Notes

MARINE MAMMAL SCIENCE, 20(1):145–151 (January 2004)

BEHAVIORAL RESPONSES OF *SOTALIA FLUVIATILIS* (CETACEA, DELPHINIDAE) TO ACOUSTIC PINGERS, FORTALEZA, BRAZIL

CASSIANO MONTEIRO-NETO
Departamento de Biologia Marinha,
Universidade Federal Fluminense,
Caixa Postal 100.644, Niteroi, RJ 24001-970, Brazil
E-mail: monteiro@vm.uff.br

FRANCISCO JOSÉ C. ÁVILA
TARCÍSIO T. ALVES-JR.
DOUGLAS SILVA ARAÚJO
ALBERTO ALVES CAMPOS
ALINE MARIA A. MARTINS
CRISTIANO LEITE PARENTE
Grupo de Estudo de Cetáceos do Ceará,
Aquasis,
Praia de Iparana s/n,
SESC-Iparana,
61600-000, Caucáia–CE, Brazil

MANUEL A. ANDRADE FURTADO-NETO
Departamento de Engenharia de Pesca,
Universidade Federal do Ceará,
Campus do Pici, 60035-600, Fortaleza–CE, Brazil

JON LIEN
Whale Research Group,
Memorial University of Newfoundland,
St. John's, Newfoundland A1C 5S7, Canada

Acoustic pingers have been tested recently in various countries as means to reduce bycatch of small cetaceans in fishing nets (IWC 2000). Behavioral reactions of cetaceans to noise vary, ranging from attraction to no response or withdrawal (Richardson and Würsig 1997). Early demonstrations of pinger effectiveness in

Newfoundland, Canada, indicated substantial differences in bycatch of harbor porpoises (*Phocoena phocoena*) between control (without pingers) and experimental (with pingers) nets (Lien *et al.* 1995). More recently, Culik *et al.* (2001) observed that pingers effectively reduced the number of harbor porpoise casualties in sink gill nets. Kastelein *et al.* (1995, 2001) tested different types of pingers in confined areas and observed that certain pingers caused a fright reaction affecting dolphin respiration rate, whereas others elicited curiosity. Underwater acoustic pingers were tested in New Zealand to evaluate their effectiveness on preventing entanglement of Hector's dolphins (*Cephalorhynchus hectori*) in gill nets. Results suggested that pingers affected Hector's dolphin distribution, with animals avoiding the immediate area where pingers were used, but remaining within the larger area of the experiment (Stone *et al.* 1997).

The tucuxi (*Sotalia fluviatilis*) has been affected by fisheries bycatch in Northeast Brazil (Monteiro-Neto 1993, Oliveira *et al.* 1995, Alves-Jr *et al.* 1996, Monteiro-Neto *et al.* 2000). The species is classified as "Insufficiently Known" by the World Conservation Union (Klinowska 1991) and is listed in Appendix I of CITES. International protective legislation is not available for *S. fluviatilis*, but all cetaceans are protected in Brazilian waters under Federal Law (Siciliano 1994). The International Whaling Commission's report on the mortality of cetaceans in passive fishing nets and traps stated that approximately 90 tucuxis are killed every year in the passive gill net fisheries along the Brazilian coast (Perrin and Donovan 1994). However, this number may be an underestimate because 76 individuals of this species were found stranded or dead along 537 km of the coast of Ceará State, northeast Brazil, from January 1992 to December 1998 (Monteiro-Neto *et al.* 2000). In the metropolitan area of Fortaleza, the capital of Ceará State, 32 animals were recorded. These numbers suggest entrapment in fishing gear may be more common than reported. Acoustic enhancement of nets may assist in the mitigation of entrapments, but reactions of *Sotalia fluviatilis* to novel sounds are unknown. The purpose of the work reported in this paper was to test the effect of acoustic pingers on behavior of marine *Sotalia fluviatilis* in Fortaleza.

