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DOES RADIO TAGGING AFFECT THE SURVIVAL OR REPRODUCTION OF SMALL CETACEANS? A TEST

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ABSTRACT

A long-term study of botos (*inia geoffrensis*) in the Brazilian Amazon permitted the comparison of survival and reproduction between 51 adults fitted with radio transmitters and an equal number that were captured and handled in the same way but released without a transmitter. For both sexes combined, 47 radio tagged botos (92.2%) survived at least three years after release compared with 42 (82.4%) without radios, equating to annual survival of 97.3% and 93.6% respectively. The difference was not statistically significant. Eight of 15 closely monitored radio tagged females were lactating at capture, and all their calves weaned successfully. Two that were pregnant at capture subsequently gave birth. The mean number of calves per year born to these 15 females after first release was 0.172 (SD = 0.107) and to 17 non-tagged was 0.174 (SD = 0.095), again a non-significant difference. These results indicate that the anchoring of packages to the dorsal fin of dolphins can be accomplished with no measurable impact on their subsequent survival or reproductive output. However, botos may be unusually robust to handling, and this study should not be used to justify using similar techniques on other species without customary caution, diligence, and expert guidance.

Key words: dolphin, boto, *Inia geoffrensis*, instrumentation, tagging effects, attachment, survival, reproduction.

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For scientific, animal welfare, and ethical reasons, the impact of research techniques on aquatic mammals, as for any animal, should be known. Many techniques have a potential cost to the study animal(s), and the decision to use each of them should involve a careful judgment of whether such costs are justified by the benefits accruing.

The attachment of instrument packages to cetaceans provides information on a broad range of biological, physiological, ecological, and conservation-related questions that could not be gained in any other way. The technique has been applied to this group of animals for several decades, during which time a great variety of package sizes and shapes has been applied to tens of species. Today, instrumentation is a common and increasingly accepted research tool. However, the cetacean body offers no simple means of attaching an instrument. There is no hair to glue to (the technique of choice for use with pinnipeds), no neck around which to put a collar (many terrestrial mammals), no ears (polar bears) and, unlike in manatees, the peduncle is not suitable for a harness. Experience with many cetacean species has demonstrated that most packages, and all remaining in place for more than a few days, must be attached using some kind of anchor that penetrates the skin and blubber, and for this reason their use has prompted concern among both the biologists using them and the wider research community. Two critical questions are whether the use of such devices compromises either the longevity or future reproductive success of the instrumented animals. Relevant information is not easily collected, mostly because the study animals are never seen after release with the device in the majority of cases. Short-term survival may be inferred from a functioning radio transmitter, but long-term survivorship is unknown and usually the death of an animal cannot be distinguished from the failure of a transmitter or its attachment. Furthermore, there is no means of assessing the reproductive success of a tagged animal, either during or after the experiment.

In a small number of studies, however, the use of instrument packages is concurrent with, and followed by, visual observations of the study population, allowing direct assessment of the performance of a dolphin during and after the experiment (*e.g.*, Irvine *et al*. 1982, Scott *et al*. 1990). Our long-term study of botos (Amazon river dolphins), *Inia geoffrensis*, in the Brazilian Amazon (Martin and da Silva 1998, 2004*a, b*; da Silva and Martin 2000; Martin *et al.* 2004) is another case in point. Here, not only have the lives of instrumented animals been followed after release, but the recapture of most in subsequent years offered the opportunity to examine them and the package placement site in detail. In this paper we compare the survival and reproductive potential of dolphins that have carried an instrument with those that have not.

METHODS

Botos were captured in the Mamirauá Reserve, central Brazilian Amazon (64°45′W, 03°35′S) during once-yearly campaigns lasting three weeks, usually in November. Full details of the procedures are given in da Silva and Martin (2000). Botos were encircled with nets and seined onto a shallow beach before being transferred to the floating processing laboratory by boat. The transfer took between one and four minutes. The modal handling time after arrival at the laboratory was 11 min, and 79% of procedures were in the range 7–20 min ($n = 345$), during which time the animal was weighed, measured, photographed, marked with unique freeze brands to allow subsequent individual recognition, and sampled for blood, tissue, and milk.

