, and some of dolphins were tagged by researchers. Among those, few tagged dolphins were also observed in Panama City.

(ii) Evidence of mortality and birth: during fieldwork, new-borns and dead dolphins were observed.

Therefore, our model is based on the assumption that population are open in the whole fieldwork, while it is considered as a closed population during sessions of photo-identification because the sampling periods were short (3 or 5 days).

To analyse the data, the encounter histories for the identified animals were first transcribed into a binary: the number ‘1’ indicating that an animal has been sighted, and ‘0’ indicating that the animal has not been sighted during mark-recapture periods. Those mark-recapture histories were subsequently analysed using the program MARK.

In the robust design, the heterogeneity model - M_h - (means that the capture probability vary for individuals) for closed population was selected because the dolphin population in Panama City, has been fed by human during several years. Despite of its prohibition by the *Marine Mammal Protection Act*, this practice is still observed in Panama City, which create an heterogeneity in the capture probability of some individuals often seen begging close to boats (Samuels and Bedjer, 2004; Bouveroux and Mallefet, 2008).

Distribution study

For each survey, all dolphins seen were recorded as well as the hour of entry and exit in each zone as well the tidal current.

RESULTS

Photo-identification

Between 2004 and 2007, a total of 16,766 pictures were taken. 263 bottlenose dolphins were identified and indexed in a photo-identification catalog. As new-borns and calves did not have enough distinctive features on their dorsal fins, they were not included in the analysis of population size, except two calves, because they showed clear features. The catalogue contains the following information: right side and/or left side of each identified dorsal fin, notes such as particular behaviors (regular beggar) or life history (presence of hooks in the jaw, eye or other parts of the body, shark bites or female with a new-born or calf) and months where each individual was observed.

Population size estimation

The abundance of bottlenose dolphins in Panama City seems to be quite stable during summer and fall. However, in June 2007 the abundance reach up to 183 dolphins, while the weakest abundance is observed during the spring 2004 with only 58 dolphins in the population (Figure 4). The discovery curve of new dolphins do not cease to increase along survey seasons. However, three times more dolphins were identified during the fall 2005 (95 dolphins) than during the summer 2006 (34 dolphins) (Figure 5).

Site fidelity

Site fidelity of bottlenose dolphins living in the study area was estimated using the proportion of dolphins observed a least once at each seasons, but also the proportion of dolphins seen only once during the whole photo-ID study. Our study reveal that 12,5% of dolphins were seen each years on the field and are therefore considered as resident dolphins, but 58,5% of the population were observed only during one season (Table 1). On 77 capture occasions realised on field, 42% of the dolphins were only captured once and 7% were captured more than 21 times (Figure 6). The greatest proportion of dolphins encountered in Panama City are considered to be rare individuals since they are only seen once.

We have evaluated the seasonal variation in the re-sighting probabilities (Figure 7). Our results show for each season more than 75% of dolphins seen between once to five times. A greater number of dolphins are re-sighted during fall 2005 and summer 2007.

Distribution

School size

The most common group size observed is five dolphins (4,9 dolphins) with a range from one to 31 dolphins. However, one-way ANOVA have been done to show the influence of zones and the moment of the day over the average number of dolphins. On average, a larger group size is observed in zone 4 (8,1 dolphins) than in others zones ($p<0,0001$), while in the zone 1 the number of dolphins in a group is the weakest (1,7) (Figure 8). There is also a significant difference between periods of the day on the average group size ($p<0,0031$); more dolphins are seen in a group during the afternoon than the morning (AM: N=4,2; PM1: N=5,1; PM2: N=5,2) (Figure 9).

Finally, we note an increase of the average number of dolphins when new born or calves are present in a group (Figure 10 and 11)

Frequency of sightings

The presence of dolphins inside the study area varies in accordance with zones and moment of the day. The frequency of dolphin sightings is the weakest in zones 1 and 3, while in the zone 6, the probability of sightings is the highest (30,93%) (Figure 12). The chi-square test confirms that the observation frequencies vary significantly according to zones ($p<0,0001$).

Observation frequency of dolphins is significantly different between moment of the day ($p<0,0001$) the highest frequency being observed between 12h00 hours to 15h59 hours (PM1) where it reaches up to 45,83%. In the morning and in the evening, frequency of sightings are identical (27%) (Figure 13).

When we analyse the frequency of dolphin sightings in all zones and for each moment of the day, we note that in the zone 4 and 6, observation frequency increases during the day, while it seems to be constant in the zone 2. In the zone 1, the frequency of dolphin sightings is weak between 12h00 and 15h59 hours (PM1); in the zone 5 the frequency of sighting decreases strongly at the end of the day, between 16h00 and 20h00 (PM2). Finally, in the zone 3, frequency of sightings is the highest in the morning, between 8h00 and 11h59 hours (Figure 14).

Tidal influence

The presence of bottlenose dolphins in different sectors of the study area has been analysed as function of the tidal current. The results show that dolphins presence in different sectors vary significantly with tidal flow ($p<0,0067$). During flood tide, sighting frequency of dolphins is higher in the Interior sector (EXT: 26,71%; INT: 38,63%) while during ebb tide, sighting frequency is higher in the Exterior sector (EXT: 38,86%; INT: 31,93%) (Figure 15).

DISCUSSION

Population size estimation

This first study on the bottlenose dolphin population size in Panama City indicates that the abundance of animals seem to be quite stable throughout fall and summer, excepted in June where the abundance increase. In spring 2004, we observe a decrease of abundance of dolphins. Other studies reveal also a seasonal difference in the abundance of bottlenose dolphins population. In the study conducted by Balmer et al. (submitted), the bottlenose dolphins living in St Joe Bay shows a seasonal fluctuation in the abundance. In his study, all models estimated reveal the highest abundance in May 2005 and the lowest abundance in July 2005, that is exactly the opposite of our result, suggesting a migration between both areas. However, according to Hurbard et al. (2004), bottlenose dolphins in Mississippi Sound varied seasonally, peaking in summer and dropping to a low in fall.

Photo-identification technique allowed us to identify 263 individuals. The difference between estimated abundance (183) and number of identified dolphins (263), may be the result of dolphins' movements and migrations with other populations living close to our study area. Indeed, (i) mark-recapture history shows that 42% of dolphins were seen between only once; (ii) over 263 identified dolphins, six tagged dolphins were observed. These dolphins have been tagged by researchers working in St Joe Bay, located approximately at 30 nM from the Channel entrance of Panama City. These observations provide direct evidence on movements of dolphins between two study areas; (iii) Finally, in the study, it must be pointed out that the West Bay and the East Bay of Panama City were never prospected, while we suspect that some dolphins swim in those regions.

