Latin American Journal of Aquatic Research
E-ISSN: 0718-560X
lajar@ucv.cl
Pontificia Universidad Católica de Valparaíso
Chile

Lopes-Souza, Aline; Schiavetti, Alexandre; Álvarez, Martín Roberto
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Latin American Journal of Aquatic Research, vol. 43, núm. 4, septiembre, 2015, pp. 675-683
Pontificia Universidad Católica de Valparaíso
Valparaíso, Chile

Lat. Am. J. Aquat. Res., 43(4): 675-683, 2015
DOI: 10.3856/vol43-issue4-fulltext-6

Research Article

Analysis of marine turtle strandings (Reptilia: Testudine) occurring on coast of Bahia State, Brazil

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ABSTRACT. This study provides an analysis of the occurrence and the spatial and temporal distribution of marine turtle strandings found in the south of the State of Bahia. Data was collected between January 2006 and June 2008. This study covers an area of 220 km of the southern coast of Bahia State (northeastern Brazil), and spatial analyses were made considering data collected in three bases suported by Petrobras-Petróleo Brasileiro S/A distributed in the area. The records were sorted according to month and year, species, age group and sex. A total of 260 stranding were reported: 183 of *Chelonia mydas* (74.1%), the most frequent species. The highest number of strandings was recorded in Gamboa do Morro Base. Juveniles presented the highest densities, but no differences between adults and small juveniles were detected. Males were more frequently stranded in Gamboa do Morro Base, while females were more frequent in Ilhéus Base. An increase in the number of stranding between 2006 and 2008 was noted; moreover, the months with more records were January, February, March, October and December. The number of stranding events was discontinuously distributed in the study area. This study also demonstrated the usefulness of implement different strategies of recording marine turtle strandings: direct monitoring efforts (patrol) in remote beaches and educational campaigns applied on beaches frequented by tourists. This study demonstrated that, despite spatial nearby, the three bases attend independent biological systems and show different stranding dynamics, thus different conservancy actions should be implemented in order to improve the knowledge on natural history of sea-turtles in the southern coast of Bahia State.

Keywords: turtle stranding, monitoring beaches, educational campaigns, conservation strategies, northeastern Brazil.

Análisis de varamientos de tortugas marinas (Reptilia: Testudine) ocurridas en la costa del Estado de Bahía, Brasil

RESUMEN. Se analiza de la incidencia y distribución espacio-temporal de los varamientos de tortugas marinas en el sur del Estado de Bahía, nordeste de Brasil. Los datos fueron obtenidos entre enero de 2006 y junio de 2008. Este estudio cubrió un área de 220 km de la costa sur del Estado de Bahía (noreste de Brasil) y el análisis espacial se realizó considerando las tres bases financiadas por la empresa Petrobras-Petróleo Brasileiro S/A. Los registros fueron ordenados según mes y año, especie, grupo etario y sexo. Se registró un total de 260 varamientos: 183 de *Chelonia mydas* (74,1%), la especie más frecuente. La mayor frecuencia de varamientos se observó en la base Gamboa do Morro. Los juveniles presentaron las mayores densidades, pero no se detectaron diferencias entre adultos y crías. Los machos vararon con mayor frecuencia en la base Gamboa do Morro, mientras que las hembras fueron más frecuentes en la base Ilhéus. Se observó un aumento en el número de varamientos entre 2006 y 2008 y además, los meses con más registros fueron enero, febrero, marzo, octubre y diciembre. El número de eventos de varamiento fue distribuido de forma discontinua en el área de estudio. Este estudio también demostró la utilidad de aplicar diferentes estrategias de registro de varamientos de tortugas marinas: esfuerzos de monitoreo directo (patrulla) en playas remotas y campañas educativas aplicadas en playas frecuentadas por turistas. Este estudio demostró que, a pesar de encontrarse próximas espacialmente, las tres bases atendieron sistemas biológicos que funcionan en forma independiente y muestran diferen-

Corresponding editor: Sergio Palma

tes dinámicas de varamiento, por lo tanto se deben implementar diferentes acciones de conservación para mejorar el conocimiento de la historia natural de las tortugas marinas en la costa sur del Estado de Bahía.

Palabras clave: varamiento de tortugas, monitoreo de playas, campañas educativas, estrategias de conservación, noreste de Brasil.