All dolphins were fitted with a plastic tag (Dalton, UK) held in place with a 6-mm nylon pin inserted through the trailing edge of the dorsal fin. Dolphins were released at the handling site.

The experimental sample in this study was 51 adult botos (Table 1), defined as having a minimum body length of 180 cm in females ($n = 22$) and 210 cm in males ($n = 29$), which were fitted with a VHF or UHF radio transmitter (Fig. 1A). The transmitters were of three designs—two VHF types (front mounted and side mounted) and one UHF (satellite linked). They varied in size from 100 × 45 × 20 mm to 150 × 50 × 20 mm and from 100 g to 170 g in air (25–45 g in water) and were attached to the dorsal fin using 3–5 pins: 6-mm threaded nylon rod held in place with nylon nuts that were welded to the rod. A nylon washer of 15-mm diameter was fitted under the nut. The attachment pins were inserted through holes cored through the dorsal fin using thin-walled stainless steel borers of 6-mm external diameter. Sample sizes for most combinations of transmitter type and pin number were insufficient to allow a comparison between them, so all were pooled for this analysis.

These techniques, or close variants of them, are now standard for attaching instrument packages to the dorsal fins of small cetaceans. Botos were selected to receive a radio tag based mainly on body size and the availability of a radio. Females with very young calves (estimated to be <3 mo old) were not instrumented. The control sample comprised adults that were captured and processed in the usual manner during the same period of time, but not fitted with radios ($n = 38$ females and 14 males). Application of the transmitter added 10–20 min to the handling time.

Proof of survival was gained through subsequent recaptures and unequivocal resightings of the marked animals. Radio signals were ignored to avoid bias between the experimental and control samples. Sighting histories of each marked boto were accumulated over succeeding years. Although most botos subsequently known to be alive in a particular year were sighted at least once during that year, some were absent from our records for up to five years before reappearing again. Others may have moved away from the study area or their brands may have become unrecognizable through repigmentation. For this reason, estimates of survival over a particular period were likely negatively biased.

To facilitate comparison between animals that were instrumented in different years (and consequently available to be resighted for varying periods of time) and with a variety of resighting frequencies, survival was measured over a fixed period of time after release with the transmitter. If a dolphin's health was to be affected by the attachment and carrying of a transmitter, it is likely that any impact would occur before the instrument had fallen off and the attachment wounds had subsequently healed. The period was therefore set conservatively at 3 yr, this being 21 mo beyond the longest attachment period, and more than twice the maximum healing time shown from recaptures and close visual examination of botos in the field.

Boat-based researchers sought and observed botos on average for 5–6 h/d and 250 d/yr. Observations of marked botos included information on the presence, size and identity of any calf seen in each group. Calves remained close to their mother for the first year of life, and were invariably in the same group for the second and third years, though less tightly associated.

Reproductive success was not measurable in males. In females it was calculated as a rate—the number of calves known to be born to each female after release divided by the number of years over which they were observed. A calf was confirmed either when it was captured with its lactating mother, or when a female was seen on several

Table 1. Summary information on the experimental sample of instrumented dolphins. The minimum instrument attachment time usually reflects the last received signal from the transmitter; in many cases the instrument likely remained attached for some weeks this.