From November 1996 to August 1998, trials with functional ($n = 30$) and dummy ($n = 20$) pingers, and 55 control trials (without pingers) were conducted at Iracema Beach, Fortaleza (03°42′54″S, 38°31′06″W), a sheltered area where groups of up to eight dolphins are seen daily. Trials lasted between 1 and 7 h, with an average time of 4.1 h of observation per trial. The pinger used was the Netmark 1000 (Dukane Corporation, Charles, IL), developed to avoid bycatches of harbor porpoises (*Phocoena phocoena*) in gill nets. Five pingers were evenly placed on a floating 100-m line set along the dolphins' swimming path in and out of the sheltered waters. The area around the test line was divided into nine quadrats (1–9) defined by GPS coordinates and easily identifiable by topographic references. Quadrats ranged from 0.5 km^2 (Q7, 8, and 9) to 0.9 km^2 (Q3), completing a total monitoring area of 6 km^2 (Fig. 1).

Dolphin sighting frequencies in the nine quadrats were recorded simultaneously by two independent trained observers during the functional and dummy pinger, and control trials. Observers were not aware if dummy or functional pingers were being deployed until the end of the specific trial. Each observer recorded and numbered

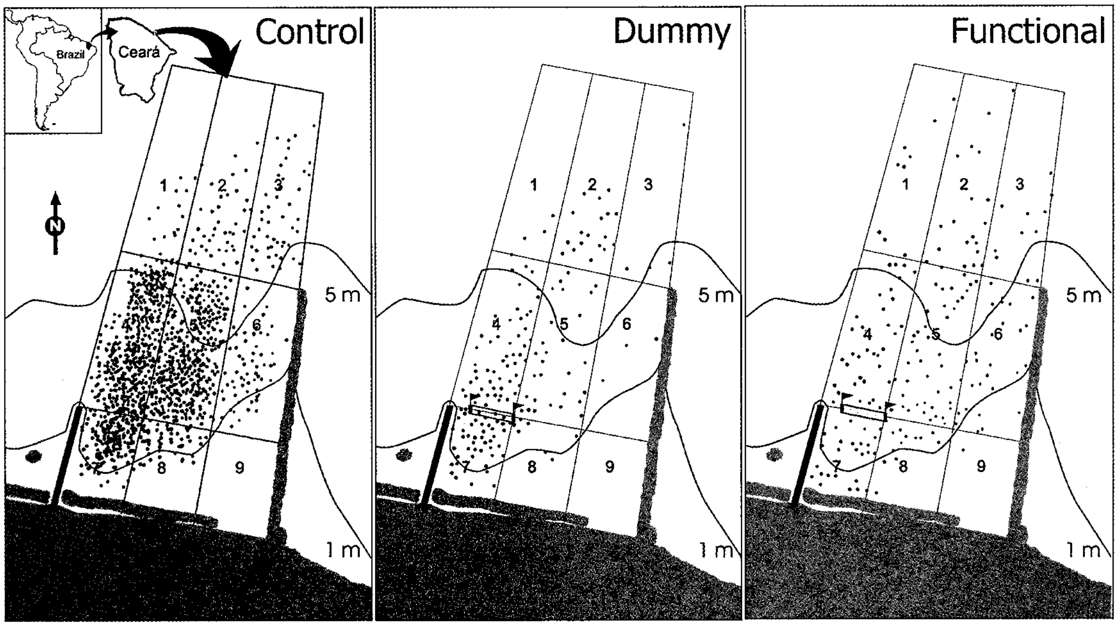

Figure 1. Dolphin sighting distribution on control, dummy, and functional pinger trials within the experiment area at Iracema Beach, Fortaleza, Brazil. Lines represent the 1-m and 5-m depth contours and numbers 1–9 the quadrats used to record dolphin sightings. Cable line with dummy and functional pingers was positioned within the rectangle between the flags indicated in the figure. Small figures indicate geographical location of South America, Brazil, and the state of Ceará.

sightings sequentially. At the end of each trial observers compared logged sightings on data sheets for validation. Only matching observations were considered in the analysis. Sighting frequencies were standardized by quadrat area and time spent on observation during each functional and dummy pinger, and control trials.

