Occurrence of sea turtles during seismic surveys in Northeastern Brazil

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Abstract

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There are seven species of sea turtles around the world. Among these, five visit the northeast coast of Brazil to reproduce and feed. These sea turtles are impacted by human activity and need conservation measures. The seismic survey is one of these activities due to its high intensity and low frequency sound emissions in the marine environment. Records of sea turtles during seismic surveys in shallow waters of the northeast of Brazil between 2002 and 2003 are presented in this study with some discussion about the effectiveness of the monitoring procedures. Three species of sea turtle were recorded within the seismic survey areas. The *Chelonia mydas* species was the most commonly sighted turtle. There was only one record of *Caretta caretta* and *Lepidochelys olivacea*. The presence of sea turtles in Sergipe state was linked to the reproductive period while this pattern was not observed in Ceará state. The absence of information about distribution and abundance of sea turtles in the surveyed areas previous to and after the seismic surveys, as well as numerous incomplete data make it hard to identify the effect of seismic surveys on those factors and also sea turtle behaviors.

Key words: *sea turtles, seismic survey, sea-life surveys, South America, Northeastern Brazil*

Resumo

Parente, C.L.; Lontra. J.D. and Araújo, M.E. **Ocorrência de tartarugas marinhas durante prospecções sísmicas no nordeste do Brasil..** *Biota Neotrop*. Jan/Abr 2006, vol. 6, no. 1 http://www.biotaneotropica.org.br/v6n1/pt/abstract?article+bn00306012006. ISSN 1676-0611

Existem atualmente sete espécies de tartarugas marinhas distribuídas no mundo. Dessas, cinco ocorrem no nordeste do Brasil, utilizando a área para reprodução e alimentação. As populações sofrem os efeitos das atividades humanas, necessitando de medidas para a conservação. Dentre as atividades de risco, destaca-se a prospecção sísmica, a qual emite sons de alta intensidade e baixa freqüência no ambiente marinho podendo causar efeitos negativos nos diversos animais. As observações de tartarugas marinhas realizadas durante as prospecções sísmicas ocorridas em águas rasas do nordeste brasileiro entre 2002 e 2003 são apresentadas em conjunto com uma discussão sobre a efetividade das observações. Foi registrada a presença de três espécies de tartarugas marinhas na área dos estudos sísmicos no nordeste do Brasil. A tartaruga *Chelonia mydas* foi a espécie mais observada nos monitoramentos, com apenas um registro das outras duas espécies identificadas, *Caretta caretta* e *Lepidochelys olivacea*. A presença de tartarugas em Sergipe esteve relacionada com o período reprodutivo, enquanto que no Ceará, a ocorrência foi maior fora da temporada reprodutiva. A ausência de dados pretéritos e posteriores à análise e a grande quantidade de dados incompletos dificultaram a identificação dos efeitos da atividade sísmica na abundância, na distribuição e no comportamento das tartarugas marinhas.

Palavras-chave: *tartaruga marinha, prospecção sísmica, monitoramento de animais marinhos, América do Sul, Nordeste do Brasil*

Introduction

Sea turtles have existed for 200 millions of years and currently there are seven living species around the world (Márquez 1990). Five of these species come to the coast of Brazil to feed and reproduce (Marcovaldi & Marcovaldi 1999). According to The World Conservation Union (IUCN) all species of sea turtle occurring along the Brazilian coast are threatened. The green-sea-turtle (*Chelonia mydas*), the loggerhead-turtle (*Caretta caratta*), and the olive-ridley-turtle (*Lepidochelys olivacea*) are classified as endangered species, while the hawksbill-sea-turtle (*Eretmochelys imbricata*) and the leatherback-turtle (*Dermochelys coriacea*) are classified as critically endangered (IUCN 2004). The five species are also listed in the official list of endangered species from Brazil (MMA 2003).

Many human activities were responsible for the present conservation status of sea turtles but capture was the main among them. Nowadays, some other factors have contributed to continuation of the endangered status, a few that stand out are the beaches' disordered occupation (by hotels, houses, and crowding) fisheries bycatch and sea pollution (Márquez 1990).

One important subject recently studied is the effect of anthropogenic noise in sea turtles. For many years sound sources have been used by seismic surveys to search the presence of oil and gas within the sea bottom (Jones 1999). In the past, chemical explosives were used that caused serious damage to the sea environment and its marine life. After the demands of conservationists and researchers, less aggressive methods to the environment were developed, such as use of airguns to do seismic surveys. Despite the reduction of environmental damage, the use of airguns continues representing danger to marine life with the risk of changing the distribution and behavior of some species (Turnpenny & Nedwell 1994).

The impact of seismic surveys on marine life depends on the environmental characteristics, such as depth and bottom type, and on the noise characteristics, such as intensity, frequency, time duration and distance from the animal to the sound source (Dobbs 2001). The airgun arrays commonly used in seismic surveys produce noise pulses with high intensity in the frequency bands between 10 Hz to 500 Hz. However, the noise pulses can reach 500 Hz to 1000 Hz during high-resolutions surveys (IBAMA 2003a). There is an overlap of those frequencies and the audible frequency range of sea turtles which perceive sounds from 60 Hz to 1000 Hz (Ridgway et al. 1969).

