Is the diversity of cetaceans in Brazil reduced by the intensification of the seismic surveys?

Cristiano Leite Parente & Maria Elisabeth de Araújo

Federal University of Pernambuco, Post-Graduation Program in Oceanography. Recife-PE, Brazil, Av. Prof. Moraes Rego, 1235, Cidade Universitária, Recife, PE, 50670-901, Brazil. e-mail: cristiano.parente@uol.com.br

ABSTRACT

New information about the effects of seismic surveys on cetaceans has been arising constantly demonstrating an increasing concern about this type of activity. The described effects include behavioral responses and changing of vocalization patterns, migratory routes diversion, auditory system damage, and increase of strandings. Although all these factors affect the diversity of species in areas where the seismic searches have been accomplished, there is no scientific information pointing this aspect. This study evaluated the relationship among seismic surveys and the diversity of species of cetaceans recorded in Brazil after the intensification of the seismic survey activity since 1999, based on progress reports of Brazilian researches to the International Whaling Commission, and reports of seismic surveys in Brazil between 1999 and 2003. The results suggest a decrease in the diversity of species in relation to the seismic surveys intensification during the years 2000 and 2001, showing that variations in the species diversity can be used as an indicator of seismic surveys impacts on cetaceans.

Keywords: Noise impact, Seismic survey, Diversity of cetacean, South America.

INTRODUCTION

Although records of new species happen time to time, there are 119 species of aquatic mammals identified in the entire world (Jefferson et al., 1994). The order Cetacea contains 84 of those species spread out in the oceans, rivers and estuaries. 13 of these species belong to the sub-order Mysticeti, and 71 to the sub-order Odontoceti. The Brazilian waters shelter 43 species of cetaceans: 8 species of the sub-

order Mysticeti and 35 species of Odontoceti (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis - IBAMA, 2001; Pinedo et al., 2002).

In Brazil like in other parts of the world these aquatic mammals suffer negative effects, due to several human activities such as fishing (e.g. Monteiro-Neto *et al*., 2000; Pizzorno *et al*.,1998; Rosas *et al*., 2002; Siciliano, 1994), tourism (e.g. Lodi *et al*., 1996; Silva Jr, 1996), and more recently the stranding of male adults of Humpback whales was related with seismic surveys in the Northeastern region of Brazil (Engel *et al*., 2004). The concern about the effects of seismic surveys on marine mammals is not recent (e.g. Green et al., 1994; Popper et al., 2000; Richardson et al., 1995). The studies demonstrated that the noise emitted by seismic survey air-guns causes diverse effects depending on the species of cetaceans due to hearing sensitivity, behavioral estate, habituation or desensitization, age, sex, location of exposure, and proximity to a shoreline (e.g. Dolman & Simmonds, 2003; Evans et al., 1993; Gordon et al., 2004; Madsen et al., 2002). Nonetheless, the existent results focus small numbers of species that occur during a seismic survey or that already have historical observation series. The extrapolation of the obtained results for some species and habitats is not accepted to others due to the variation of the acoustic characteristics of the environment and applied technology (e.g. Goold, 1996; Mate et al., 1994; McCauley et al., 2000).

The species diversity has been an excellent tool for the analysis of environmental impacts (e.g. Myers, 1989; Gaston, 2000; Weitzman, 1993). However, variation in the cetacean diversity in function of the intensification of seismic surveys has not been verified yet. It is possible that this kind of analysis has not been accomplished due to: 1) difficulty of a historical observation series of marine mammals with standardized procedures, and 2) researches on cetaceans are addressed to the most common species in certain areas. Considering the variations in cetacean behavior responses to seismic surveys it is possible that the diversity of species in a certain area could be altered because of the intensification or reduction of seismic surveys.

This research intends to verify the effect of the variation in seismic surveys efforts after the end of the monopoly of the petroleum market in Brazil on the diversity of cetaceans recorded among the years 1999 and 2003.

MATERIAL AND METHODS

Data source

The information about diversity of cetaceans in Brazil was obtained from the Brazilian progress reports published by the International Whaling Commission (IWC) among the years 1999 and 2003 (IWC, 2004) which are annually organized by the Brazilian government based on results of collaborators involved in research and conservation of cetaceans in the country. As the results are originating from different institutions and researchers without standardized procedures and sampling effort, it was considered only the presence and absence of species in Brazil without abundance analysis.