INTRODUCTION

Many species of large marine vertebrates, such as marine mammals, marine turtles and seabirds, are subject to strandings for different reasons (Peckham *et al.*, 2008; Velozo *et al.*, 2009; García-Borboroglu *et al.*, 2010; Williams *et al.*, 2011). Animals can be found dead or alive, ashore or floating in coastal waters, and such data should be treated differently (Casale *et al.*, 2010). While inferences from strandings should be carefully employed (Hart *et al.*, 2006), when studied across large spatio-temporal extents, the findings can provide information about geographic and seasonal distribution, natural and anthropogenic impacts, and life history and natural history of marine vertebrates, including marine turtles (Epperly *et al.*, 1996; Tomás *et al.*, 2008).

Five species of marine turtles are found in Brazil: *Caretta caretta*, *Eretmochelys imbricata*, *Lepidochelys olivacea*, *Chelonia mydas* and *Dermochelys coriacea* (Marcovaldi & Laurent, 1996). Four species of marine turtles have been identified reproducing on the beaches of the southern Bahia coast, which comprises one of the three main nesting areas in Brazil (Marcovaldi & Marcovaldi, 1999): *C. caretta*, *E. imbricata*, *L. olivacea* and *C. mydas* (Camilo *et al.*, 2009).

According to Wallace *et al.* (2010), the regional management units for the marine turtles are areas occupied by populations that function independently and have different demographic processes. The southern Bahia coast is included in the management unit of the West Atlantic (for *L. olivacea*) and south-western Atlantic (for *C. caretta*, *E. imbricata* and *C. mydas*). All these management units are small in area and almost unique to the Brazilian coast. Therefore, there is a need to maintain the life cycle of these species to the full extent of the Brazilian coast to prevent loss of genetic diversity.

Each of these marine turtles species is threatened in Brazil (MMA, 2014) as a result of environmental degradation and pollution in their habitat, hunting, egg collecting, fisheries bycatch and as a consequence of fishing with trawl and drag nets (Bugoni *et al.*, 2001; Almeida *et al.*, 2011; Castilhos *et al.*, 2011; Marcovaldi *et al.*, 2011; Santos *et al.*, 2011; Braga & Schiavetti, 2013).

In 1980, the National Program for Protection of Marine Turtles, the TAMAR Project (IBAMA), was founded in Brazil (Marcovaldi & Marcovaldi, 1999). Currently, the project has 22 bases discontinuously distributed along the Brazilian seacoast; however, other partnering institutions also contribute to the conservation of the chelonian species (Camilo *et al.*, 2009).

The Praia do Forte (northern Bahia State) is considered by TAMAR Project the core nesting area for marine turtle reproduction in the northeastern Brazil (Marcovaldi & Marcovaldi, 1999). Nevertheless, marine turtles were reported nesting in marginal reproductive areas south (Camilo *et al.*, 2009) and north (Parente *et al.*, 2006) of this core area. According to Lesica & Allendorf (1995), the study of peripheral populations, which is the subject of this paper, may help in the conservation of the species as a whole. These marginal or peripheral populations allow for the expression and preservation of a larger set of genes, which decreases the chance of inbreeding and thus strengthens population viability, as well as provides a demographic reserve for the species as a whole (Allendorf *et al.*, 2012). Thus, studies of marginal reproductive areas are necessary to aid in the development of management strategies for the conservation of these chelonian species on the Brazilian coast.

The aim of this study was to analyse the temporal and spatial distribution of marine turtle strandings on the southern coast of Bahia State, a marginal reproductive area without any institutional conservation action nearby.

MATERIALS AND METHODS

Study area

The study area is located within the South Atlantic trade winds belt (NE-ESE), which is related to the high-pressure cell existing in this region (Dominguez *et al.*, 1992; Bittencourt *et al.*, 2000, 2005, 2007) (Fig. 1). This study covers an area of 220 km of the southern coast of Bahia State (northeastern Brazil), between the municipalities of Valença (13º22´26”S, 38º96´58”W) and Una (15º19´23”S, 38º99´76”W). The coastline was divided into three bases supported by Petrobras-Petróleo Brasileiro S/A for different periods (Fig. 1, Table 1). The bases in Gamboa do Morro (GBM) and Baia de Camamu (BCM) are along remote beaches without tourism activities, and Ilhéus (IOS) base falls