Functional *vs.* control, dummy *vs.* control, and functional *vs.* dummy comparisons were conducted. A Monte Carlo permutation approach was taken to independently test differences in dolphin sighting frequencies per quadrat. Legendre and Legendre (1998) and Manly (1997) observed that permutation tests provide better results when applied to data that do not meet the assumptions of the parametric statistical models. A data matrix with trials as rows and quadrats (1–9) and experiments (functional, dummy, control) as columns was constructed in an Excel spreadsheet. Each cell contained one specific standard sighting frequency (SF). The average standard sighting frequency (MSF) for each quadrat within each experiment (functional, dummy, control) was calculated. Sighting frequencies were compared by calculating the differences between MSFs. One-tail hypotheses (H_0: a − b) were generated for each quadrat, and tested independently. The observed differences were used as benchmark values for comparison. The original data were then subjected to 10,000 permutations, generating 10,000 rows of null differences. These outcomes were compared to the benchmarks, and a result was found significant when less than 5% of the null values met the one-tail test condition. After preliminary analysis, quadrat 9 was excluded from the analysis since it contained one single observation during a functional pinger trial. All permutation analysis were performed with Excel's Resampling (Resampling Stats) macros.

Table 1. Results from Monte Carlo Permutations independently testing differences in mean standardized sighting frequencies (MSF) on quadrats Q1–Q8 between dummy (D), functional (F), and control (C) trials. **–highly significant; NT–not tested.

Q1	Q2	Q3
F-D $\geq$ 6.47	F-D $\geq$ 2.26	F-D $\geq$ 2.06
$P = 0.422$	$P = 0.4382$	$P = 0.5735$
F-C $\geq$ 5.70	F-C $\geq$ 10.97	F-C $\geq$ 4.11
$P = 0.9093$	$P = 0.9404$	$P = 0.9113$
D-C $\geq$ 2.63	D-C $\geq$ 4.61	D-C ≤ -1.05
$P = 0.371$	$P = 0.3835$	$P = 0.6205$
Q4	Q5	Q6
F-D ≤ -43.34	F-D $\geq$ 0.72	F-D $\geq$ 0.77
$P = 0.015$**	$P = 0.4777$	$P = 0.541$
F-C $\geq$ 67.18	F-C $\geq$ 25.39	F-C $\geq$ 9.00
$P = 0.0179$**	$P = 0.6538$	$P = 0.8729$
D-C $\geq$ 11.65	D-C $\geq$ 1.63	D-C $\geq$ 0.94
$P = 0.2263$	$P = 0.4297$	$P = 0.3951$
Q7	Q8	Q9
F-D ≤ -145.47	F-D ≤ -2.91	NT
$P = 0$**	$P = 0.4723$	
F-C $\geq$ 169.67	F-C $\geq$ 10.01	NT
$P = 0.00$**	$P = 0.9441$	
D-C $\geq$ 104.93	D-C $\geq$ 3.16	NT
$P = 0.0001$**	$P = 0.3982$	

A total of 345 h of monitoring were completed. The number of dolphins seen during dummy, functional, and control trials varied between one and eight, but the average number of dolphins during any of the trials was about five animals. Significant differences in the distribution of *S. fluviatilis* within the Iracema Beach experimental area were detected in quadrats Q4 and Q7 where the pinger line was set (Fig. 1, Table 1). At Q4, MSF were significantly lower than those occurring at dummy pinger and control trials, but differences were not significant for dummy *vs.* control comparison. All comparisons were significant at Q7 (Fig. 2, Table 1). Our results are consistent with Stone *et al.* (1997) in which Hector's dolphin avoided the immediate area where pingers were active. These outcomes suggested that functional pingers also affected *S. fluviatilis* distribution, at least closer to the pinger line within the experimental area. Other studies found similar results for different target species (IWC 2000).