So, the population of bottlenose dolphins in Panama City appear to be an open population along the fieldwork. In addition, two newborns and five dolphins were observed on field in 2004 and three dead dolphins in 2005. All these information confirms the model used to estimate the abundance: a closed population during short photo-identifications sessions (3 or 5 days) and an open population across months.

Photo-identification catalogs have been also created by the researchers working in St Joe Bay and Apalachicola Bay. One study on dolphins' migrations between St Joe Bay and Panama City will be realise by comparison of both photo-identification catalogs.

Comparison between photo-identification catalogs will allow to estimate the importance of dolphins' migration between St Joe Bay and Panama City.

Dolphin migrations have been reported in other studies, for instance in the Shannon estuary in the west of Ireland (Rogan et al., 2000) and in the Moray Firth in the NE of Scotland (Culloch, 2004), where the number of dolphins increase during the summer, corresponding to a seasonal distribution. The same way could explain the peak we observed in the abundance in June.

School size and distribution

This study shows that the mean schools size of dolphins is evaluated to five individuals. This number changes according to zones and moment of the day. Indeed, the average number of observed dolphins is higher in zone 4 (8 dolphins) than in other zones (between 2 and 4 dolphins). This variation in the group size could be related to hunting activities. Indeed, generally, during hunting activities, a greater number of dolphins is required especially when hunting is cooperative (“carousel” techniques, “wall” techniques). The behavioral observations on the field show that feeding is most frequent in zone 4, where the mean number of dolphins in a group increases (Bouveroux and Mallefet, 2007). Shane (1990a) mentioned that school size for coastal bottlenose dolphins depends on habitat and activity. Groups with new-borns or calves were larger than groups without new-born or calves. The same results are described in the studies conducted by Campbell et al. (2002) in Turneffe Atoll, Belize and by Hubart et al. (2004) in Missippi Sound.

Frequency observation of dolphins is higher inside the Channel entrance and close to the mouth of the Channel, single link between St Andrew Bay and Gulf of Mexico. This preferential distribution could be due to the topography of this area. Indeed, there is a strong tidal current and a more important depth in the channel. A lot of fish are also present in this zone and near the jetties. The abundance of fish represents an interesting feeding area for the dolphins (Bouveroux, 2004). Their most frequent preys are ladyfish, *Elops saurus*; jackfish, *Seriola zonata*; spanish mackerel, *Scomberomorus maculatus*; sheepshead, *Archosargus probatocephalus;* striped mullet, *Mugil cephalus* and blue fish, *Pomatomus saltatrix* (personal observation). Link between fish abundance and dolphin distribution has been highlighted in previous studies around the world (Wells et al., 1980; Barros and Odell, 1990; Acevedo and Burkhart, 1998; Barros and Wells 1998; Acevedo and Parker, 2000). It appears that bottlenose dolphins favour coastal waters where nearshore fish lives (Acevedo and Burkhart, 1998). In their study, Rogan et al. (2000), showed that significantly more dolphin groups were encountered in the mouth of estuary than in inner zones. Confirming that dolphin distribution follows prey distribution since estuary waters is known to be rich in fish species. Further seasonal studies on bottlenose dolphin food habits and prey distribution are necessary to describe variations in dolphin distribution and habitat use in Panama City.

The distribution of dolphins in Panama City seems to be influenced by the tidal current. Short-term movements of dolphins can be influenced by tidal sate, because that affects the movement of marine sediment and fish movements along tidal font (Johnston et al. 2005). In some places, activities such as feeding and resting can be related to current strength and tide state (Mendes et al. 2002). According to Hanson and Defran (1993), feeding behaviors increase during periods of high tide current. In the study of Mendes et al. (2002), bottlenose dolphins were significantly more abundant in the study area during flood tide, especially when the front was stationary. For Weeks et al. (1988), movements of dolphins in the San Jacinto River were generally observed against the tidal current. Influence of tidal current on others marine mammals was also documented. In the study of Felleman (1991), killer whales (*Orcinus orca*) moved with the flood and against ebb current of the tide. For harbour porpoises (*Phocoena phocoena*), relative density was significantly higher during flood than ebb tide phase (Johnston et al. 2005).

Work is in progress in order to characterize the behavioral activities of dolphins in the various zones of Panama City.

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FIGURE LEGENDS

Figure 1. Map of the study area showing the study area divided into six different zones delimited based on easily recognisable landmarks. Interior sector is composed by zones 1, 2 and 3 (corresponding to St Andrew Bay waters) and exterior sector is composed by zones 4 and 5 (corresponding to Gulf of Mexico waters).

Figure 2. Typical transects used for surveys of bottlenose dolphins during fieldworks between 2004 and 2007.

Figure 3. The discovery curve of new dolphins along survey seasons with the evolution of dolphins captures for each seasons.

Figure 4. Number of new individuals identified during seasons and discovery curve for bottlenose dolphins in Panama City.

Figure 5. Proportion of individuals seen according to the number of sightings.

Figure 6. Proportion of individuals seen according to the number of sightings and across seasons.

Figure 7. Average number of dolphins as a function of the six different zones.

Figure 8. Average number of bottlenose dolphins regarding the moment of day. AM, morning (08h00-12h00); PM1, afternoon, (12h00-16h00); PM2, evening (16h00-20h00).

Figure 9. Average number of dolphins in a group as a function of the number of new-borns present.

Figure 10. Average number of dolphins in a group as a function of the number of calves present.

Figure 11. Observation frequency of bottlenose dolphins regarding zones.

Figure 12. Observation frequency of bottlenose dolphins regarding the moment of the day.