Some studies have been done about the effect of airguns on fishes, turtles and marine mammals (e.g. Lenhardt 1994, Sverdrup et al. 1994, Harris et al. 2001, Stone 2000, 2003, McCauley et al. 2003). Nevertheless, changes in behavior are the focus of those studies, since physiological damages are very hard to observe in live animals (Cummings & Brandom 2004). Behavior responses to airguns were observed in sea turtles. Studies carried out by Lenhardt (1994) showed that sea turtles increase their movements after airgun shots and do not return to the depth where they usually rest. McCauley et al. (2000) did observations of sea turtles in cages and concluded that noises from airguns louder than 166 dB re 1μPa rms increased their swimming activity, and louder than 175 dB re 1μ Pa rms caused erratic behavior. They also estimated an alert behavior at a distance of 2 km from the noise source and escape behavior at a distance of 1 km.

Despite those studies, the knowledge concerning the effects of seismic surveys on sea turtles is very restricted (National Research Council 1990). Seismic surveys are conducted mainly in shallow waters and in the northeast of Brazil. Sea turtles were observed during subaquatic explosions next to the Archipelago of "Fernando de Noronha" but researchers did not observe any effect on the specimens (Sanches & Bellini 1998).

Therefore, considering all sea turtle species occurring on northeast of Brazil are threatened (MMA 2003, IUCN 2004), the Brazilian Institute of Environment and Natural Renewable Resources (IBAMA) started to require sightings and observations during seismic surveys to expand the knowledge about the sea turtle's life cycle and to try to avoid effects of the activity (IBAMA 2003a). The information from these sightings is essential to establish efficient measures to the management of sea turtles.

This study describes the occurrence and distribution of sea turtles during seismic surveys in northeastern Brazil between June 2002 and August 2003. The species diversity and weather effects recorded were analyzed to support a discussion about the effectiveness of those observations.

Material and Methods

This sightings of sea turtle during seismic surveys were done in the following states of northeast Brazil: Sergipe (10°S - 37° W), Rio Grande do Norte (05°S - 35° W) and Ceará (03°S - 38°W), between July, 2002 and August, 2003 (Table 1 and Figure 1). The characteristics of seismic surveys and observations of sea turtles are described as following:

Characteristics of seismic surveys

The Ocean-Bottom-Cable (OBC) seismic survey method used four or six boats to Lay-out (6 m). These boats were responsible for spreading and pulling out cables with hydrophones along the sea bottom. The cables were then connected to a Record Boat. After that, the Gunboat (35 m) crosses the area dragging air-guns that emit sound pulses in low-frequency. The generation system of sound pulses used by the Gunboat was four to eight Generator-Injector (GI) airguns with an operation capacity of 1410 psi each, supplied by a compressor operating at 2000 psi, standardized for all projects.

Characteristics of biota monitoring

The methodology was designed to observe marine mammals but sea turtle observations were included as another goal of the projects. The sightings were done by a single observer aboard the Gunboat during the Caioba-Camurim project. It began with sunrise and was concluded at the end of Gunboat activities that continued throughout the night as a whole. Night vision glasses of the type Gen 1 Pathfinder® was used to aid observations during the night period.

During RNS-144, Guaricema-Dourado, and AXEC projects the sightings were done by three observers who would change between the Gunboat and the Monitoring boat (16 m), which was used exclusively for observing animals. During the night, only the Gunboat had an observer aboard so that this period of observation would be the same as the Caioba-Camurim project.

In the project CES-134, five observers were aboard the Cable Lay-Out boats besides those aboard the Gunboat and Monitoring boat. This procedure was applied to increase the efficacy of monitoring due to large presence of Antillean manatees (*Trichechus manatus*) in that area. Seismic surveys were not done at night in this project resulting in no monitoring effort during this period.

The information on dates and times of sightings, name of boat, boat's geographical coordinates, distance of animal or group in relation to the observation point, and depth at the point of observation was recorded on a specific form. All boats were equipped with satellite navigation systems (DGPS) to help with the recording of the sighting positions.

Data analysis

The sighting databank was analyzed in relation to the diversity, distribution, distance between sightings and land, and distance between sea turtles and boats, and behavioral responses of sea turtle to the seismic surveys were determined. The sea turtles distribution was plotted on maps of the seismic areas. These maps were developed with georeferenced images software.

The effort was analyzed according to days and hours and a sighting index was created by dividing the number of sea turtles by the effort in hours for each seismic survey (turtle/hour). This index was used to reduce bias during comparison of sea turtle abundance among seismic projects.

The time of sighting was grouped into two hours intervals to verify the effect of luminosity on observations of sea turtles. The statistical test Kruskal-Wallis was applied to evaluate differences among intervals.

The sea turtle observations were associated with depth and distance from land for each project. The distances from land were calculated in kilometers by the distance between coordinates of each sighting and the closest point in line to the coast.

Besides that, the effect of sea and weather conditions in sightings of sea turtle were verified. To do this, analysis indexes were grouped according to sea and weather conditions presented in the forms (calm, moderate, and storm) and then the Kruskal-Wallis statistical test was applied to verify significant differences among them.

The influence of airguns on sea turtles was analyzed by comparing the index of sightings (turtle/hour) according to airgun state (switched on or switched off) for each seismic project. Likewise, the behaviors were analyzed according to airgun state. The Wilcoxon statistical test was applied in both analyses to verify significant differences between indexes. All statistical analyses used the significant level of $p<0.05$.

Results

The seismic surveys in northeast Brazil totaled 320 days and 2028 hours of biota sightings. Three sea turtles species were identified as follows: The green-sea-turtle (*Chelonia mydas*), the loggerhead-turtle (*Caretta caretta*), and the olive-ridley-turtle (*Lepidochelys olivacea*). There was a large variation in the index of sea turtles among seismic surveys (Figure 2).

All sightings of sea turtle occurred between 04:00 h and 18:00 h and there were no sightings during the dark period. The highest index of sightings occurred between 08:00h and 10:00h, while the lowest index occurred between 0400h and 0600h (Figure 3). Although data have suggested a direct relation between lighter time and higher indexes, the Kruskal-Wallis test was not significant ($H=7.3835$; $p=0.2868$).