Our results also suggested that dummy pingers may have had an effect on dolphin distribution in quadrat 4. Noise while setting up the experiment and boats passing by the experimental area may have alerted individuals. Statistical analysis of pinger experiments have led to different results. Lien *et al.* (1995) and Jefferson and Curry (1996) did not detect significant differences between dummy and functional pinger experiments, but both authors observed a reduction in dolphin bycatches when functional pingers were used. Kraus *et al.* (1997) and Gearin *et al.* (2000) statistically demonstrated that pingers reduced the incidental bycatches of harbor porpoises. The large data variability inherent in experiments conducted in the natural environment

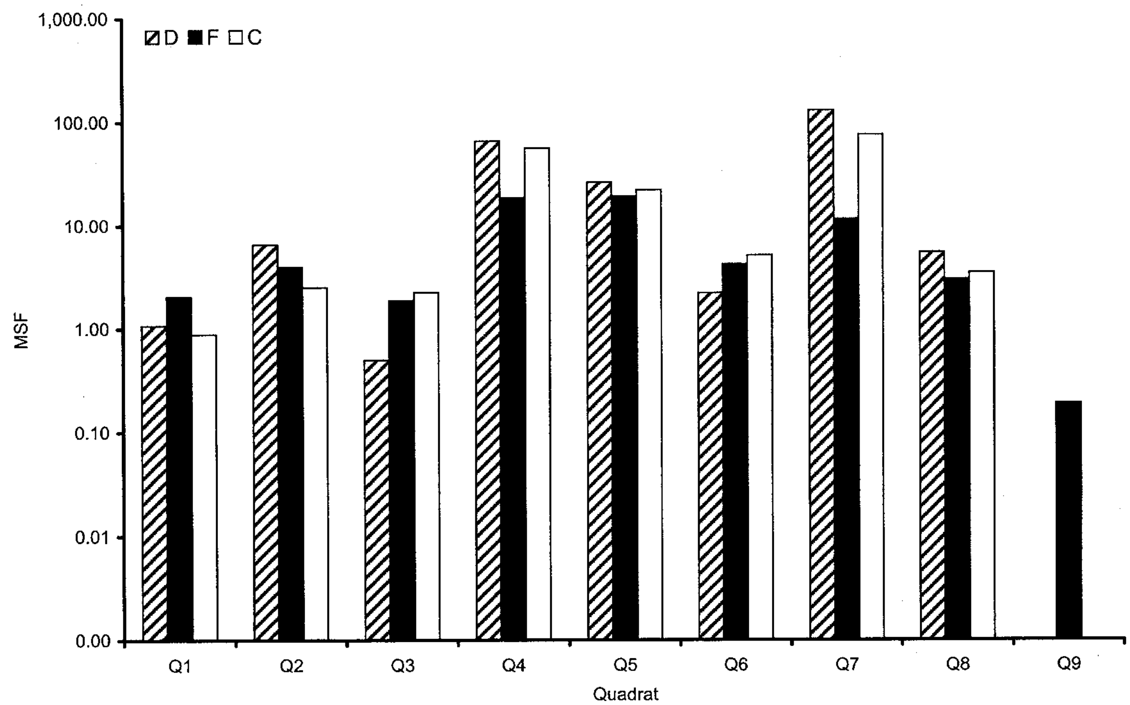

Figure 2. Mean standardized dolphin sighting frequencies per quadrat during 20 dummy (D), 30 functional pinger (F), and 55 control trials (C), expressed on log scale.

and lack of statistical power may be responsible for inconsistent results. Nevertheless, recent studies by Borodino *et al.* (2002) found a significant bycatch reduction of the Franciscana dolphin in gill nets, using the same Netmark 1000 pinger.