Animal no.	Sex	Body length (cm)	Date of capture	Reproductive status (females)	Min. tag attachment (mo)	Known to survive ≥ 3 yr?
1	F	184	26.01.94	Lactating	0.3	Y
3	F	185	26.01.94	Not lactating	0	Y
4	F	194	29.01.94	Not lactating	0.7	Y
5	F	188	04.02.94	Not lactating	2.2	Y
6	F	200	04.02.94	Not lactating	0.2	Y
7	F	194	04.02.94	Not lactating	0	Y
8	F	194	04.02.94	Not lactating	2.0	Y
9	M	222	04.02.94		2.2	Y
10	F	195	10.11.94	Lactating	1.5	Y
13	F	184	12.11.94	Lactating	0	Y
15	M	229	12.11.94		2.6	Y
17	M	225	15.11.94		3.3	N
19	M	229	16.11.94		2.4	Y
20	M	217	16.11.94		3.3	Y
21	M	220	16.11.94		4.0	Y
22	M	221	21.11.94		5.1	Y
23	M	214	21.11.94		2.6	Y
24	M	230	21.11.94		4.1	Y
25	M	224	30.10.95		0	Y
29	M	242	28.10.95		1.2	N
30	F	197	28.11.95	Lactating	1.2	Y
33	M	242	30.10.95		0	Y
34	M	249	30.10.95		0.9	Y
43	F	206	06.11.95	Lactating	0	N
46	F	199	08.11.95	Lactating	0	Y
48	M	218	09.11.95		0.5	Y
65	M	226	18.11.96		1.4	Y
66	M	241	18.11.96		9.5	Y
67	M	248	18.11.96		12.5	Y
72	F	196	22.11.96	Not lactating	1.6	Y
73	F	195	26.11.96	Lactating	0.4	Y
75	F	200	28.11.96	Not lactating	2.5	Y
77	M	216	29.11.96		2.7	N
78	M	212	29.11.96		8.5	Y
85	F	192	07.12.96	Not lactating	2.4	Y
101	M	242	15.11.99		0.6	Y
115	M	226	14.11.98		0.2	Y
118	M	211	16.11.98		11.8	Y
119	M	234	16.11.98		1.4	Y
123	F	207	18.11.98	Looked pregnant	15.2	Y
124	M	228	19.11.98		0.8	Y
125	M	225	19.11.98		1.8	Y
126	M	218	19.11.98		0.5	Y
127	M	215	20.11.98		5.3	Y
130	F	198	21.11.98	Not lactating	0	Y
131	M	212	23.11.98		13.7	Y
133	F	198	27.11.98	Lactating	1.0	Y
140	F	200	10.11.99	Lactating	8.1	Y
149	F	188	13.11.99	Not lactating	2.0	Y
152	M	231	13.11.99		0	Y
160	F	194	19.11.99	Not lactating	5.8	Y

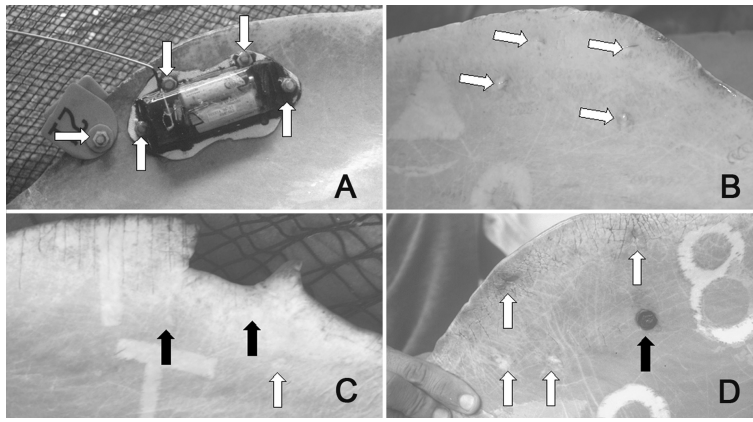

Figure 1. (A) Side-mounted VHF transmitter and plastic tag immediately after attachment. The arrows show the pin locations. (B) Four healed pin holes on a male after 6 yr. (C) Damage to the fin of female no. 8 after 3 yr. The white arrow points to a healed pin hole. Black arrows show the original location of two pins that migrated vertically out of the fin, causing the loss of some tissue. This female was recaptured with a calf 10 yr after release with the transmitter. (D) Four healed pin holes and an *in-situ* pin (black arrow) after 1 yr. The pin was removed, to reveal that skin had grown on the inner surface of the hole.