Distribution and diversity of species

Forty-six sea turtles were observed during the monitoring of biota in the seismic surveys. The green-sea-turtle (*Chelonia mydas*) was the highest species sighted (0.087 turtle/hour). The two other species (*Lepidochelys olivacea* and *Caretta caretta*) were only seen once. The index of unidentified species (0.100 turtle/hour) was higher than the index of identified species (0.090 turtle/hour) and correlated with 57% of records. The distribution of sea turtle by seismic survey area is presented in Figure 4.

The green-sea-turtle (*Chelonia mydas*) was sighted in all projects except in the Caioba-Camurim project, which was carried out in Sergipe state. In fact, there was only one record of sea turtle at this project but was not possible to identify it. RNS-144, which was carried out in the Rio Grande do Norte state, also had low sightings of sea turtles. In this project all sightings were related to green-sea-turtle with an index of 0.012 turtle/hour.

The third area of lowest abundance was the Guaricema-Dourado area with 0.014 turtle/hour. It was possible to identify species (*Chelonia mydas*) in only one opportunity in this project with the unidentified species corresponding to 81.8% of the observations of the project and 34.6% of unidentified species in all projects.

The Ceará state had the highest abundance with 77.8% of the sightings as a whole. The area of most abundance was the project CES-134 with 0.147 turtle/hour followed by the project AXEC with 0.016 turtle/hour.

Sea turtles were observed between 1.6 km and 41.1 km away from the coast. The loggerhead-turtle and olive-ridley-turtle, both recorded only once, were as far as 41.1 km from coastline in the Ceará state and 15.9 km from coastline in Sergipe state, respectively.

The green-sea-turtle was also widely distributed and was sighted between 1.6 and 39.3 km from the coastline. But its highest abundance was approximately 10 km away from the coastline with 56.3% of the total sightings for the species. The index of sea turtle was 16.7% at a distance of over 30 km from the coastline.

Only 22 records had information regarding depth of sea turtles with a total of 0.124 turtle/hour. The index of sea turtles up to depths of 10 m was 93.3% (0.116 turtle/hour) and all of these were green-sea-turtles. The loggerhead-turtle was sighted in area of 40 m depth and no information about depth was collected for the olive-ridley-turtle.

Effect of sea and weather conditions and of airguns on sightings of sea turtles

The sightings of sea turtles seem to have varied with the sea and weather conditions, but only 19 records had this information. Among these, the highest index of sightings occurred when sea and weather conditions were classified as calm (0.039 turtle/hour; 46.6%), followed by moderate (0.033 turtle/hour; 38.9%) and storm (0.012 turtle/hour; 14.5%). However, the Kruskal-Wallis test did not consider those differences significant (H= 3.4209; p=0.1808).

The information about airgun state (switched on or switched off) was presented in 32 records. The index of sightings with airguns on was 0.054 turtle/hour and during airguns off was 0.075 turtle/hour. In the project Caioba-Camurim (Sergipe state), the single sea turtle was sighted during airguns on, while in the project RNS-144 (Rio Grande do Norte State) all of them occurred during airguns off. The Wilcoxon test did not consider the differences significant between airguns states (Z=-1.75; p=0.0896). The loggerhead-turtle and olive-ridley-turtle were sighted during airguns on and the first species was dead at 10 m from the boat, while the second was live at 30 m from the boat and dove immediately.

The IBAMA has defined a minimum distance of 500 m between sea turtle and Gunboat as requirement to switch off airguns temporarily (IBAMA 2003b). But only 26 sightings recorded this distance and only 17 records had information about airguns state as a whole.

The sightings of sea turtles occurred between 3 and 2000 m, although only one occurred 500 m from the boat. Most of the animals (17 sightings) were until 50m from boat, but only 61.5% (13 sightings) gave information about airguns state. In eight sightings, the sea turtles were 30 m from the Gunboat during airguns on and they were immediately switched off. In these cases, the activity was restarted after the observer did not sight the sea turtle again.

The following behaviors were observed for the sea turtles, the highest index was for swimming (0.093 turtle/hour) followed by still (0.006 turtle/hour), playing (0.004 turtle/hour), and floating (0.003 turtle/hour). Some other behaviors were not identified (0.004 turtle/hour) and there were an index of dead animals (0.011 turtle/hour). The Wilcoxon test (Z=-1.57; p=0.1159) did not result in significant difference between indexes of behavior according airgun state (Figure 5).

Discussion

The sea turtles are a highly migratory species, moving among continents oceanwide to reproduce, feed and rest (Meylan 1982). The sea turtles distribution in Brazil is well known and the main areas used for reproduction, feeding and resting are defined as a whole. Northeastern Brazil is very important region to sea turtles and five species are recorded in that area (Marcovaldi & Marcovaldi 1999, Sanches, 1999). Although there is this general knowledge about sea turtles in northeast Brazil, there are no information correlating its occurrence with seismic surveys. This lack in knowledge is evident concerning the effects of seismic surveys on sea turtle distribution and behavior.