The data about seismic surveys occurred between 1999 and 2003, and were extracted from annual reports of the Petroleum National Agency of Brazil (Agência Nacional do Petróleo – ANP, 2004). The information about the 2-Dimensions (2D) and 3-Dimensions (3D) seismic surveys was organized in an electronic database allowing evaluating the evolution of seismic surveys during the period according to the applied technology.

Data analyzes

The information about cetaceans occurrence was organized in an electronic database to accomplish an annual table of presence and absence of cetaceans species in Brazil. This table allowed to quantify the number of cetacean species recorded during a certain period, and to apply the Shannon-Wiener diversity index (H') based on Log_2 (Shannon, 1948).

The tables with the annual list of species and annual seismic studies were submitted to clustering analyses with the weighted pair-group method, arithmetic average (WPGMA) in Q modules to verify similarity level among the studied years (Legendre & Legendre, 1998). Bray Curtis' coefficient was used in both tables to allow comparisons, and a cophenetic analysis was carried out to test the goodness of fit of clustering to the set of data (Rohlf & Sokal, 1981). The logarithms of the number of recorded species and the number of seismic surveys in each year were compared, and submitted to Mann-Whitney no-parametric statistical test to verify the viability of comparisons among seismic surveys and total cetaceans diversity.

RESULTS

Seismic surveys

A total of 92 seismic surveys occurred among the period corresponding to 19 seismic programs using the technology 2-Dimensions (2D) totaling 318,687.3 km of extension, and 73 using technology 3-Dimensions (3D) adding 150,019.5 km² of prospected area. The number of surveys in execution/ month was larger in 2000 with 23 programs (mean=16.7 survey/month; SD=3.6), following by 2001 (n=21; mean=10.3; SD=7.7), 1999 (n=12; mean=6.2; SD=4.3); 2002 (n=8; mean=6.4; SD=1.2), and 2003 (n=7; mean=3.9; SD=1.9). The figures 1 and 2 show the evolution of the seismic surveys completed in the period.

The cluster analysis of the number of seismic surveys in operation/ month in each year showed a large similarity between the years 2000 and 2001, when compared to other studied years (Figure 3), indicating that these years had more intense seismic surveys. The cophenetic analysis showed a good adjustment of the data explaining more than 70% of possible variations (λ=0.71456).