consecutive occasions with a calf of a consistent size in close attendance. Here, the sample was restricted to females ($n = 15$ with radio tags and 17 without) that were seen and/or recaptured sufficiently frequently over at least a five-year period such that a calf surviving a year or more would likely have been detected. We cannot exclude the possibility that some calves were overlooked, especially any that may have died within the first few weeks or months after birth, but this source of potential error would be the same for both instrumented and non-instrumented groups. Because the females in this sample were seen frequently, observational data up to the time of analysis (April 2005) were used.

RESULTS

Thirty-eight radio tagged botos (74.5% of those instrumented) were recaptured and examined between one and 10 years after release with their transmitter. Examination of the attachment sites during these recapture events indicated that the nylon attachment pins usually pulled through the fin sideways, and that the wound healed leaving a scar ~10 mm in diameter (Fig. 1B). In 21 cases (42% of those seen closely enough to assess, and all with front-mounted devices), the pin apparently migrated out towards the dorsal surface and left a notch with a trailing healed line (Fig. 1C). In two botos, pins remained in the fin after the transmitter fell away, and skin grew in the hole much like in a human ear-ring piercing (Fig. 1D). In these cases, the pins had stabilized in the tissue and seemed likely to remain permanently unless removed in a subsequent recapture. They were visible in profile as a slightly raised stub on the fin.

The transmitters functioned for 0–15.2 mo ($\bar{X} = 2.7$, SD = 0.52 mo) (Table 1). In many cases, subsequent observation of the animals showed that failure was due to

the package (including the attachment pins) falling away from the animal, but most of the failures within three months were likely due to a device malfunction. In some of these animals the transmitter was seen to be still attached but not transmitting. With four botos we knew that the package remained attached for more than a year, and in the great majority of cases we knew that they did not. In only one case—a male that was not seen more than three months after release and whose transmitter was last detected five months after release—were we not able to confirm that the package had fallen away in less than 18 mo.

No botos died during the capture and handling process. Fifty of the 51 radio tagged botos of both sexes (98.0%) survived at least two years after release (by which time all transmitters had fallen away and attachment wounds had healed), an average annual survival rate of 99%. Forty-seven (92.2%) survived at least three years, compared with 42 of 51 (82.4%) without instruments ($\chi_1^2 = 1.22$, $P = 0.27$).

Separating the sexes, at least 26 of 29 (89.7%) radio tagged males survived to 3 years, as did 10 of 14 (71.4%) without instruments ($\chi_1^2 = 2.03$, $P = 0.13$). The corresponding values for females were 21 of 22 (95.5%) with radio tags and 32 of 37 (86.5%) without ($\chi_1^2 = 1.22$, $P = 0.27$). There was, therefore, no statistically significant difference in survival between the experimental and control sample for either or both sexes. However, the statistical power for detecting such differences could be low. For example, with survival to 3 yr in non-tagged animals of 82% (annual = 93.6%), the power for detecting a decrease to 72% (annual 89.6%), 62% (annual 85.3%), and 52% (annual 80.4%) in tagged animals is 22%, 62%, and 91%, respectively.

At first capture, eight of the 15 closely monitored instrumented females were lactating, six were not lactating and not obviously pregnant, and one was not lactating and appeared to be pregnant. All eight suckling calves survived to weaning and subsequent independence (at approximately 2.5–3.5 yr). The pregnant-looking female (no. 123) was seen with a young calf eight months after release, subsequently weaned this calf, and gave birth to another four years after release. Boto no. 123 was the animal that carried its radio for the longest period (15 mo). Another female (no. 149) was not lactating at first capture, but was suckling a calf of approximately 2 mo of age at recapture 12 mo later.