The sea turtles observed in this study for instance, use northeast Brazil mainly to reproduce (Sanches 1999, Silva et al. 2001). However, the hawksbill-sea-turtle (*Eretmochelys imbricata*) was not observed in this study despite the fact that this species has the largest number of nests along the coast of Rio Grande do Norte state (Sanches 1999) where the project RNS-144 was carried out. The absence of this species can be explained by the fact that its reproductive period in that region occurs between November and April, and is very close to shore (Claudio Bellini, personal communication), while the project RNS-144 was carried out between August and October. Another species previously described to occur along northeastern Brazil is the leatherback-turtle (*Dermochelys coriacea*), but its presence in this area is considered rare, being more common in the southeast and south of Brazil (Sanches 1999). Aside from that, the species *Chelonia mydas*, *Caretta caretta* and *Lepidochelys olivacea* did occur during seismic surveys in shallow waters of northeastern Brazil between 2002 and 2003. For this reason their occurrence and distribution will be discussed separately.

The green-sea-turtle, Chelonia mydas

The green-sea-turtle is an abundant species along the Brazilian coast (Sanches 1999). It uses mainly oceanic islands to nest and it is usually not found along the northeastern coast during the turtle's reproductive period, which is between September and March and in some cases in April (Marcovaldi & Marcovaldi 1999). Nevertheless, it was the most common species in this study, being present in all prospected areas.

Even though the species uses mainly oceanic islands to nest, there are records of nesting along the coast of the Sergipe and Rio Grande do Norte states (Sanches 1999), where the Caioba-Camurim, Guaricema-Dourado, and RNS-144 projects occurred. The absence of species during observations in the Caioba-Camurim project can be explained by the development period of that project (June to August) which occurred while the species is typically not near Sergipe, but in feeding areas (Hendrickson 1980). This hypothesis is reinforced by presence of the species during the Guaricema-Dourado project that also was carried out in Sergipe state during reproductive period of green-sea-turtle.

The low index of green-sea-turtle in the Rio Grande do Norte state during the project RNS-144 also can also be explained by the reproductive period of the species in that state. As the state is located north of Sergipe state, the reproductive period of that species begins later, about November (Claudio Bellini, personal communication), and few specimens had arrived in the area during the time period of the seismic survey. Nevertheless, this hypothesis could not be confirmed by this study due to absence of previous sightings in the area of seismic survey.

The state of Ceará has a feeding area for green-sea-turtles located along the west coast, called Almofala (Marcovaldi et al. 1998, Sanches 1999; Lima 2001, Marcovaldi 2001). The sea turtles use that coastline mainly between January and July (Lima et al. 1997, Projeto TAMAR 2005) when specimens come from Suriname (Pritchard 1973) and Ascension's Island (Carr 1975, Mortimer & Carr 1987) after nesting.

This species is found most frequently along coastline of Ceará state (Sanches 1999) and it is found near shore due to the large presence of algae and sea grass forage (Hendrickson 1980, Bjorndal 1997). The sea grass banks are abundant in areas of depths upto 10m, being most common between 2 and 3m (Laborer-Deguen 1963, Eskinazi-Leça et al. 2004). Therefore, since the project AXEC was carried out along the west coast of the Ceará state, during the feeding time period of sea turtles, the low abundance of species during that project can be related with the depth of the area which varied from 25 to 58 m.

The depth could also explain the high abundance of green-sea-turtles during the CES-134 project, carried out along the east coastline of the Ceará state in area between 2 and 10 m depth. The index of sightings of sea turtles in that project was extremely high compared to the four other projects.

According to Lima et al. (1997) the sea turtles leave feeding areas from the Ceará state in July and return to nesting areas. However, the turtles that nest in Suriname may stay longer in the area around Ceará. This is likely because the reproductive period in Suiname occurs mainly between March and May and there are records of sea turtles marked in Suriname and captured in the Ceará between April and September (Pritchard 1973).

Pendoley (1997) reported that seismic surveys carried out in feeding areas of sea turtles can represent risk to all classes of population, be it male or female, juveniles or adults. But like in the states of Sergipe and Rio Grande do Norte, it was not possible to infer about effect of seismic surveys in the distribution of green-sea-turtles in the state of Ceará due to absence of previous observations.

The olive-ridley-turtle, Lepidochelys olivacea

The olive-ridley-turtle is an essentially pelagic species comes nearshore during its reproductive period (Hendrickson 1980) and it is the main species along the coastline of Sergipe between September and March (Marcovaldi & Marcovaldi 1999, Sanches 1999, Silva et al. 2001). The north coastline of that state has a very important nesting area to sea turtles called Biological Reserve of Santa Isabel. For this reason, it is possible during the Caioba-Camurim project that species was feeding in pelagic areas, which would explain its absence in that area. The species was sighted during the Guaricema-Dourado, which was carried out during the nesting period, even though this was a single observation. It is also possible that the high number of unidentified sea turtles recorded during the Guaricema-Dourado corresponds to the olive-ridley-turtle and they were not identified due their feeding behavior on benthic organisms (Hendrickson 1980), which makes it difficult to see the turtles as they are spending longer periods underwater. Its occurrence from Bahia to Sergipe is sporadic (Márquez 1990) and it has been previously recorded in the state of Ceará with a nest in Almofala (Lima et al. 2003), the absence of species in other seismic surveys areas could be result of the problem with identify them at sea, since animals were only observed from boats in few times.

The loggerhead-turtle, Caretta caretta

The loggerhead-turtle is widely distributed along coastal tropical and subtropical areas around the world (Márquez 1990) and has been found in neritic waters feeding benthic organisms (Hendrickson 1980). There are records of its accidental capture in water between 638 m and 4000 m (Barata et al. 1998) even though the deepest dive recorded is 233 m (Lutcavage & Lutz 1997).

The species has been previously recorded in Brazil with nests in states of Maranhão and Ceará with an annual production of over a thousand nests, and from Sergipe and Bahia (Márquez 1990). These previous records justify its presence during the project AXEC carried out in west coast of Ceará and it was the animal recorded in the greatest water depth and furthest from coastline of all of the seismic surveys.