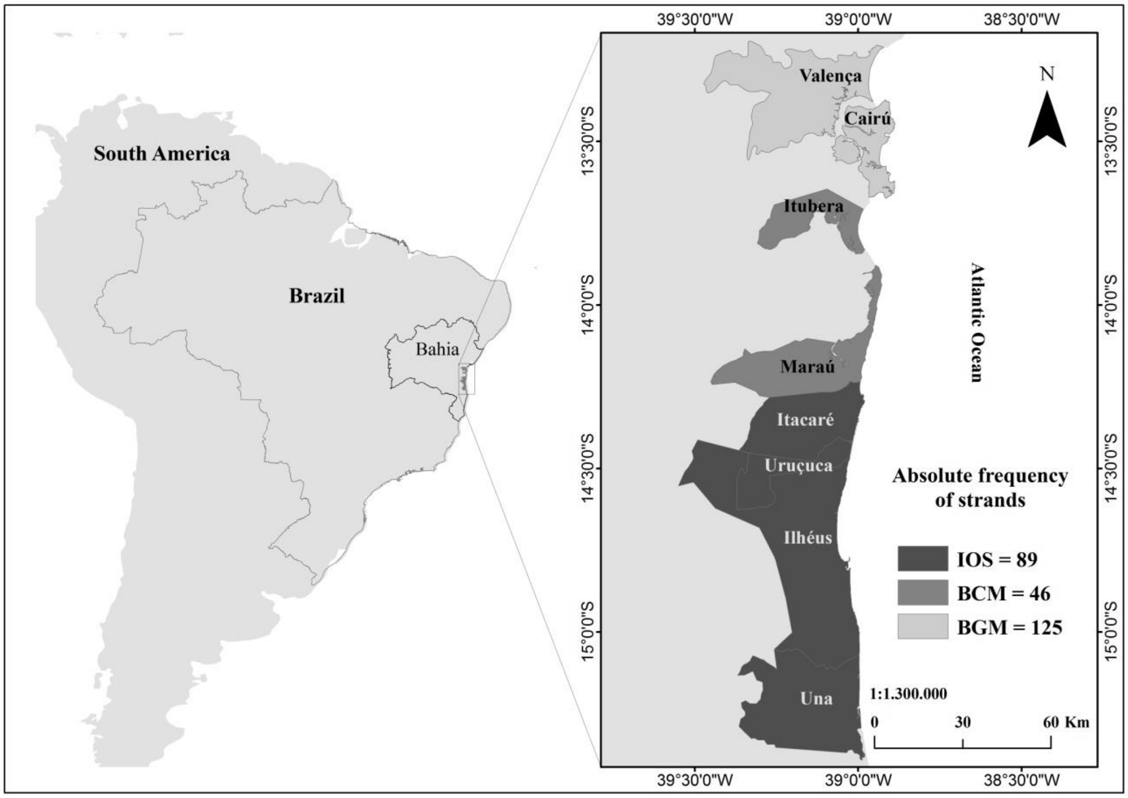

Figure 1. Map of study area in Bahia State southern coast (northeastern Brazil), considering the three bases Gamboa do Morro (GBM), Baia de Camamu (BCM) and Ilhéus (IOS) and the municipalities covered by each base. The numbers show the absolute frequency of strandings in each base during the period from January 2006 to June 2008.

Table 1. Sampling effort at each base as a function of the operating time and tracking area. It is also presented the base name, the sampling period (month), the extension of beach comprehended by the base (km), and the sampling effort performed.

Base	Sampled period (month)	Sampled area extension (km)	Sampling effort (month*km)
Gamboa do Morro (GBM)	30	31	930
Baia de Camamu (BCM)	13	72	936
Ilhéus (IOS)	13	117	1521

in a region of the coast mainly supported by tourism (on a tourist and residential/urban beach).

Data collection

Marine turtles stranded were found on the beach, dead or alive, with the help of tourist and locals' calls/complaints or during beach monitoring efforts between January 2006 and June 2008. The study areas were monitored by foot; everyday, a different stretch of 15 km of beach was monitored until all research area was travelled. Surveyors then returned to the starting point of monitoring.

Species information, the location (GPS) of each stranding, the condition of the animal (alive or dead) and the curved carapace length (CCL) (Bolten, 1999) were collected. Dead animals and carcasses were necropsied. When possible, sex was determined by reproductive tract visual observation in adult individuals (Wyneken, 2001), for which the visual analysis is reliable.