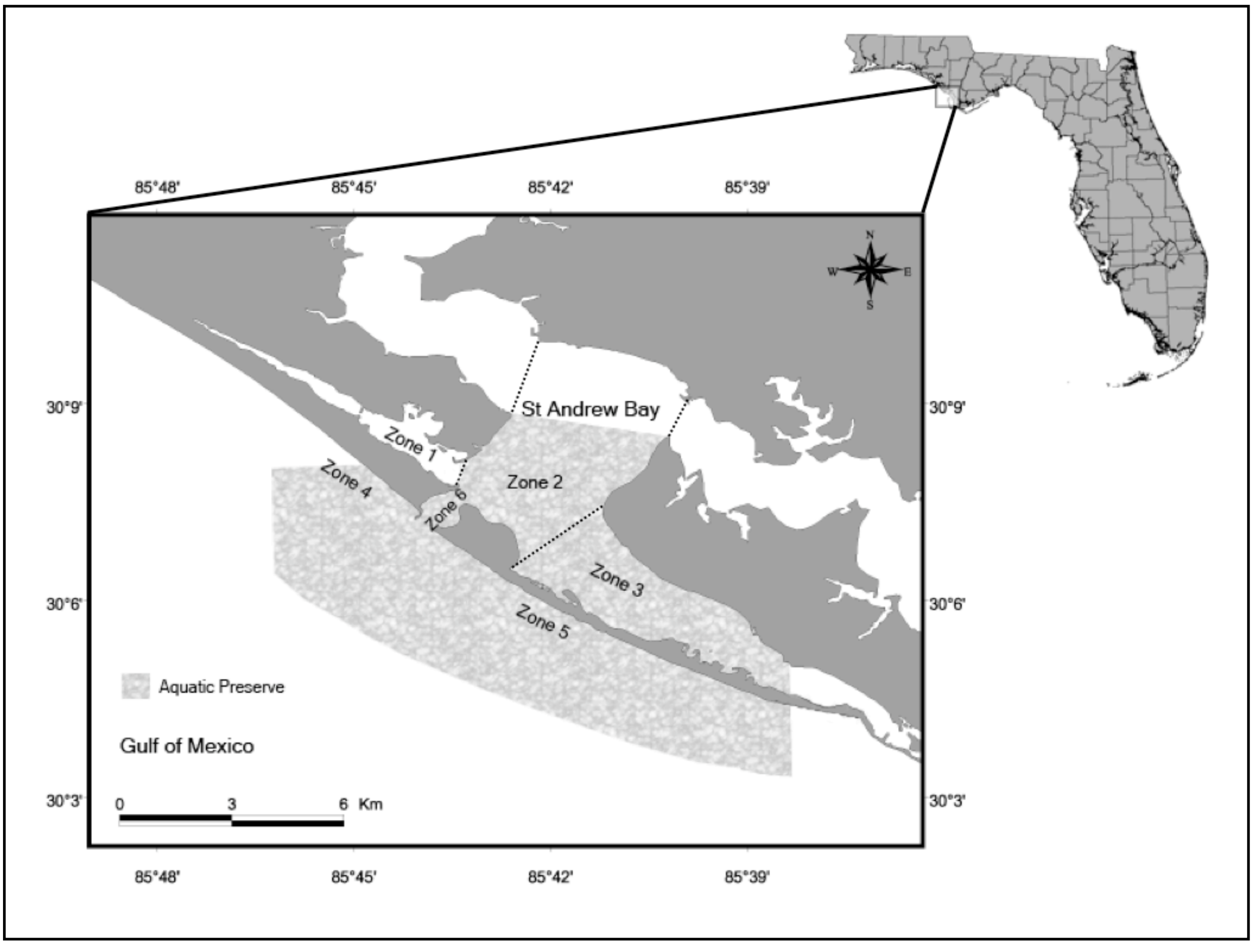
Figure 13. Observation frequency of bottlenose dolphins regarding zones and for each moment of the day.

Figure 14. Influence of tidal current on the probability of dolphins' sighting.

TABLE AND FIGURES

	One Season	Two Seasons	Three Seasons	Four Seasons
# of dolphins sights	154	47	29	33
% of dolphins seen a least once	58,55	17,87	11,026	12,547

Table 1.



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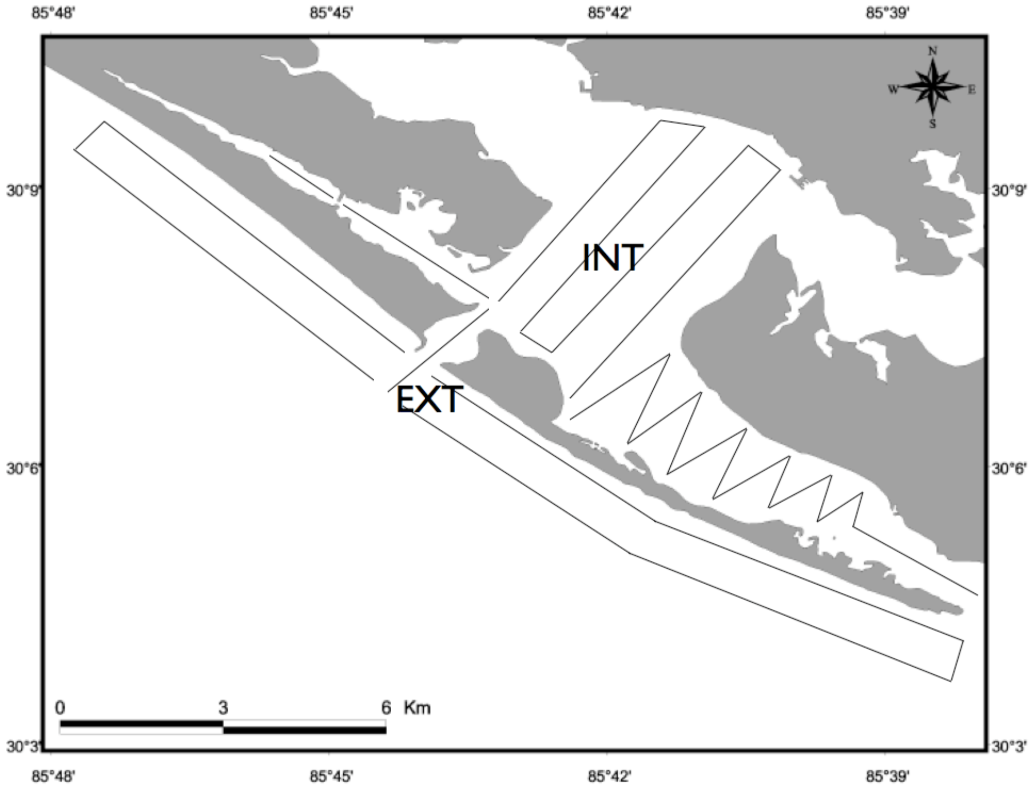