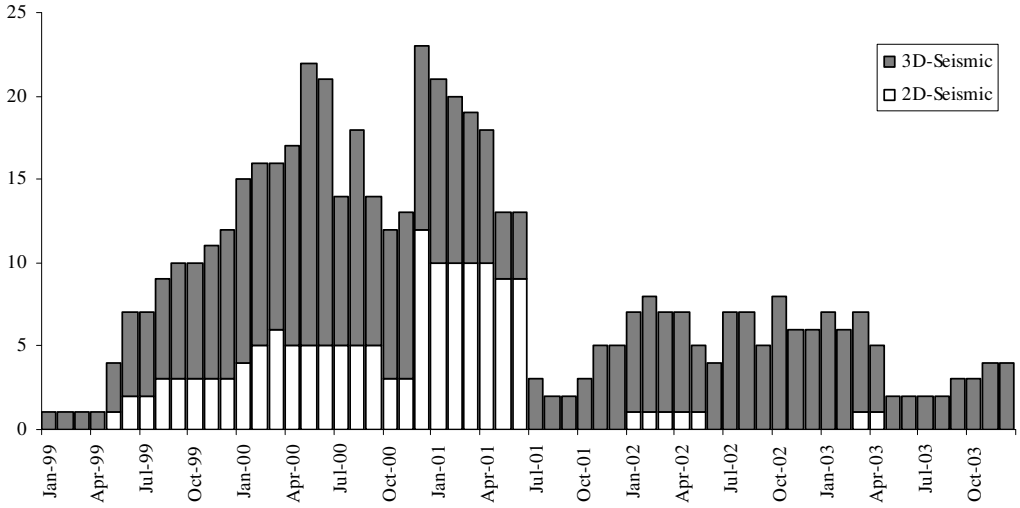

Figure 1: Number of seismic surveys in Brazil from January 1999 to December 2003

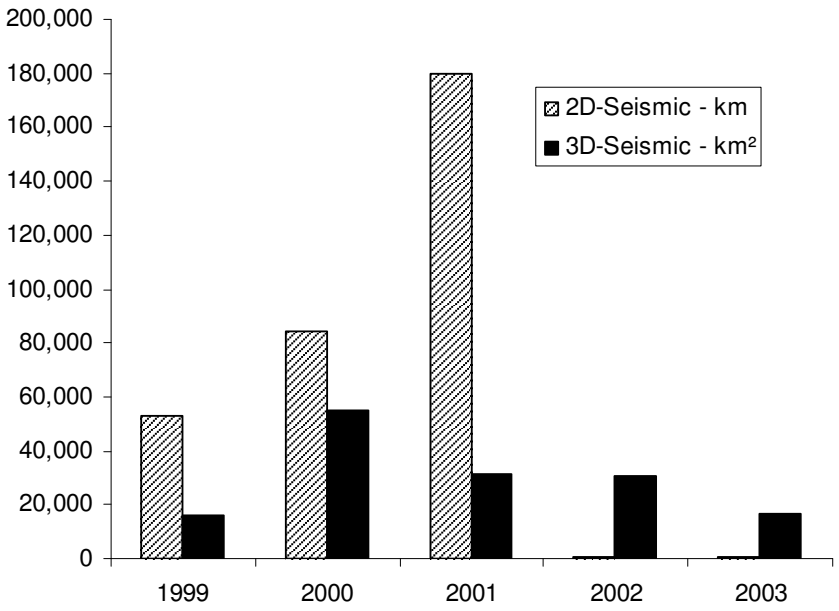

Figure 2: Extension of the seismic surveys in Brazil among the years 1999 and 2003 according to tecnology

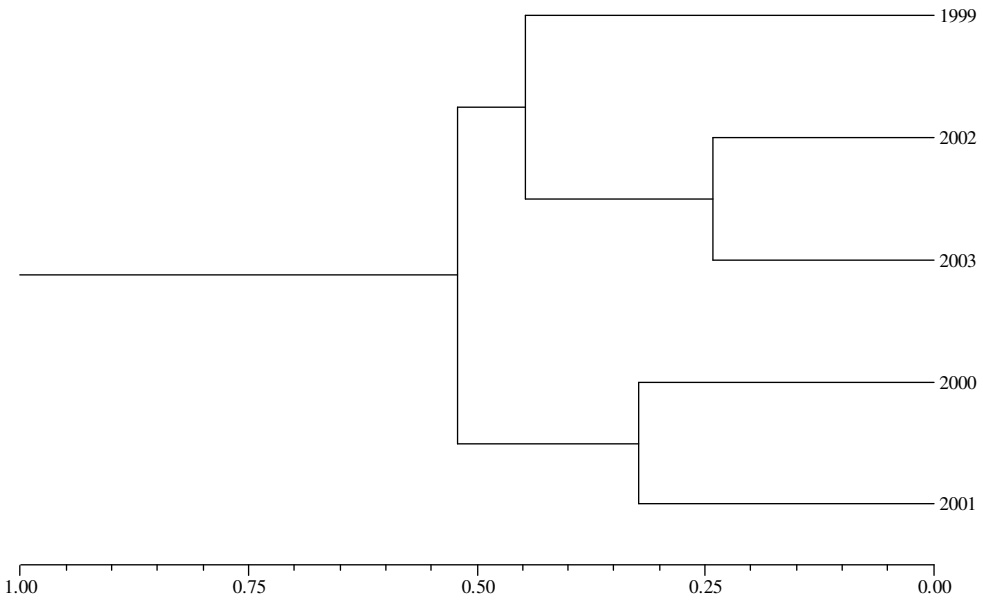

Figure 3: Tree of the clustering analyses of the years in function of the volume of seismic surveys in the period ($\lambda = 0.71456$)

Diversity of cetaceans

Of the 43 species of cetaceans recorded in Brazil, 35 (85%) occurred between the years 1999 and 2003 representing the families: Balaenidae, Balaenopteridae, Delphinidae, Iniidae, Kogiidae, Phocoenidae, Physeteridae, Pontoporiidae, and Ziphiidae. The Table 1 shows the relation of present and absent species per year. The cetaceans that were not identified at the species taxonomic level were not considered.

The number of species varied in relation to the years. The family Delphinidae was the main responsible for the reduction in the total number of species recorded during the years 2000 and 2001. The cluster analysis of the present and absent species for each year, including species identified to genus level, showed large similarity between the years 2000 and 2001 when compared to other studied years (Figure 4) alike to the seismic surveys analysis. The cophenetic analysis showed a good data adjustment answering to almost 80% of the variations in the cetacean diversity for all years (λ=0.79167).