When GPS location was not able to be determined, the location of the stranding was classified by taking into account characteristics of the stranding location (name of beach or river, county, etc.).

Curved carapace length (CCL) was used to classify specimens in age classes (small juveniles, juveniles and adults) according to Almeida *et al.* (2011), Castilhos *et al.* (2011), Marcovaldi *et al.* (2011), Limpus & Chaloupka (1997), and Santos *et al.* (2011) (Table 2). The values presented in Table 2 for adults are all below the mean value for monitored nesting females on the shores of Brazil.

Data analysis

Marine turtle stranding records came from tourist or locals' calls/complaints and during beach patrols. Moreover, both sources depend on monitoring areas and periods of activity experienced by each base. Thus, comparisons between bases and seasons should consider the sampling efforts (month*km), calculated as the total operating time (month) multiplied by the beach extension (km) monitored by each base (Table 1). As not all bases were monitored with the same effort, these results should be regarded as a rough estimation for comparing these areas (Casale *et al.*, 2010).

Spatial analysis was conducted using ArcGIS software. The relative frequency regarding species, age group, sex and climatic season (rainy or dry), standardising the records with the sampling effort, was analysed using a Chi-square test (Siegel & Castellan Jr., 2006).

RESULTS

Between January 2006 and June 2008 (30 months), a total of 260 marine turtle were found stranded. Only 5.0% (13) were of unidentified species. The most frequent species was *C. mydas* (74.1%), followed by *L. olivacea* and *C. caretta* (both with 10.9%), and finally, *E. imbricata* (4.1%) (Fig. 2).

Table 2. Age classes (small juveniles, juveniles and adults) for the fourth marine turtles species found, defined as function of curved carapace length (CCL), according to Almeida *et al.* (2011), Castilhos *et al.* (2011), Marcovaldi *et al.* (2011) and Santos *et al.* (2011).

Species	Small juveniles	Juveniles	Adults
Chelonia mydas and *Caretta caretta*	<20 cm	21-80 cm	>80 cm
Eretmochelys imbricata ♂	<20 cm	21-70 cm	>70 cm
Eretmochelys imbricata ♀		21-75 cm	>75 cm
Lepidochelys olivacea	<10 cm	11-46 cm	>46 cm

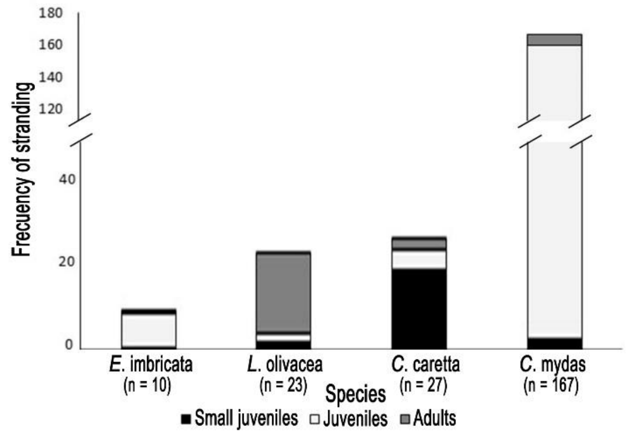

Figure 2. Frequency of marine turtle strandings (according to species and age group) occurred in the beach extension between the municipalities of Valença and Una (Brazil, BA) from January 2006 to June 2008 (n = 247).

From the 260 strandings, 226 marine turtles were found dead (86.9%) and only 34 alive (13.1%), of which 22 (64.7%) were reintroduced to seawaters. Most of the marine turtles found alive were *C. caretta* (n = 17 strandings, 50%), followed by *C. mydas* (n = 15 individuals, 44%); mostly small juveniles 92.6% and 80%, respectively. The lowest number of strandings alive were found for *E. imbricata* (n = 1) and *L. olivacea* (n = 1), with 3% each both small juveniles.

Regarding age classes, juveniles were more common (n = 172; 75.8%) than adults (n = 30; 13.2%) and small juveniles (n = 25; 11%). Considering species and age classes, we noted that the small juveniles belonged to *C. caretta* (n = 19; 76%), whereas most juveniles belonged to C. *mydas* (n = 157; 91.3%) and most adults pertained to *L. olivacea* (n = 19; 63.3%) (Fig. 2).