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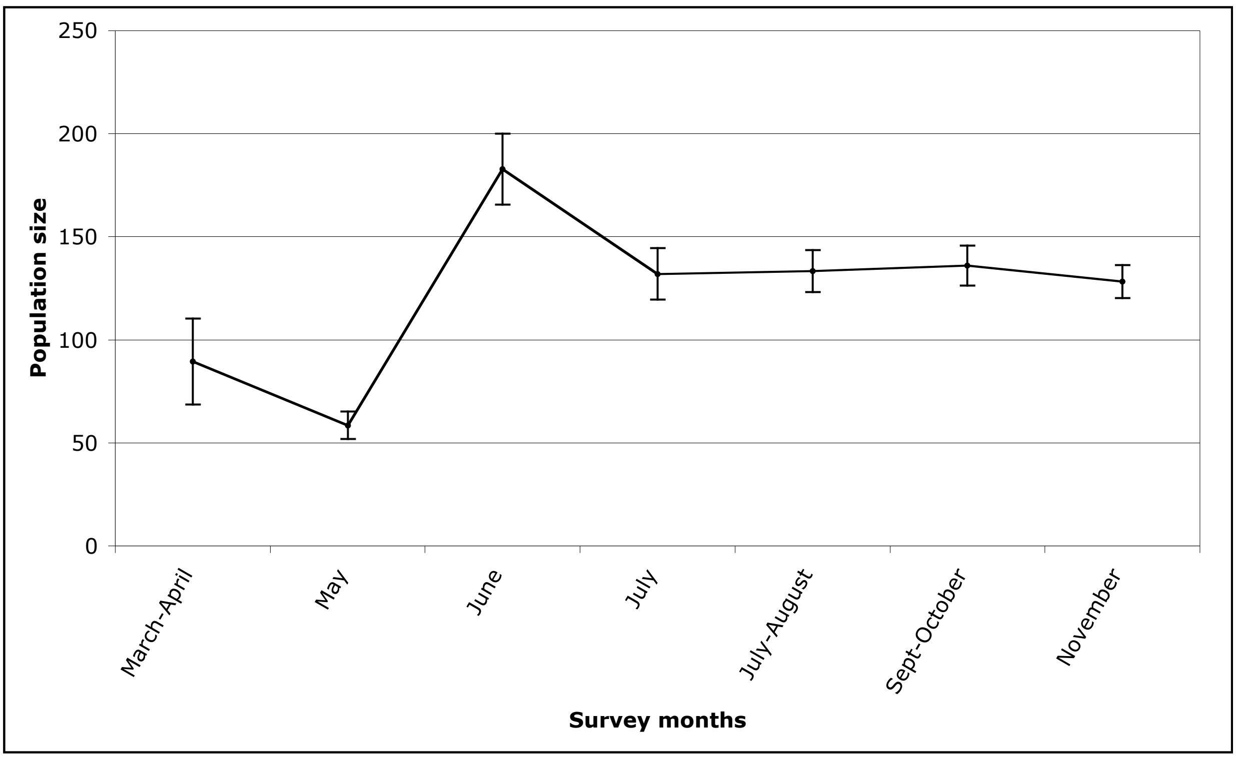

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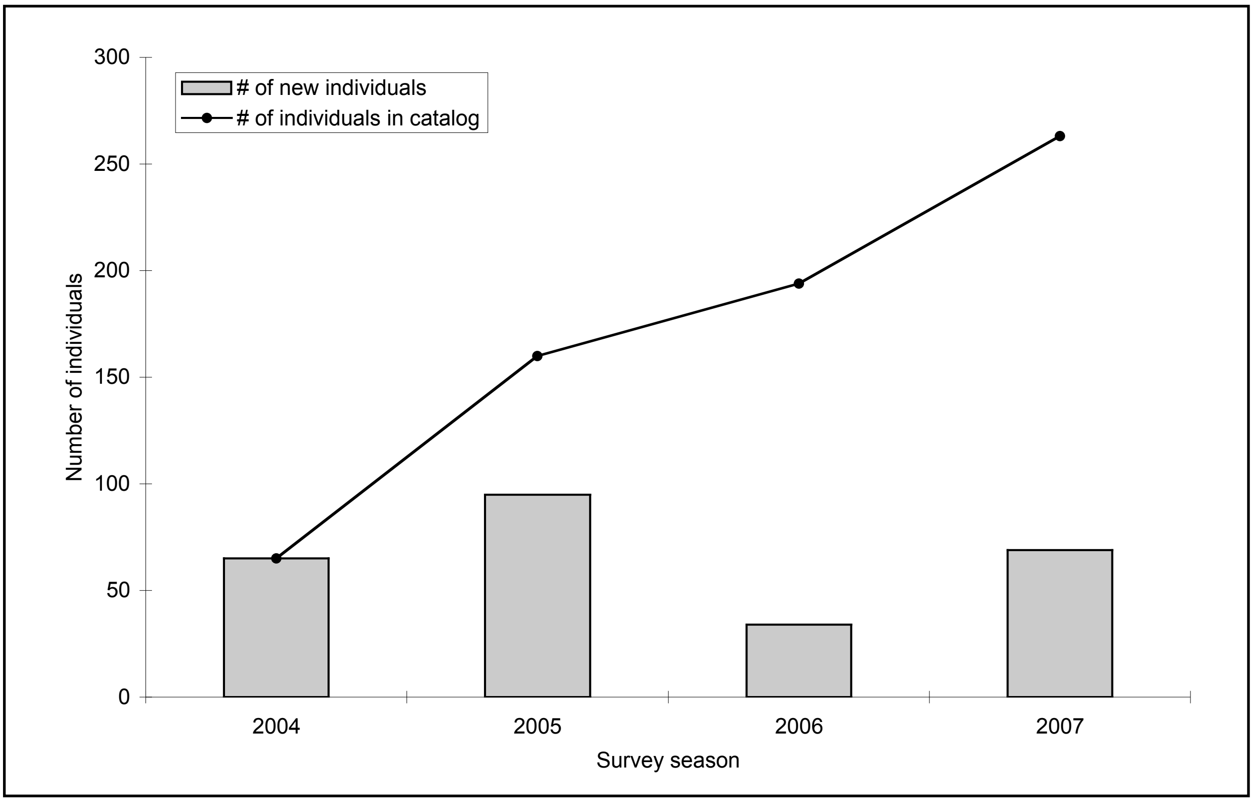