The Shannon-Wiener diversity indexes (H') for the studied period were: H'=3.178 in 1999, H'=2.996 in 2000, H'=2.565 in 2001, H'=3.296 in 2002, and H'=3.401 in 2003. These indexes showed a light variation in the diversity of species among the years with reduction in the years 2000 and 2001.

Table 1: Presence (1) and absence (0) of cetacean species registered in Brazil among 1999 and 2000

Taxonomy	1999	2000	2001	2002	2003
Mysticeti	**4**	**6**	**4**	**5**	**5**
Balaenopteridae					
Balaenoptera acutorostrata	1	1	1	1	1
Balaenoptera bonaerensis	0	1	1	0	1
Balaenoptera borealis	0	1	0	0	0
Balaenoptera edeni	1	1	0	1	1
Balaenoptera physalus	0	0	0	1	0
Megaptera novaeangliae	1	1	1	1	1
Balaenidae					
Eubalaena australis	1	1	1	1	1
Odontoceti	**19**	**15**	**11**	**18**	**22**
Delphinidae					
Delphinus capensis	1	0	0	0	0
Delphinus delphis	1	0	0	1	0
Feresa attenuata	0	1	0	0	1
Globicephala macrorhychus	1	1	1	1	1
Globicephala melas	0	0	0	0	1
Grampus griseus	0	0	0	0	1
Lagenodelphis hosei	1	0	0	0	0
Orcinus orca	1	0	0	1	1
Peponocephala electra	1	0	0	1	1
Pseudorca crassidens	1	1	0	0	0
Sotalia fluviatilis	1	1	1	1	1
Stenella attenuata	1	1	1	1	1
Stenella clymene	1	1	1	1	1
Stenella coeruleoalba	1	0	0	1	1
Stenella frontalis	1	1	1	1	1
Stenella longirostris	1	1	1	1	1
Steno bredanensis	1	1	1	1	1
Tursiops truncatus	1	1	1	1	1
Iniidae					
Inia geoffrensis	1	1	1	1	1
Kogiidae					
Kogia breviceps	0	1	0	0	1
Kogia sima	0	1	0	1	1
Pontoporiidae					
Pontoporia blainvillei	1	1	1	1	1
Phocoenidae					
Phocoena spinipinnis	1	0	0	0	1
Physeteridae					
Physeter macrocephalus	1	0	1	1	1
Ziphiidae					
Berardius arnuxii	0	0	0	0	1
Mesoplodon europeus	0	0	0	1	0
Ziphius cavirostris	0	1	0	1	1
Total	23	21	15	23	27

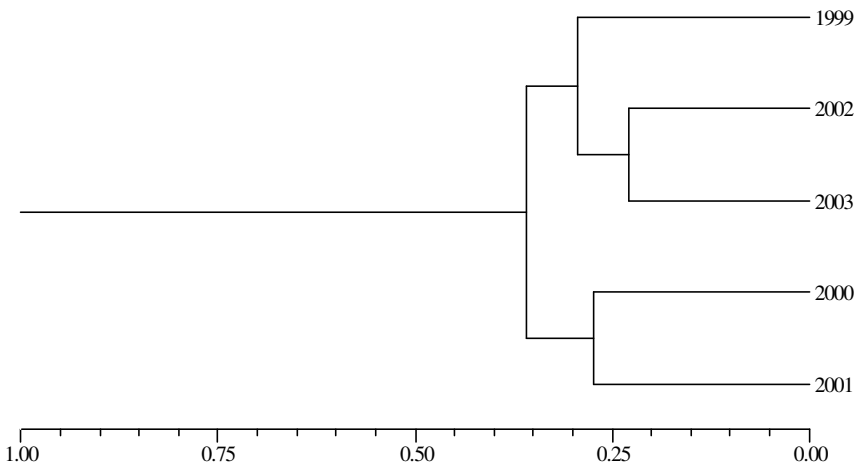

Figura 4. Tree of the cluster analyses grouping the years studied in function of the similarity in the presence and absence of cetacean species ($\lambda = 0.79167$)

Seismic survey vs. Diversity of cetaceans

The overlapping of logarithms of the number of cetacean species recorded per year, and the number of seismic surveys that occurred during the same period suggests an inverse relationship between these two factors, indicating a decrease of the diversity when the seismic surveys increases (Figure 5). The Mann-Whitney test comparing the natural logarithms of the numbers of seismic surveys and the number of species did not show a significant difference among the same ones [U=9.5; z(U)=0.6265; p=0.5309] allowing direct comparisons.