The CCLs showed intraspecific and interspecies variations. The largest CCL mean was found in *E. imbricata* (65.0 ± 15.9 cm) and the lowest in *C. caretta* (32.9 ± 32.4 cm). The CCL means were 48.8 ± 15.6 cm and 46.4 ± 31.5 cm) for *C. mydas* and *L. olivacea*, respectively (Fig. 3).

Sex was identifiable in only 25 of the necropsied individuals, being 17 females (12 *C. mydas*, 3 *L. olivacea*, 2 *E. imbricate*) and 8 males (4 *L. olivacea*, 2 *C. mydas* and 2 *E. imbricate*). In any stranded *C. caretta* was able to identify the sex. This sex bias (2 females: 1 male) did not necessarily represent the true proportion of strandings among the sexes and may be due to the difficulty in determining the sexes.

The origin of the 260 stranding records was classified into two groups: those reported by tourist and

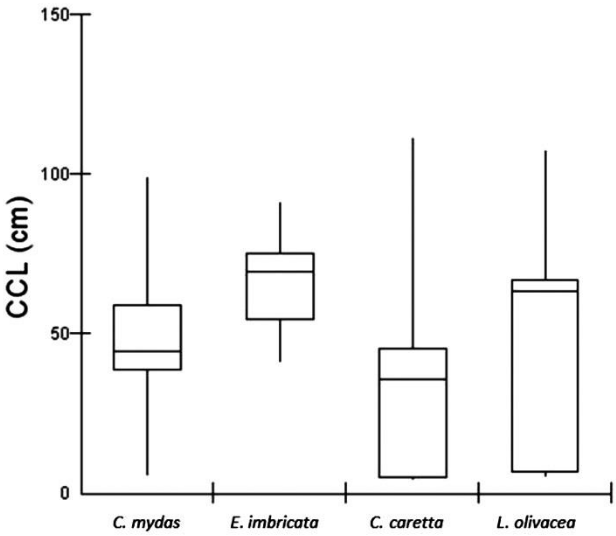

Figure 3. Mean, 25% to 75% quartiles, maximum and minimum values of curved carapace length (CCL) for the fourth sea turtles species stranded on coast of Bahia State, Brazil, in the period from January 2006 to June 2008.

locals' calls/complaints (35.4%) and those found during beach monitoring efforts (64.6%). When analysing the origin of the records from each base, it was noted that the records for the IOS base mainly originated from calls (66.3%), whereas the reports for GBM and BCM bases mostly resulted from beach monitoring (80.8% and 80.4%, respectively).

The stranding relative frequency varied between years, from 0.16 strands/sampling efforts in 2006 to 0.06 in 2008 (yet the latter had only six months evaluated). The lowest rate was 0.01 strands/sampling effort in 2007. When analysing monthly strandings of all species, it was noted that the months with the largest number of events were January, February, March, October and December, which corresponded to the rainy season (summer) in the region (Fig. 4). Comparing the relative frequencies of summer (N = 194) and winter (N = 66), we observed significant differences (χ^2 = 63.01, df = 1, P < 0.001), even considering both record sources (calls/complaints and beach monitoring efforts) (Fig. 3).

When analysing the spatial distribution of strandings, we verified that they were discontinuously distributed along the study area and that there is a higher (χ^2 = 47.37, df = 2, P < 0.001) absolute frequency of stranding events at the GBM base (Fig. 1).

Despite the sampling effort in each base, the most frequently stranded marine turtle was *C. mydas* at all bases, and *E. imbricata* had the lowest stranding frequency (Fig. 5a). With regard to the stranding rate classified according to age group, adults were more frequent at the GBM and IOS bases, while juveniles and small juveniles were concentrated at the GBM base (Fig. 5b).

DISCUSSION

Chelonia mydas accounted for the highest number of strandings, especially juvenile-stage individuals. This may be due to the distribution of feeding areas of this species (Almeida *et al.*, 2011) and the coastal geomorphology of the region (Dominguez *et al.*, 1992). The diet of a green marine turtle depends on its age. When juvenile (pelagic phase), they are omnivores with a bias toward carnivory (Guebert-Bartholo *et al.*, 2011). After leaving the pelagic phase, they become herbivores and primarily feed on aquatic plants and algae, and eventually they feed on jellyfish and sponges (Nagaoka *et al.*, 2012; Awabdi *et al.*, 2013; Reisser *et al.*, 2013).The study area contains rock formations and reefs parallel to the coast (Caló *et al.*, 2009), making it suitable for the establishment of benches of algae and aquatic plants and thus attractive to green marine turtles.