In studies done by Lenhardt (1994) with loggerhead-turtles in captive, they use the sea bed to rest and emerge to breathe about every 10 minutes before acoustic stimulus from seismic surveys. After beginning stimulus sea turtles started to swim without any one returning back to the bottom or stopping swimming. The loggerhead-turtles stayed slightly submerged in the interface water-air to reduce the effects of noise. If the same behavior had occurred during the seismic surveys of northeast Brazil, the index of sightings for species would have been higher.

Considerations about sighting effectiveness to identify seismic surveys effects

The most information concerning effects of seismic surveys in marine life is related to cetaceans and pinnipeds (e.g. Evans et al. 1993, Richardson et al. 1995, Harris et al. 2001, Stone 2003, Parente 2005). The study that gives the best information about the behavior response of sea turtles during the use of airguns was done by McCauley et al. (2000) in Australian waters.

The behavior in Testudomorpha is more complicated to evaluate than in mammals due to unreliable identification of behavior responses to external stimulus (Bartol et al. 1999). In the present study, behaviors described are very superficial and hard to analysis when associated with airgun states. This occurred because the forms were developed with the main objective to describe marine mammals' behavior, despite being very superficial.

McCauley et al. (2000) studied sea turtles exposed to airgun shots, and observed an increase in its swimming activity with agitation and presented erratic movements in consequence of increased noise levels. The increase of turtles' swimming speed and diving behavior were also observed with 500 Hz at 113 dB and with 30 Hz at 164 dB, respectively (Lenhardt 2002). Different from the research developed by McCauley et al. (2000) and Lenhardt (2002), this study only characterized the behavior without consider velocity and direction of sea turtles according to airguns shots. Without this information the record of "swimming" behavior does not explain anything about behavior response of specimens to the seismic surveys because it is not possible to define changes on turtles' swimming patterns.

The "swimming" behavior could be an indicative of seismic survey impacts if considered information presented by Lenhardt (1994). Stone (2003) recorded similar behavior to cetaceans adding an increase of surface exposures. Despite predominance of "swimming" behavior in the present study and presence of "floating" behavior, there is no information that supports the hypothesis of Lenhardt (1994).

An evident error in behavior categories presented in forms to sea turtles is the "playing" behavior. This is a largely studied behavior in marine mammals and it is related to learning and handling ability of some cetacean species but there is no information concerning this behavior to sea turtles. The record of this behavior to sea turtle figures little knowledge of observers about this subject and generates doubt about the effectiveness of sightings.

The sea and weather conditions directly influenced observation of marine life, mainly when this observation is done by floating, flying or fixed superficies. Previous studies have shown direct correlation between good weather conditions and luminosity with highest indexes of sightings around oceans (e.g. DeMaster et al. 2001, Harris et al. 2001, Stone 2003, Parente 2005). The data from this study suggests the same effects of these subjects in indexes of sighting, but statistical analyses did not shown it significantly. It is possible that the sample size was too small and this should be increased for this analysis in the next studies.

According to IBAMA (2003b) all sea turtles sighted upto 500m away from the Gunboat shall be recoded and airguns shots stopped as to not disturb the animals. The results from this research show that it is very hard to sight a sea turtle at long distances and most of the sightings occurred with the specimens being 50m away from the boat. Although airguns have been turned off in all these cases, this result demonstrates that the methodology used did not circumvent close contact of sea turtles with the highest intensities of noise pulses.

Likewise, anterior studies indicate that marine life stay far away from airguns when they are turned on and approach when they are switched off (Stone 2000, Harris et al. 2001, Almeida et al. 2004, Carmo et al. 2004). The same was not observed in this study suggesting at first that the activity did not affect the specimens. But the absence of data concerning direction of swimming of sea turtles in relation to the Gunboat makes it not possible to draw any conclusions about this particular behavior.

According to Pendoley (1997), the period between nesting in a reproductive station is biologically critic to females of sea turtles because eggs are being formed. Therefore, the seismic surveys during reproductive stations of sea turtles could impact the species and egg formation and should be avoided in areas and periods classified as important to species conservation. Long term studies to identify effects of seismic surveys in sea turtles populations should be continued in Brazil and around the world to generate precise information concerning this subject.

Conclusions

The information about occurrence and distribution of sea turtle species in northeast Brazil acquired during seismic surveys in shallow water contributed to the knowledge of species. Nevertheless, they were unable to give information about the effects of the activity on the distribution and behavior of sea turtles being which would have allowed for necessary corrections and adjustments in methodology to improve this information. Other factor that influenced low effectiveness of sighting was the absence of previous information concerning sea turtles occurrence and distribution in the areas.

The most common species present in northeast of Brazil, during seismic surveys, was the green-see-turtle (*Chelonia mydas*) and its highest index of sightings was in the state of Ceará. Its distribution in that state was strongly influenced by low depth and proximity of coastline suggesting that areas as an important foraging area for the species. The presence of sea turtles in state of Sergipe was related to reproductive period.

Finally, the high number of specimens unidentified and the low quality of information suggest it is necessary to training observers and use other techniques to monitoring sea turtles during seismic surveys. As this study only explores data from seismic surveys occurring in shallow waters during two years using ocean-bottom-cable techniques, it is recommended to extend this analysis to other years and techniques.