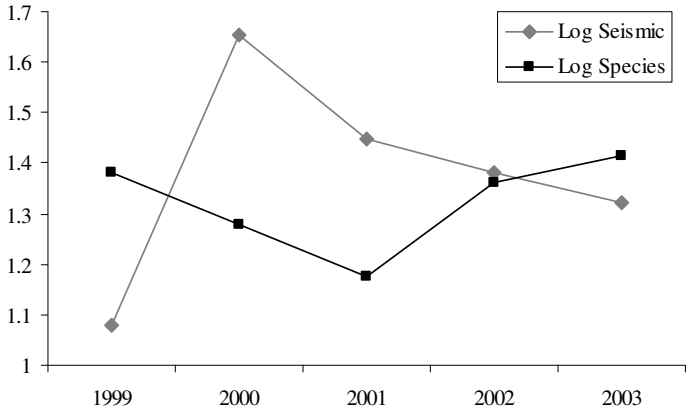

Figure 5: Relationship between the natural logarithms of cetacean species and the natural logarithms of seismic surveys accomplished among 1999 and 2003

DISCUSSION

The information about seismic surveys recorded during the studied period in Brazil had a fast growth until 2001, declining during the following years. According to the International Association of Geophysical Contractors of Brazil (IAGC), around 50% of the world fleet of marine seismic survey were in the country during the years 2000 and 2001 (IBAMA, 2003) resulting the great volume of surveys observed in this study. According to a note of the National Organization of the Petroleum Industry (Organização Nacional da Indústria do Petróleo - ONIP, in Portuguese) which considers the exploration level still modest, the investments in acquisition of seismic data in Brazil after the end of the monopoly of the petroleum industry were of 200 million dollars/year, representing a growth larger than 200% in relation to the previous years during the monopoly of the Government company (ONIP, 2003).

The reduction of the seismic survey activities in Brazil after June 2001 was reflex of the end of the great season on 2D seismic surveys and the increase of the demands of environmental control by the Brazilian government which resulted in periods and exclusion areas, as well as the demand of specific environmental studies according to the environmental sensibility of each area (Vilardo et al., 2003). In spite of these demands that still involve observation of aquatic mammals during the seismic surveys with interruptions of air-guns shots when species are in the ray of 500 meters of the Gunboat, there is little information originating from these observations. The results about the occurrence, distribution and behavior of the species observed during these surveys have not been published to the interested scientific community, resulting a little evolution in the adopted procedures to minimize the impacts of seismic surveys over the diversity of cetaceans in the Brazilian continental shelf waters.

An analysis the marine mammals monitoring data during the seismic surveys in shallow waters using techniques of Ocean Bottom Cables (OBC) accomplished in the northeast of Brazil during the years 2002 and 2003, showed that monitoring is little effective to report about seismic effects on marine mammals populations. The needs to improve the monitoring involve: training of observers to identify cetacean species and record its behaviour; standardization of data sampling during the seismic surveys; marine mammals surveys before, during and after seismic surveys to analyze distribution and abundance variations; use of acoustic monitoring techniques to identify species and noise levels, and the introduction of cetacean diversity analyses (Parente, 2005).

The main source of data about the recorded species during the studied period was provided from strandings and punctual observations with few marine mammals surveys (Parente, 2005; Zerbini et al., 2004a). Stranding records offer good information about general location of species but it is little exact for

distribution studies because they are influenced by the behavior and health condition of the animal, currents effects (Zerbini et al., 2004a), and are related with effort of rescue teams to check beaches.

The use of qualitative data (presence/absence) in the analysis of cetacean diversity developed in this study reduced errors originated from the evaluation of secondary data. Although it can vary with the research effort in the country, as observed in the IWC analyzed progress reports, the cetacean research efforts in Brazil have been almost constant with tendency towards growth, indicating that the variation in the number of species is not effect of the increase or reduction of effort.