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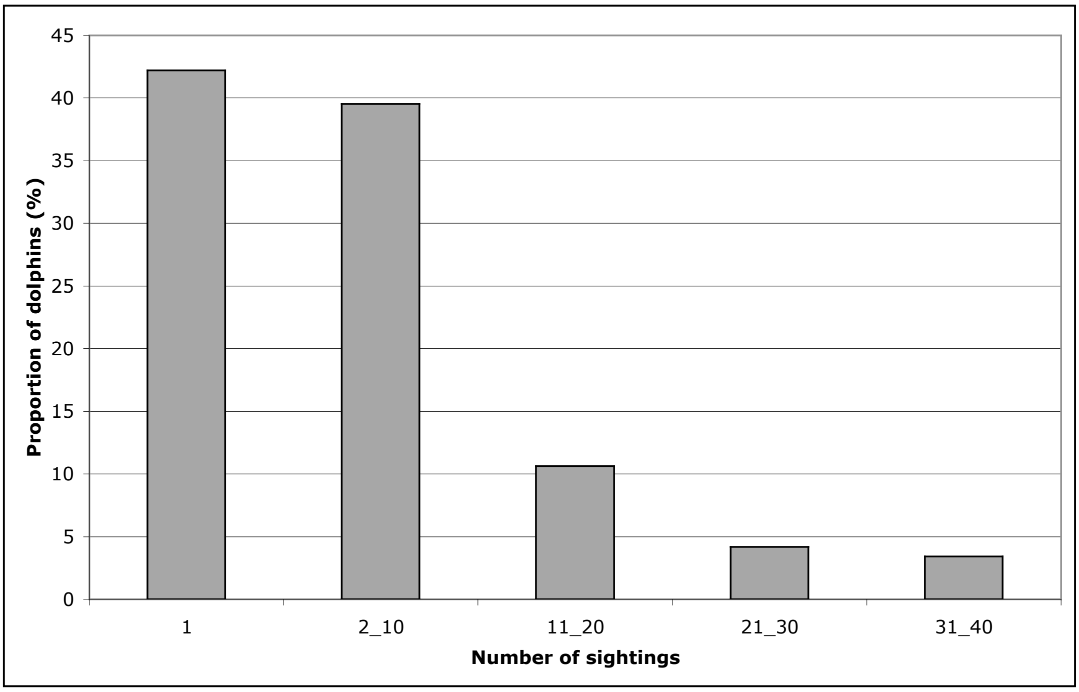

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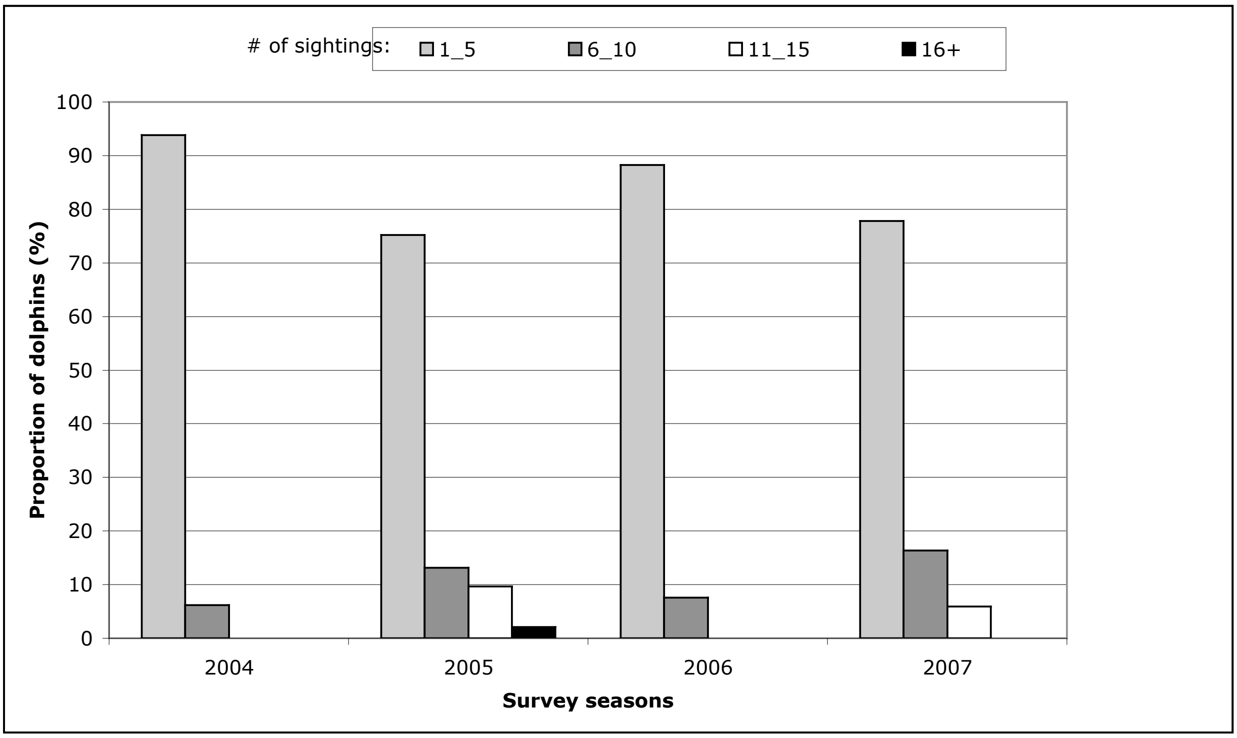

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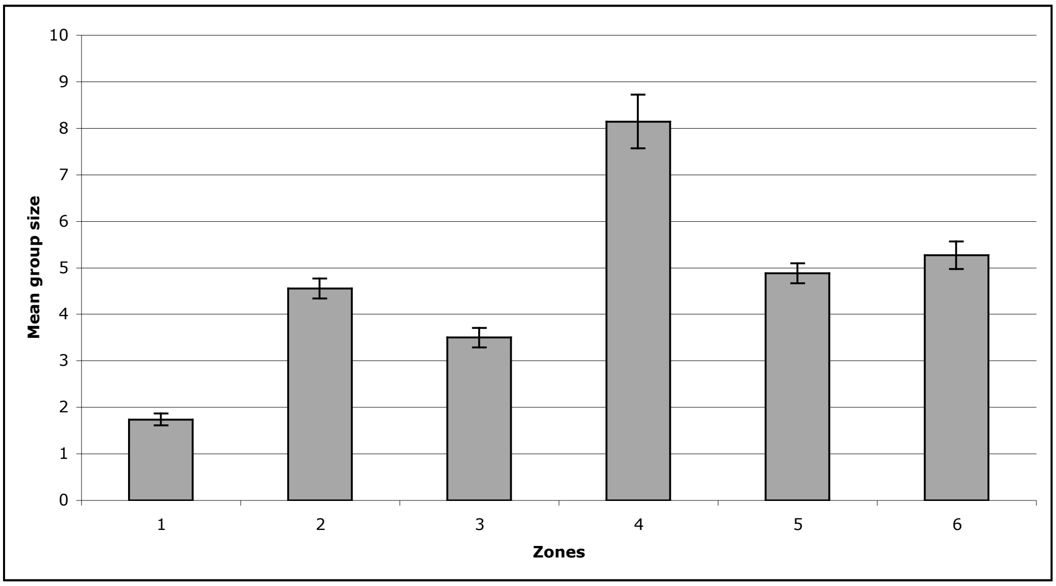