Dolphin habituation to sound reducing pinger effectiveness may occur over time (Gearin *et al.* 2000). To test this hypothesis we correlated MSF on Q4 and Q7 against sequential trial days. If habituation occurred we would expect to find a significant positive correlation between variables. Pearson's Correlation Coefficient was positive but non-significant in both cases (Q4, $r = 0.28$; Q7, $r = 0.31$), suggesting that, within the time limits of our study, habituation was not detected. In fact, Oleisuk *et al.* (2002), observed that if habituation occurs, it may do so over many months or years of exposure to sound.

During the trials with dummy pingers, most of the sightings were concentrated in quadrats 4 and 7, where dolphin exhibit feeding behavior (Oliveira *et al.* 1995); they were less frequently seen in quadrats 1 and 3 (Fig. 1, 2). Dolphins often crossed under the pinger line without altering their swimming path. On the other hand, during the functional pinger trials, sightings were dispersed in all quadrats, with highest frequency in quadrat 5 (Fig. 1, 2). Animals avoided their usual movement path and never crossed under the pinger line. On 14 occasions (47% frequency), animals swam parallel to the line and around it, either towards the nearshore or back to deeper waters. The minimum observed distance between a dolphin and the experiment line during functional pinger trials was about 5 m.

These preliminary results suggest that acoustic pingers attached to gill nets may be used successfully to prevent bycatches of *Sotalia fluviatilis*, and possibly other small cetaceans, along the Northeast coast of Brazil.

Acknowledgments

We thank all members of the Ceará Cetacean Study Group (Associação de Pesquisa e Preservação de Ecossistemas Aquáticos–AQUASIS), students at the Instituto de Ciências do Mar-Universidade Federal do Ceará for their contribution on fieldwork and laboratory activities, and the reviewers for providing helpful comments. Mr. Wesley Yi of Dukane Corporation kindly provided the Netmark 1000 functional and dummy pingers for the experiment. Luis Eduardo de Souza Moraes provided the essential expertise on permutation statistical methods. This research was possible, thanks to the financial support of IBAMA (Instituto Nacional do Meio Ambiente e dos Recursos Naturais Renováveis), Fundação O Boticário de Proteção à Natureza and the John D. and Catherine T. MacArthur Foundation, Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq). The Canadian International Development Agency (CIDA) assisted the project through a bilateral cooperation program between the Memorial University of Newfoundland and Universidade Federal do Ceará.

Literature Cited

Alves-Jr, T. T., F. J. C. Ávila, J. A. Oliveira, M. A. A. Furtado-Neto and C. Monteiro-Neto. 1996. Registros de cetáceos para o litoral do Estado do Ceará, Brasil. Arquivos de Ciências do Mar 30(1–2):79–92.

Borodino, P., S. Kraus, D. Albareda, A. Fazio, A. Palmerio, M. Mendez and S. Botta. 2002. Reducing incidental mortality of Franciscana dolphin *Pontoporia blainvilei* with acoustic warning devices attached to fishing nets. Marine Mammal Science 18: 833–842.

Culik, B.M., S. Koschinski, N. Tregenza and G. M. Ellis. 2001. Reactions of harbor porpoises *Phocoena phocoena* and herring *Clupea harengus* to acoustic alarms. Marine Ecology Progress Series 211:255–260.

Gearin, P. J., M. E. Gosho, J. L. Laake, L. Cooke, R. L. DeLong and K. M. Hughes. 2000. Experimental testing of acoustic alarms (pingers) to reduce bycatch of harbor porpoise, *Phocaena phocaena*, in the state of Washington. Journal of Cetacean Research and Management 2:1–9.

IWC (International Whaling Commision). 2000. Annex I: Report of the sub-committee on small cetaceans. Journal of Cetacean Research and Management 2(supplement): 235–263.

Jefferson, T. A., and B. E. Curry. 1996. Acoustic methods of reducing or eliminating marine mammal–fishery interactions: Do they work? Ocean and Coastal Management 31:41–70.