It is well documented that the loggerhead marine turtle is the species that reproduces in most of the Brazilian coast, and the coast of Bahia State represents their main breeding site (Marcovaldi & Marcovaldi, 1985). A study reported the occurrence of *C. caretta* (Camilo *et al.*, 2009) nesting and breeding on a beach located in southern Bahia. As we found that the smallest juveniles stranded were *C. caretta* in all three regions of the study area, our results affirm the value of the entire southern Bahia coast as a breeding and development area and nesting site for this species.

The strandings recorded for *Lepidochelys olivacea* were almost all adults, both male and female. This is the smallest species of marine turtle present in Brazil. The distance from the study area to the closest registered breeding sites (Sergipe State) (Marcovaldi & Marcovaldi, 1985) reaches 500 km, which agrees with the high dispersal ability of this species (Palovina *et al.*, 2004). Also suggested by Palovina *et al.* (2004), olive ridley marine turtles forage while diving over 100 m deep. In the study area, the continental shelf-break occurs between 15 and 50 km away from the coastline (Knoppers *et al.*, 1999), which could mean that these species co-inhabit during their non-reproductive phase, as well as are impacted by human foraging activities. The presence of adults in this area means that during their non-reproductive phase, this species is distributed along areas of the coast of Brazil where the official program of marine turtle protection (TAMAR Project) does not act.

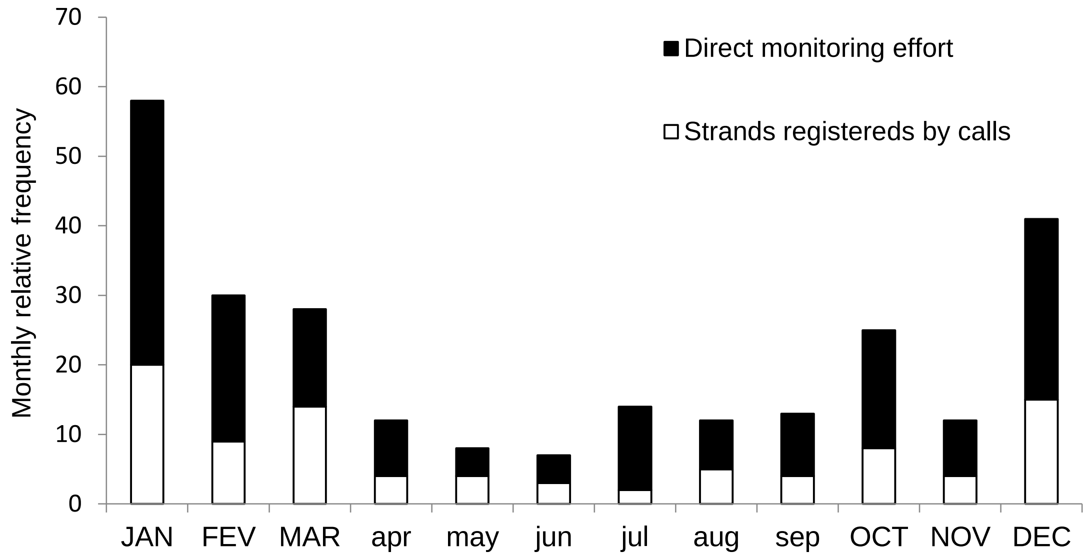

Figure 4. Monthly relative frequency of marine turtles strandings, according to sampling efforts performed in each month, occurred in beach extensions ranging from the municipalities of Valença to Una (Brazil, BA), in the period from January 2006 to June 2008. Months on cap letter correspond to marine turtles reproductive season and rainy season in the study area.