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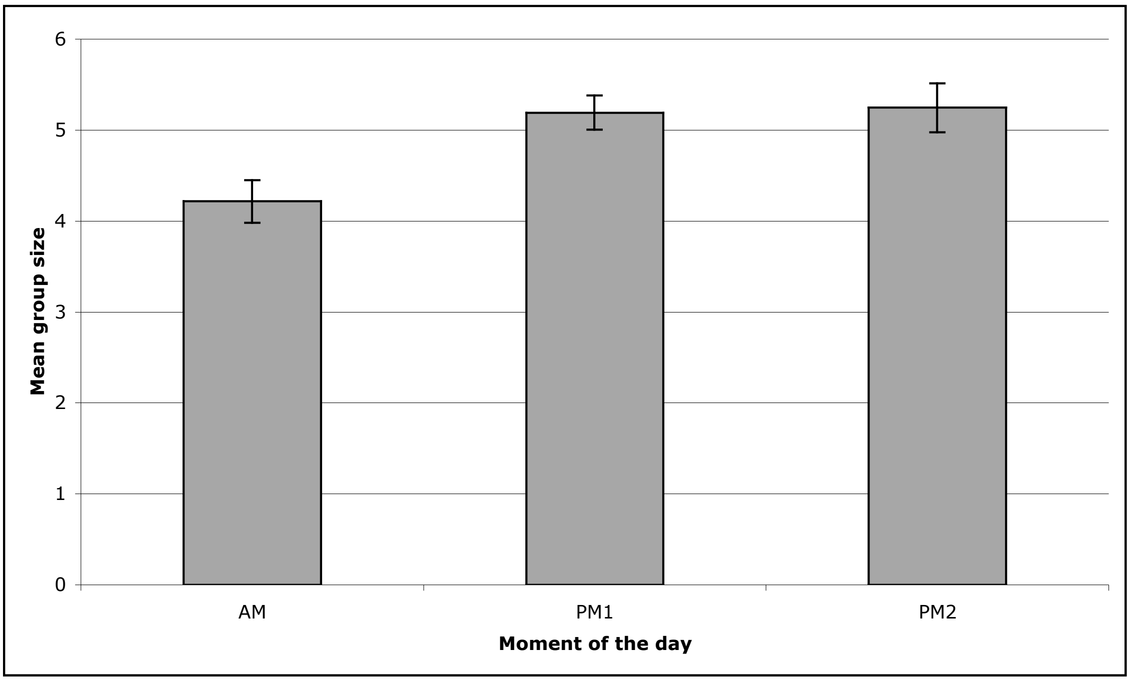

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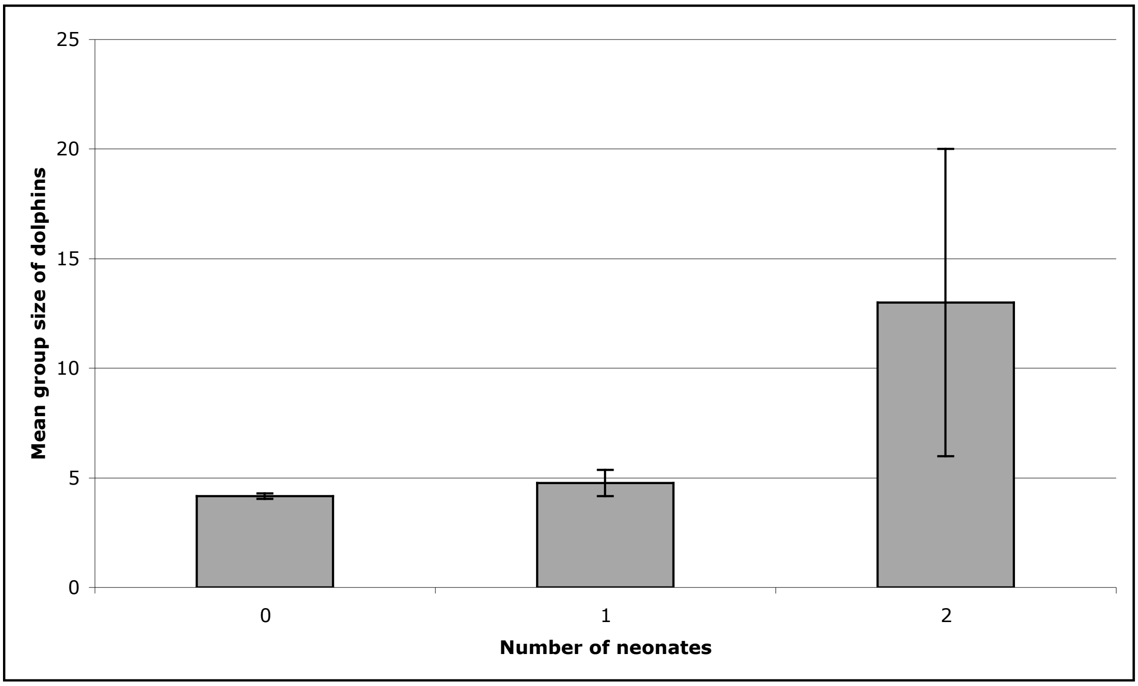