Kastelein, R. A., A. D. Goodson, J. Lien and D. de Haan. 1995. The effects of acoustic alarms on harbour porpoises (*Phocoena phocoena*) behaviour. Pages 157–167 *in* P. E. Nachtigall, J. Lien, W. W. L. Au and A. Read, eds. Harbour porpoises: Laboratory studies to reduce by-catch. De Spil, Woerden, The Netherlands.

Kastelein, R. A., D. de Haan, N. Vaughan, C. Staal and N. M. Schooneman. 2001. The influence of three acousitc alarms on the behavior of harbor porpoises (*Phocoena phocoena*) in a floating pen. Marine Environmental Research 52:351–371.

Klinowska, M. 1991. Dolphins, porpoises and whales of the world. The IUCN Red Data Book. IUCN, Gland, Switzerland.

Kraus, S. D., A. Read, A. Solow, K. Baldwin, T. Spradlin, E. Anderson and J. Williamson. 1997. Acoustic alarms reduce porpoise mortality. Nature 388:525.

Legendre, J., and P. Legendre. 1998. Numerical ecology. Elsevier, New York, NY.

Lien, J., C. Hood, D. Pittman, P. Ruel, D. Borggaard, C. Chisholm, L. Wiesner, T. Mahon and D. Mitchell. 1995. Field tests of acoustic devices on groundfish gillnets: Assessment of effectiveness in reducing harbour porpoise by-catch. Pages 349–364 *in*

R. A. Kastelein, J. A. Thomas and P. E. Nachtigall, eds. Sensory systems of aquatic mammals. De Spil, Woerden, The Netherlands.

MANLY, B. F. J. 1997. Randomization, bootstrap and Monte Carlo methods in biology. Texts in statistical science. Volume 41 Chapman & Hall/CRC, New York, NY.

MONTEIRO-NETO, C. 1993. A mortalidade de pequenos cetáceos por ação da pesca artesanal. Boletim Informativo da Associação Brasileira de Oceanografia 12(4):1–11.

MONTEIRO-NETO, C., T. T. ALVES-JR., F. J. C. ÁVILA, A. A. CAMPOS, A. F. COSTA, C. P. NEGRÃO AND M. A. A. FURTADO-NETO. 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.

OLESIUK, P. F., L. M. NICHOL, M. J. SOWDEN AND J. K. B. FORD. 2002. Effect of sound generated by an acoustic harassment device on the relative abundance and distribution of harbor porpoises (*Phocoena phocoena*) in Retreat Passage, British Columbia. Marine Mammal Science 18:843–862.

OLIVEIRA, J. A., F. J. C. ÁVILA, T. T. ALVES-JUNIOR, M. A. A. FURTADO-NETO AND C. MONTEIRO-NETO. 1995. Monitoramento do boto cinza, *Sotalia fluviatilis* (Cetacea, Delphinidae) em Fortaleza, Ceará State, Brazil. Arquivos de Ciências do Mar 29(1–2):28–35.

PERRIN, W., AND G. DONOVAN. 1994. Incidental entrapment of cetaceans in passive fishing gear. Report of the International Whaling Commision (Special Issue 15):73–82.

RICHARDSON, W. J., AND B. WÜRSIG. 1997. Influences of man-made noise and other human actions on cetacean behaviour. Marine and Freshwater Behaviour and Physiology 29(1–4):183–209.

SICILIANO, S. 1994. Review of small cetaceans and fisheries interactions in coastal waters of Brazil. Report of the International Whaling Commission (Special Issue 15):241–250.

STONE, G., S. KRAUS, A. HUTT, S. MARTIN, A. YOSHINAGA AND L. JOY. 1997. Reducing by-catch: Can acoustic pingers keep Hector's dolphins out of fishing nets? Marine Technology Society Journal 31(2):3–7.

Received: 7 September 2000
Accepted: 7 April 2003