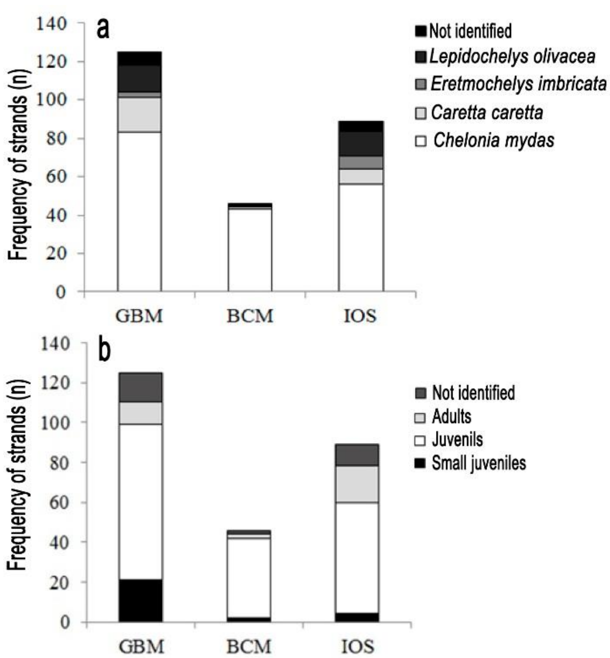

Figure 5. Frequency of marine turtles strands according to species a) and age group b) in the bases Gamboa do Morro (GBM), Baia de Camamu (BCM) and Ilhéus (IOS) during the period January 2006 to June 2008.

Most stranded animals were found during beach monitoring, which shows the effectiveness of this type of activity in studies involving stranding of marine animals (Batista *et al.*, 2005; Meirelles *et al.*, 2009; Velozo *et al.*, 2009). However, most records (66.3%) at the IOS base came from calls by tourist or locals during the rainy season, which corresponds to summer vacations in Brazil. During this period, there is an increased frequency of tourists on the beaches, which, together with educational campaigns, may have contributed to the increase in stranding reports. An increase in reports after educational campaigns was also observed in the study area for cetacean strandings reports (Batista *et al.*, 2012).

Of all strandings, 75% occurred in the summer (Fig. 4). This can be explained by a confluence of factors, but primarily, this is the breeding season of these species (Camilo *et al.*, 2009). A higher number of adults (71%) and small juveniles (93%) were found during this period. Moreover, these months correspond to summer vacation season, which should increase the probability of finding stranded animals as described above. Finally, the change in wind direction during this season, which starts to blow from the ocean to the beach predominantly from the northeast (Dominguez *et al.*, 1992; Bittencourt *et al.*, 2007), can direct marine turtles to the beach and increase the risk of stranding as well as drift carcasses coming from the sea.

The frequency of marine turtle strandings has increased in the study period (2006-2008) because of the expansion of the sampling area. This expansion enabled the identification of different population dynamics among species. Bases covering distances of approximately 100 km each showed strandings of species and different life stages (Figs. 2, 5), which illustrates the dynamics of marine coastal systems of the State of Bahia and the need to implement different conservation strategies for each.

CONCLUSIONS

This study showed that despite being spatially proximate, the three bases show a variety of stranding dynamics affecting species and age classes differentially. Thus, different conservancy actions should be implemented to improve the understanding of the natural history of seaturtles along the southern coast of Bahia State.

If there are three different “systems” that operate on one third of the coast of Bahia, as identified by the observed variations between the bases, it is necessary to expand the sampling area to the north and south. This could help determine whether there are other “systems” related to different populations of marine turtles, their composition, temporal structure and phases of life. This is considering the fact that all the species are recorded in the Bahia State.

This study also showed the need to implement different strategies of recording marine turtle strandings. We therefore recommend that studies of strandings use direct beach monitoring (patrols) as the main strategy in isolated areas, complemented by efforts with educational campaigns in areas with a higher presence of people on the beaches.

Finally, more studies are needed to assess other factors associated with strandings of marine turtles in the studied region; these factors include marine topography, the action of winds, ocean circulation and interaction with fishing and other human activities. The implementation of these study factors is aimed at mitigating the impacts on the populations of these endangered marine turtle species in Brazil.

ACKNOWLEDGMENT

The authors are thankful to Petrobras-Petróleo Brasileiro S/A and the Instituto Mamíferos Aquáticos - IMA (Aquatic Mammals Institute) for the provision of data to staff and trainees from all the bases who have helped in monitoring and data collection; the authors are also thankful to the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior-CAPES and Conselho Nacional de Pesquisa Cientifica e Tecnologica-CNPq for scholarships (first and second authors respectively). Anonymous reviewers improved the manuscript.

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Received: 7 March 2014; Accepted: 13 May 2015