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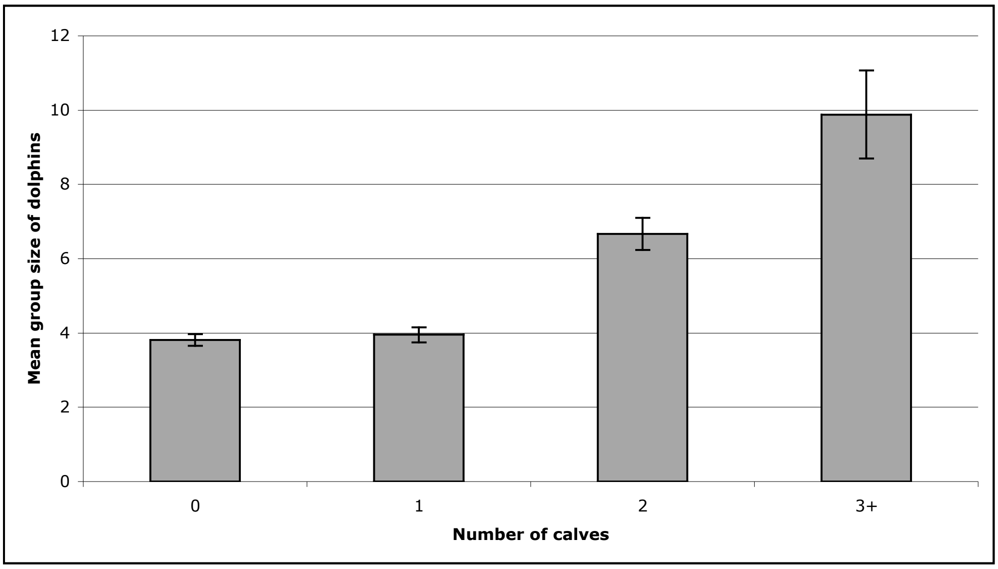

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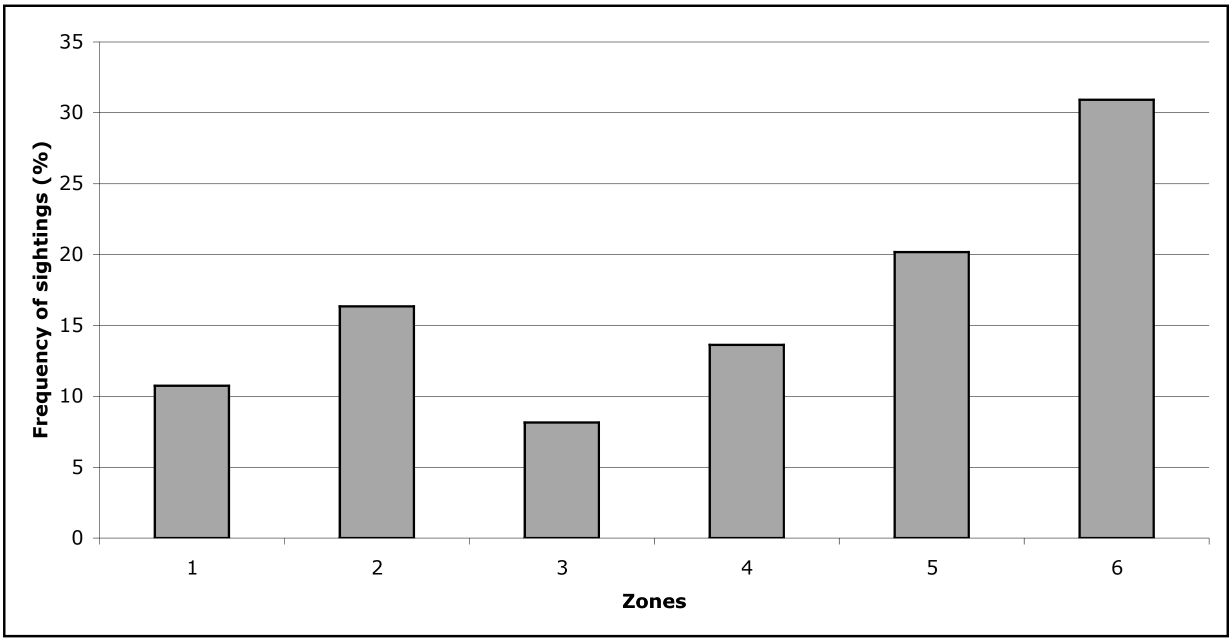

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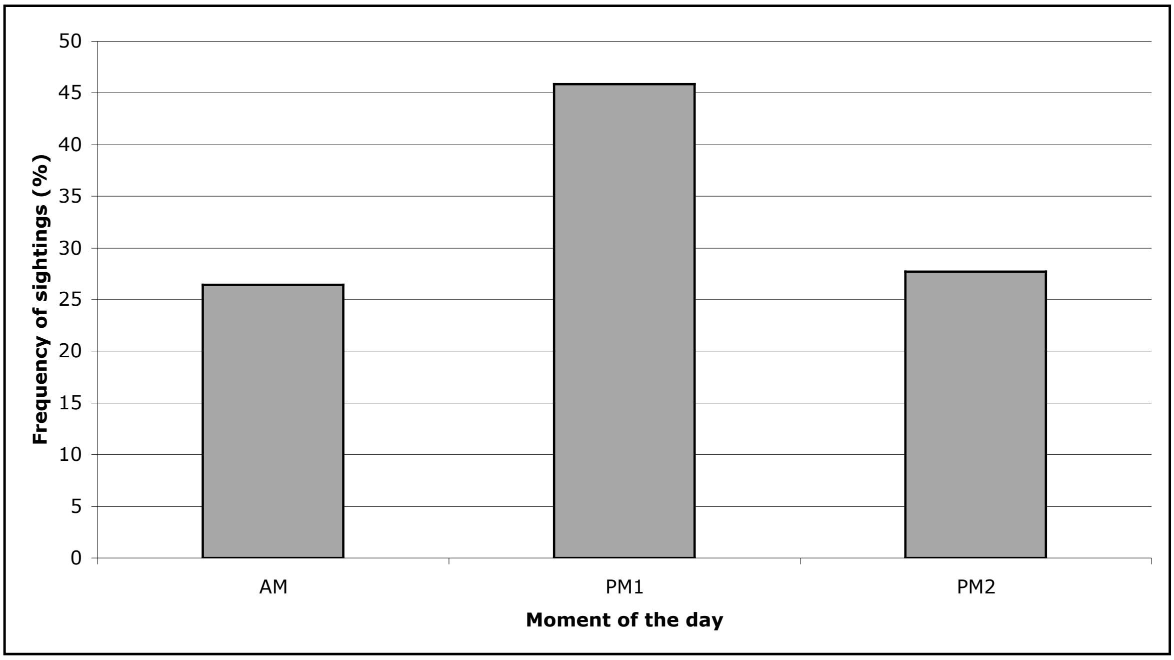