Taking into consideration the little influence of the effort in the data variation in this study, it is possible to observe a reduction in the diversity of cetaceans among the first three years of the analysis with the minimum in the year 2001, turning to increase in 2002 and 2003 and reflecting in the Shannon-Wiener diversity index. The reduction in records of the Delphinidae family was the main responsible for this effect. Little information exists about the effect of seismic survey air-gun emissions on species of Delphinidae family. The information just includes the species *Delphinus delphis* (Goold, 1996) and *Tursiops truncatus* (Evans et al., 1993) resulting in population decline, suggesting that a portion of these populations has moved to other areas during the seismic surveys. It is also possible that this movement does not happen due the direct effect on species but for an indirect effect in function of the decline of preys in the explored area (Simmonds et al., 2003). Avoidance and changes in the migratory routes were also observed in other species of cetaceans such as *Physeter macrocephalus* (Mate et al., 1994), *Eschritius robustus* (Malme et al., 1983; 1984 in Richardson et al., 1995), *Balaena mysticetus* (Koski & Johnson, 1987 in Richardson et al., 1995), and *Megaptera novaeangliae* (McCauley et al., 2000).

Considering the little information about the effects of sound pulses emitted by air-guns used in seismic surveys over the great majority of the cetacean species, and the possibility of these pulses to cause avoidance and changing in migratory routes in some species, the observed reduction in cetacean diversity during the studied period might have been influenced by the intensification of seismic surveys among the years 2000 and 2001. As most of the information on cetacean incidence in Brazil is originated from stranding records, it is possible to suppose that individuals with oceanic habits tended to move away from the areas where seismic surveys happened, and did not strand in the Brazilian coast reflecting less species diversity during the increase of seismic surveys.

The analysis did not consider the distance of the cetacean records in relation to the areas of seismic surveys due to the absence of this correct information in the IWC Progress Reports. However, the seismic surveys happened mainly in the northeast and southeast regions, and according to the IWC Progress Reports analyzed the largest numbers of cetacean researchers were in the northeast, south and southeast

regions of Brazil. The cetacean observation cruises accomplished during the period happened mainly in the southeast and northeast regions of the country (Santos et al., 2001; Zerbini et al., 2004b).

These results suggest that the diversity of cetaceans is negatively affected by seismic surveys intensity. Even though the seismic survey effects were little evident and there was an increase of the cetacean diversity after a decrease of seismic surveys, it is suggested a maximum limit of six seismic surveys occurring at the same time in Brazil to not affect seriously the diversity of cetaceans in the Brazilian continental shelf. However, it is possible that other environmental or anthropogenic factors might have caused that variation in the cetacean diversity observed in this study, although such information does not appear in the scientific literature.

Although this study used secondary data for the diversity analyses, it demonstrated the viability of the use of diversity indexes in the study of the effects of seismic surveys on cetaceans. Nevertheless, the use of this tool cannot be substituted by abundance and distribution studies. This tool should be tested in other areas with quantitative data because the results of existent studies on the effect of seismic surveys on cetaceans do not demonstrate the total evasion of species from the occurrence areas.

The researches about the effects of anthropogenic noises generated by seismic surveys over marine mammals that occur in Brazil are still very incipient. In part it happens due to limited financial resources for this type of research. It is recommended to analyze the monitoring of all marine mammals during the seismic surveys accomplished since 1999 in Brazil to verify the information about diversity, abundance and distribution. With the results of this analyzes it will be possible to propose alternatives to improve the data sampling, monitoring and direction of researches. Also tests of alternative techniques with bioacoustic use should be developed to supervise the evolution of noises in the Brazilian continental shelf.

ACKNOWLEDGMENTS

The authors thanks the geologist of Brazilian National Agency of Petroleum Jotávio Gomes for the information on seismic accomplished in the period and Aline Holt for your collaboration in the text revision. Thanks also the financial support supplied by the Comissão de Aperfeiçoamento de Pessoal ao Ensino Superior (CAPES-MEC).

REFERENCES

Agência Nacional do Petróleo. 2005. Dados não-exclusivos. Available in http://www.anp.gov.br. Accessed in 15 January 2005. [In Portuguese]

Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. 2001. *Mamíferos aquáticos do Brasil: plano de ação*, versão II. Edições IBAMA, Brasília, Brasil, 102p. [In Portuguese]

Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. 2003. *Impactos da atividade de prospecção sísmica marítima*. Informação ELPN/IBAMA Nº 012/03. Rio de Janeiro, Brasil, 66p. Available in http://www.ibama.gov.br. Accessed in 12 March 2004. [In Portuguese]

International Whale Commission. 2004. Documents to download. Available in http://www.iwcoffice.org/_documents/docmain.htm. Accessed in 20 December 2004.