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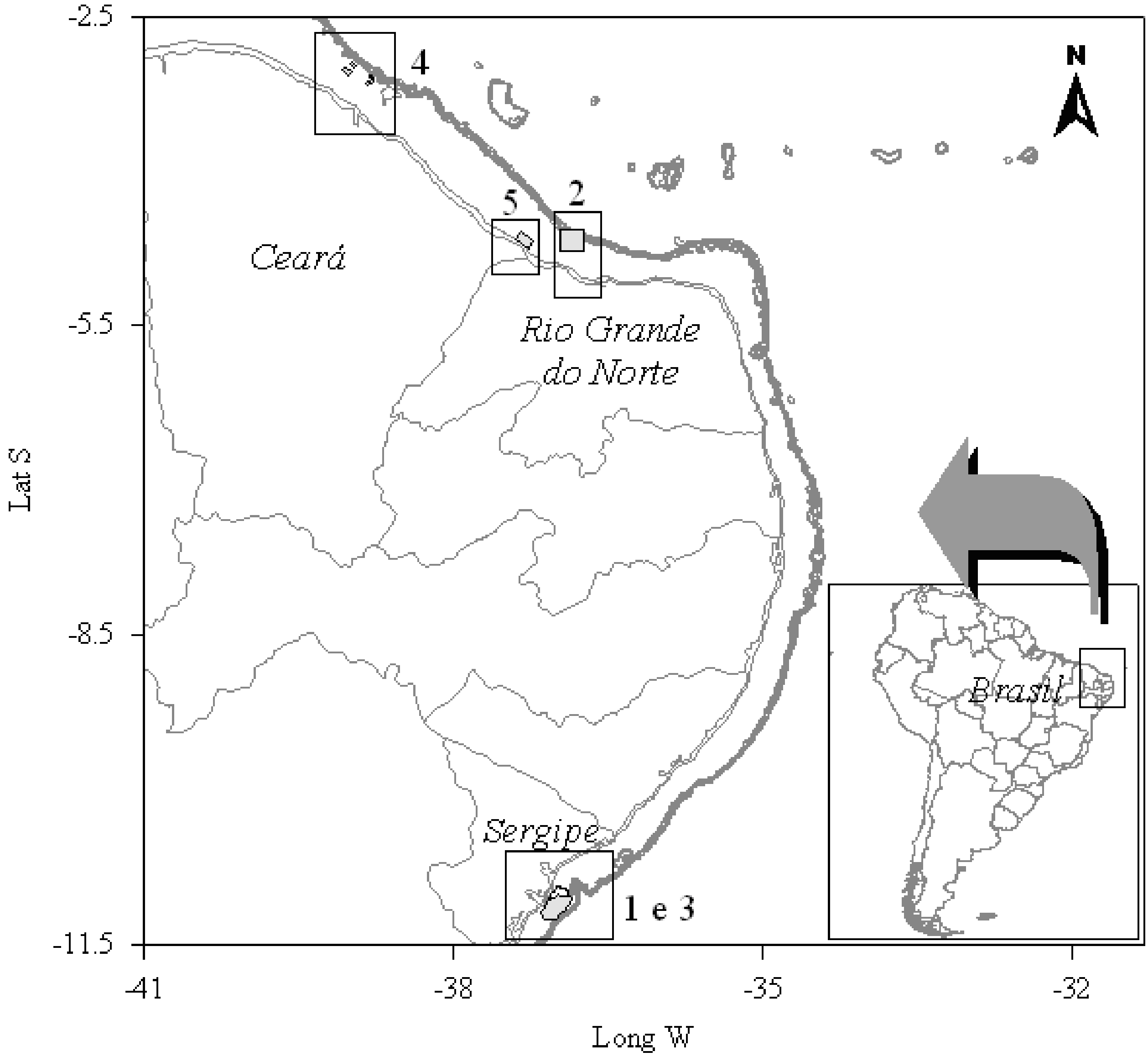

Figure 1 – Map of northeastern Brazil focusing on the ocean-bottom-cable seismic surveys done between 2002 and 2003. (1 – Caioba-Camurim; 2 – RNS-144; 3 – Guaricema-Dourado; 4 – Atum-Xaréu-Espada-Curimã; 5 – CES-134)