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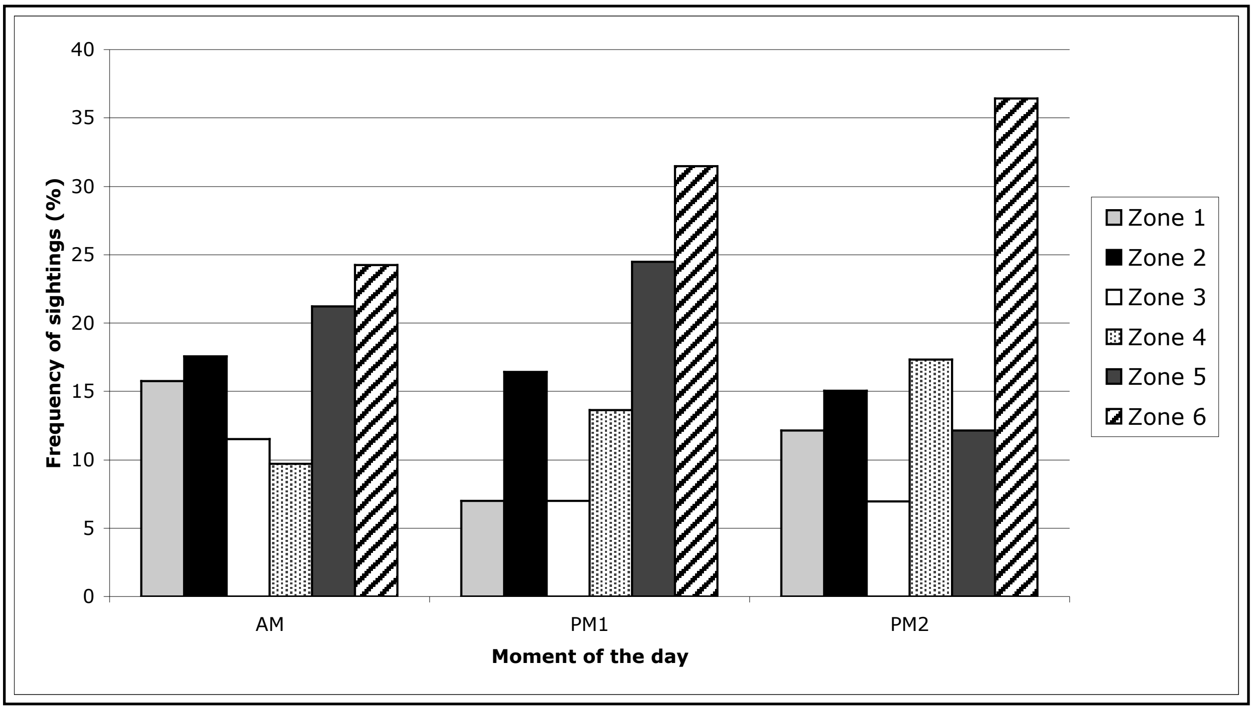

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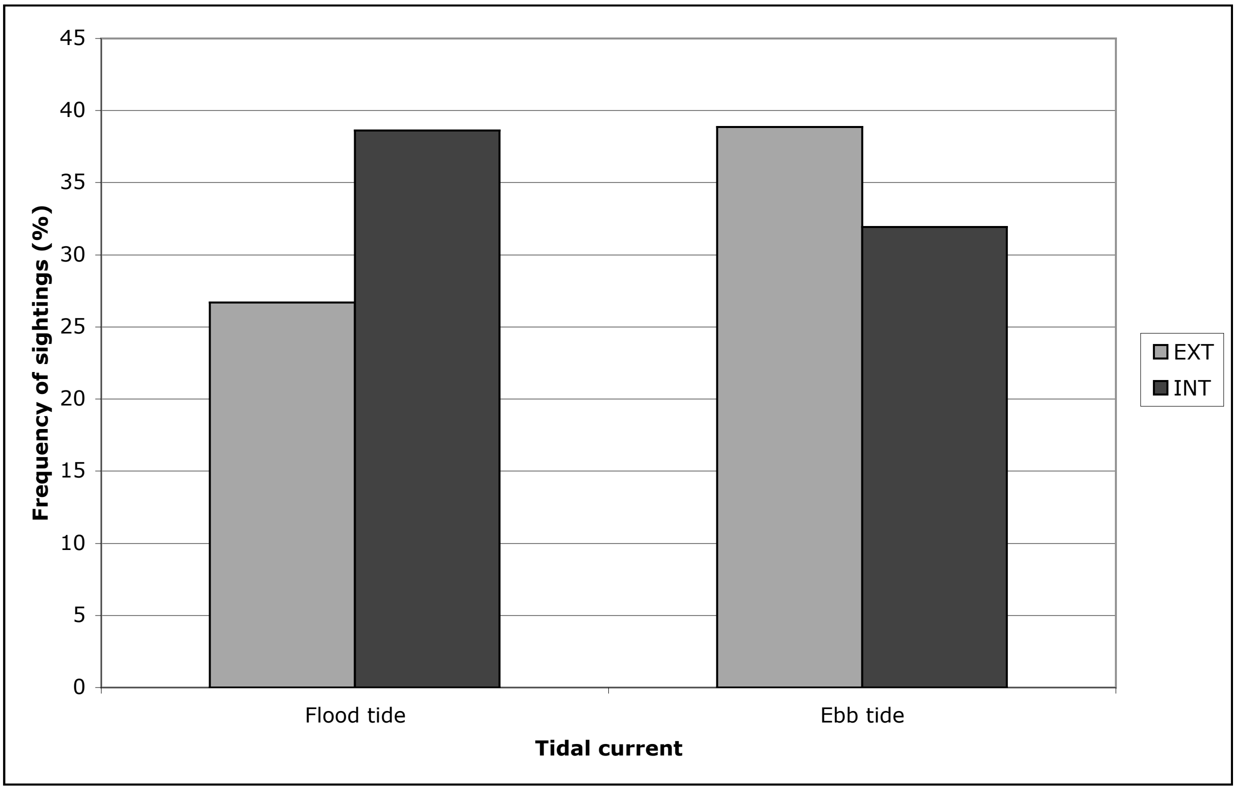
45
40
35
30
25
20
15
10
5
0
Frequency of sightings (%)
Flood tide
Ebb tide
Tidal current
EXT
INT

Figure 14.