Dolman, S. & Simmonds, M. P. 2003. *Update on the impacts of acoustic pollution: with particular regard to research developments*. Unpublished report to the International Whaling Commission scientific committee, SC/55/E5. 9pp.

Evans, P. G. H.; Lewis, E. J. & Fisher, P. 1993. *A study of the possible effects of seismic testing upon cetaceans in the Irish Sea*. Rep. from Sea Watch Foundation, Oxford, UK., for Marathon Oil UK Ltd. 35 pp.

Gaston, K. J. 2000. Global patterns in biodiversity, *Nature*, 405, 220-227.

Goold, J. C. 1996. Acoustic assessment of populations of common dolphin *Delphinus delphis* in conjunction with seismic surveying. *Journal of the Marine Biology Association*, 76, 811-820.

Gordon, J.; Gillespie, D.; Potter, J.; Frantzis, A.; Simmonds, A. P.; Swift, R. & Thompson, D. 2004. A review of the effects of seismic surveys on marine mammals, *Marine Technology Society Journal*, 37, 16-34.

Green, D. M.; DeFerrari, H. A.; McFadden, D.; Pearse, J. S.; Popper, A. X.; Richardson, W. J.; Ridgway, S. H. & Tyack, P. L. 1994. *Low frequency sound and marine mammals: current knowledge and research needs*. (NRC report), National Academy Press, Washington, D.C., USA. 75pp.

Jefferson, T. A.; Leatherwood, S. & Webber, M.A. 1994. *Marine mammals of the World: FAO species identification guide*. FAO/UNEP. Available in www.fao.org/documents.html. Accessed in 25 april 2004.

Legendre, P. & Legendre, L. 1998. *Numerical ecology*. 2nd English edition. Developments in Environmental Modelling, 20, Elsevier, New Yourk. 853pp.

Lodi, L.; Siciliano, S. & Bellini, C. 1996. Ocorrência e conservação da baleia-franca-do-sul, *Eubalaena australis*, no litoral do Brasil. *Papeis Avulsos de Zoologia do Museu de Zoologia da Universidade de São Paulo*, 39(17): 307-328. [In Portuguese]

Madsen, P. T.; Møhl, B.; Nielsen, B. K. & Wahlberg. M. 2002. Male sperm whale behaviour during exposures to distant seismic survey pulses, *Aquatic Mammals*, 28, 231-240.

Mate, B. R.; Stafford, K. M. & Ljungblad, D. K. 1994. Change in sperm whale (*Physeter macrocephalus*) distribution correlated to seismic surveys in the Gulf of Mexico. *Journal of the Acoustic Society of America*, 96, 3268-3269.

McCauley, R. D.; Fewtrell, J.; Duncan, A. J.; Jenner, C.; Jenner, M.-N.; Penrose, J. D.; Prince, R. I. T.; Adhitya, A.; Murdoch, J., & McCabe, K. 2000. Marine seismic surveys: a study of environmental implications, *APPEA Journal*, 40, 692-708.

Monteiro-Neto, C.; Alves-Junior, T. T.; Ávila, F. J. C.; Campos, A. A.; Costa, A. F.; Silva, C. P. N. & Furtado-Neto, M. A. A. 2000. Impact of fisheries on the tucuxi (*Sotalia fluviatilis*) and rough-toothed dolphin (*Steno bredanensis*) populations off Ceará State, northeastern Brazil. *Aquatic Mammals*, 26(1):49-56.

Myers, N. 1989. Loss of biological diversity and its potential impact on agriculture and food production. *In:* D. Pimentel & C.W. Hall (eds), *Food and Natural Resources*, Academic Press, San Diego, 49-68.

Organização Nacional da Indústria do Petróleo. 2003. Consolidação da indústria sísmica no Brasil. Nota Técnica ONIP 004/2003, Brasil, 7pp. Available in http://www.onip.org.br. Accessed in 26 July 2004. [In Portuguese]

Parente, C. L. 2005. Monitoramento de mamíferos marinhos durante estudos sísmicos no nordeste do Brasil. Master Thesis, *Universidade Federal de Pernambuco*, Recife, Pernambuco, Brasil. 72pp. [In Portuguese]

Pinedo, M. C.; Barreto, A. S.; Lammardo, M. P.; Andrade, A. L. V.; Geracitano, L. 2002. Northernmost records of the spectacled porpoise, Layard's beaked whale, Commerson's dolphin, and Peale's dolphin in the southwestern Atlantic Ocean. *Aquatic Mammals*, 28(1): 32-37.