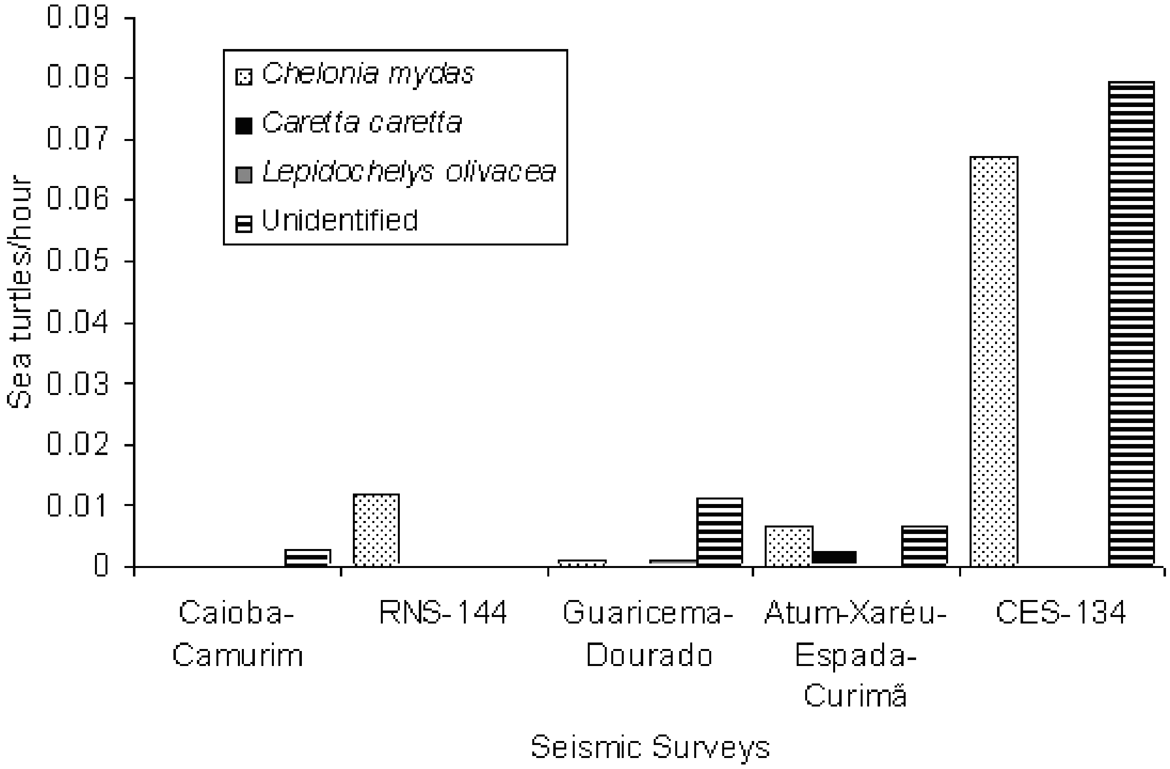

Figure 2 – Index of sea turtle sightings by seismic survey done in the northeastern Brazil between 2002 and 2003

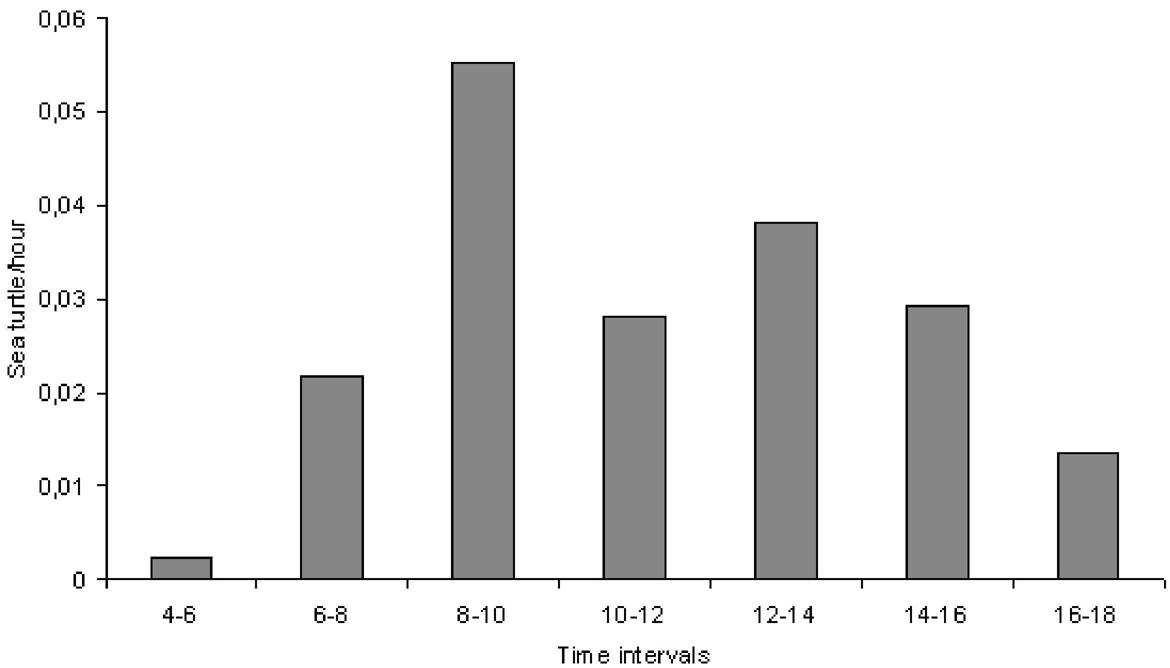

Figure 3 – Indexes of sea turtle sightings during the seismic surveys that occurred in northeastern Brazil between 2002 and 2003 according to the time of day.