Pizzorno, J. L. A.; Dorneles, P. R.; Lailson-Brito, J. Jr.; Azevedo, A. F & Gurgel, I. M. G. N. 1998. Additional information on humpback whale (*Megaptera novaeangliae*) in the southeastern Brazilian coast. *Report of the International Whaling Commission*, 48, 443-446.

Popper, A. X.; DeFerrari, H. A.; Dolphin, W. F.; Edds-Walton, P. L.; Greve, G. M.; McFadden, D.; Rhines, P. B.; Ridgway, S. H.; Seyfarth, R. M.; Smith, S. L. & Tyack, P. L. 2000. *Marine mammals and low frequency sound.* (NRC report), National Academy Press, Washington, D.C. USA. 146pp.

Richardson, W. J.; Greene-Jr, C. R.; Malme, C. I. & Thomson, D. H. 1995. *Marine Mammals and Noise*. Academic Press. San Diego, California, USA. 576pp.

Rohlf, F. J. & Sokal, R. R. 1981. Comparing numerical taxonomic studies. *Systematic Zoology*, 30, 459-490

Rosas, F.C.W.; Monteiro-Filho, E.L.A. & Oliveira, M.R. 2002. Incidental catches of franciscana (*Pontoporia blainvillei*) on the southern coast of São Paulo state and the coast of Paraná state, Brazil. *The Latin American Journal of Aquatic Mammals* (Special Issue 1) 1, 153-160.

Santos, M. C. O., Siciliano, S., Souza, S. P., & Pizzorno, J. L. A. (2001) Occurrence of southern right whales (*Eubalaena australis*) along southeastern Brazil, *Journal of Cetacean Research and Management*'s (Special issue), 2, 153-156.

Shannon, C. E. 1948. A mathematical theory of communication. *Bell System Technical Journal*, 27, 379-423.

Siciliano, S. 1994. Review of small cetaceans and fishery interactions in coastal waters of Brazil. *Report of the International Whaling Commission*, 15, 241-250.

Silva-Júnior, J. M. 1996. Aspectos do comportamento do golfinho-rotador, *Stenella longirostris* (Gray, 1828), no Arquipélago de Fernando de Noronha. *Master Thesis of the Universidade Federal de Pernambuco*, Recife, Pernambuco, Brasil. 131pp. [In Portuguese]

Simmonds, M. P.; Dolman, S. J. & Weilgart, L. S. (Eds). 2003. Oceans of noise: A WDCS scientific report. A report of the Whale and Dolphin Conservation Society. 164pp. Available in http://www.wdcs.org. Accessed in 29 February 2004.

Vilardo, C.; Fontana, A.; Serrão, M.; Bravo, L.; Barboza-Filho, J. C. & Campos, A. N. 2003. Impactos ambientais da atividade de sísmica marítima e o licenciamento ambiental federal. *Anais do VI Congresso de Ecologia do Brasil, Capítulo III: Ecossistemas aquáticos, costeiros e continentais*, Fortaleza, Ceará, Brasil, 240-241. [In Portuguese]

Weitzman, M. 1993. What to preserve? An application of diversity theory to crane conservation, *Quarterly Journal of Economics*, 108, 155-183.

Whitmore, T. C. & Sayer, J. A. (eds.). 1992. *Tropical deforestation and species extinction*. Chapman & Hall, London, UK. 153pp.

Zerbini, A. N., Andriolo, A., da Rocha, J. M., Simões-Lopes, P. C. Siciliano, S., Pizzorno, J. L., Waite, J. M., DeMaster, D. P. & VanBlaricom, G. R. 2004b. Winter distribution and abundance of humpback whales (*Megaptera novaeangliae*) off Northeastern Brazil. *Journal of Cetacean Research and Management's*, 6(1), 101–107.

Zerbini, A. N.; Secchi, E. R.; Bassoi, M.; Dalla-Rosa, L.; Sousa, L.; Moreno, I. B.; Möller, L.M. & Caon, G. 2004a. Distribuição e abundância relativa de cetáceos na Zona Econômica Exclusiva da região sudeste-sul do Brasil. *Série Documentos Revizee: Score Sul*. São Paulo, Brasil. 40pp. [In Portuguese]