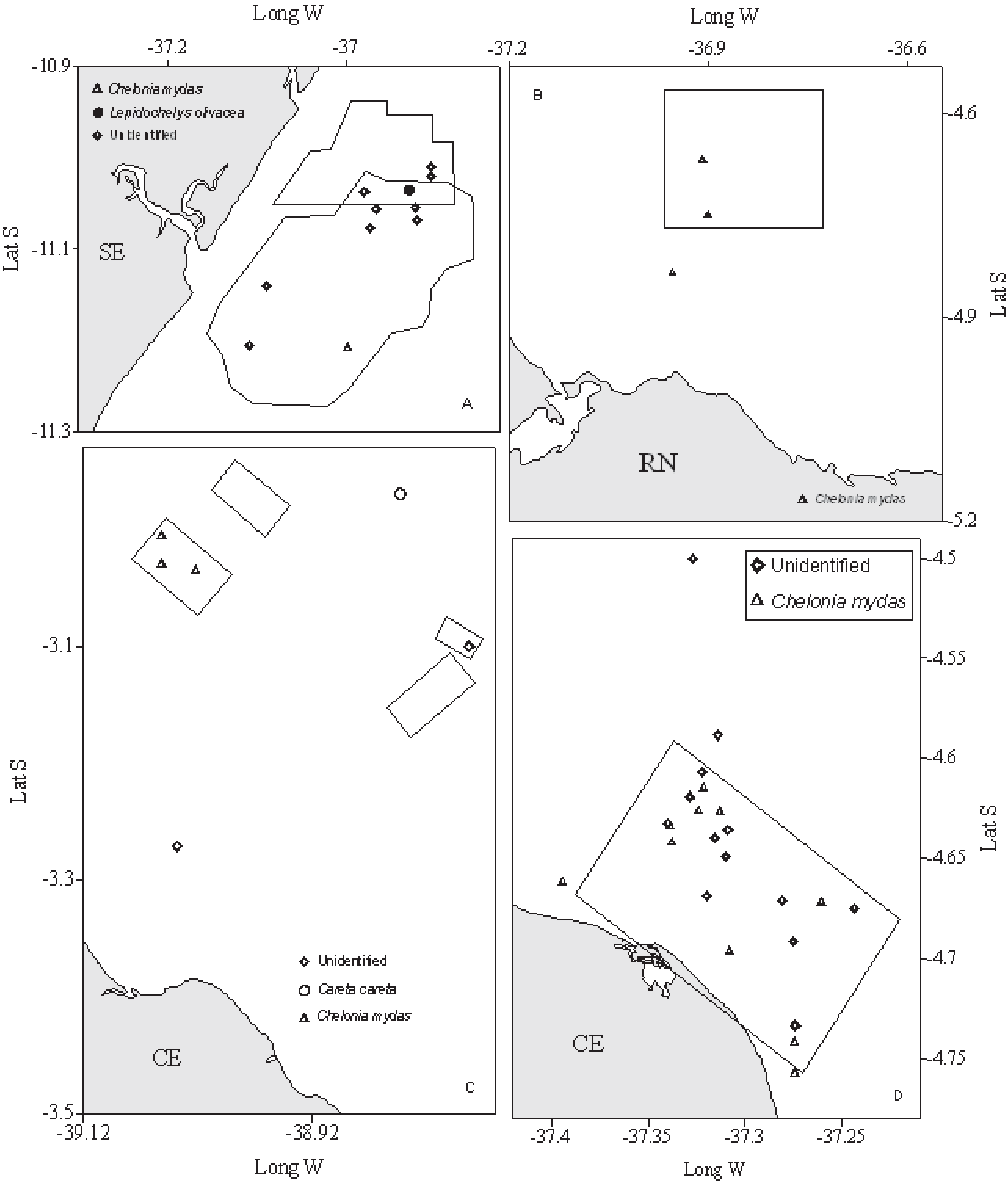

Figure 4 – Sea turtles distribution during the seismic surveys that occurred in northeastern Brazil between 2002 and 2003 (A – Caioba-Camurim and Guaricema-Dourado; B – RNS-144; C – Atum-Xaréu-Espada-Curimã; D – CES-134). Outlined areas indicate area of survey

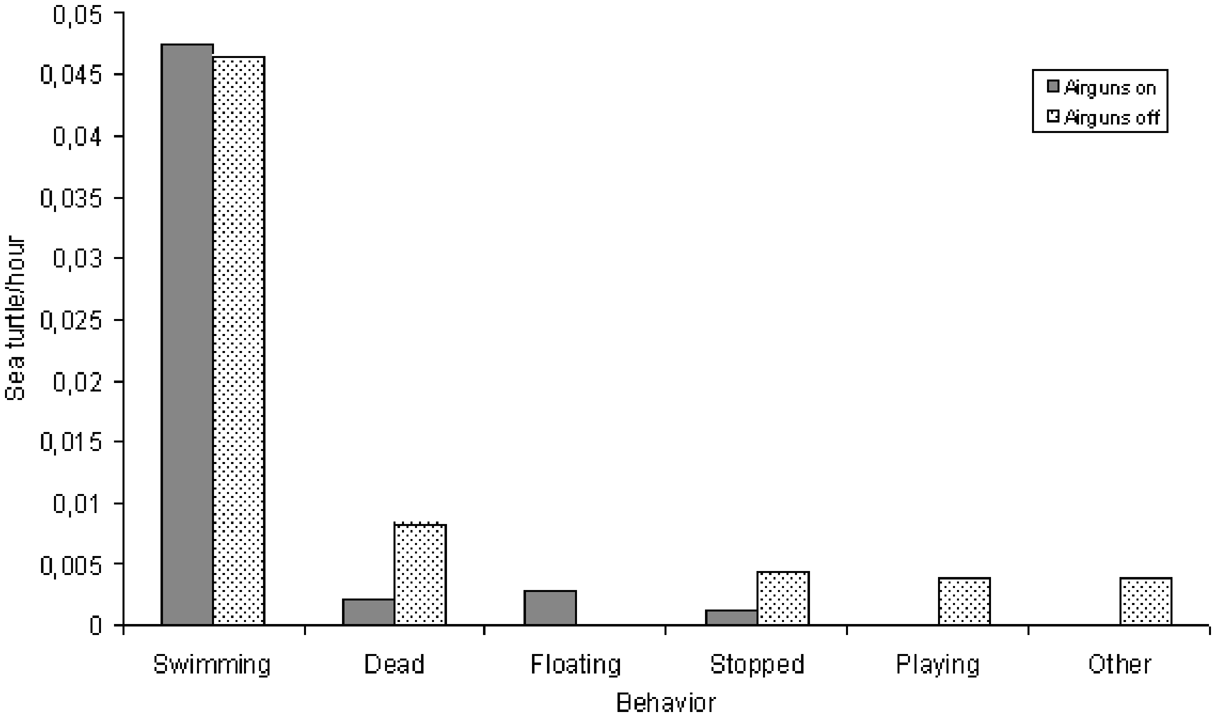

Figure 5 – Index of sea turtles behaviors observed during the seismic surveys occurring in northeastern Brazil between 2002 and 2003 according to the airgun state