The mean number of calves per year born to these 15 radio tagged females after first release was 0.172 (SD = 0.107) and to the 17 non-tagged was 0.174 (SD = 0.095). The difference was not statistically significant (SE difference = 0.036, $t_{28} = 0.06$, $P = 0.95$). The 95% confidence interval for the difference (*i.e.*, the range of plausible values) is (−0.072, 0.076). The power of the *t*-test (5% level) for the sample sizes used in the study to detect differences of 0.072 (= 2 SE), 0.109 (3 SE), and 0.145 (4 SE) was estimated as 48% 83% and 97%, respectively (Barker Bausell and Li 2002).

DISCUSSION

These results show that the attachment of an instrument package to the dorsal fin of botos by means of through-pins, and subsequently carrying the package for up to 15 mo, had no measurable impact on survivorship or reproductive success. This experiment could not directly measure any additional effect of capture and handling, but all survived at least five months beyond release and only one may have died within a further 18 mo. Any damaging effect of capture and handling would

likely be evident in days or weeks, so we conclude that there was no life-threatening impact on this sample of animals. Concern about the possible impacts of attaching instruments to the dorsal fin of dolphins has resulted from research showing that the thermoregulation of the reproductive organs may be affected if the fin was sufficiently damaged such that its venous heat-exchange mechanism was compromised (Rommel *et al*. 1992, 1993). Data from the present study do not allow this question to be addressed in the short-term because only one animal was visibly pregnant at the time of tagging (though another was later found to be so), but there is no evidence of any long-term effect on the reproduction of female botos whose dorsal fins carried radio tags that were pinned in place using standard techniques.

How should these results be interpreted? Clearly, one test on one species is not sufficient to imply that instrumentation has no impact on the lifespan or reproduction of any small cetacean. In many respects, botos are behavioral, morphological, and ecological outliers of the Order, so it would be inappropriate to use them to make sweeping generalizations. For example, botos are much more tolerant of capture and handling than the sympatric delphinid, *Sotalia fluviatilis*, which we have not attempted to fit with radio tags because some individuals become stressed relatively quickly. However, this study does show that the anchoring of instrument packages to the dorsal fin of small cetaceans using through-pins *can* be accomplished without compromising either their longevity or future reproductive success. This demonstration should not diminish researchers' usual care and caution when attempting to capture and instrument new species, nor the necessity to involve suitably experienced personnel before embarking on such work. It may, however, reassure researchers and permit-awarding authorities who were concerned that instrumentation might always involve long-term cost to study animals.

Information on the suitability of other species to dorsal fin attachment of research devices will become increasingly available as both instrumentation and longitudinal observational studies proliferate, and we would encourage researchers to analyze and present their results as the opportunity arises. Technical papers often have low priority in the drive to publish results from primary data, but the time has surely come to quantitatively test what many of us have perceived (or perhaps trusted) for years.

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Literature Cited

Barker Bausell, R., and Yu-Fang Li. 2002. Power analysis for experimental research: A practical guide for the biological, medical and social sciences. Cambridge University Press, Cambridge, UK.

DA SILVA, V. M. F., AND A. R. MARTIN. 2000. A study of the boto, or Amazon river dolphin (*Inia geoffrensis*), in the Mamirauá Reserve, Brazil: Operation and techniques. Pages 121–131 *in* R. R. Reeves, B. D. Smith and T. Kasuya, eds. Biology and conservation of freshwater cetaceans in Asia. Occasional paper of the IUCN Species Survival Commission no. 23. IUCN, Gland, Switzerland.

IRVINE, A. B., R. S. WELLS AND M. D. SCOTT. 1982. An evaluation of techniques for tagging small odontocete cetaceans. Fishery Bulletin, U.S. 80:135–143.

MARTIN, A. R., AND V. M. F. DA SILVA. 1998. Tracking aquatic vertebrates in dense tropical forest using VHF telemetry. Marine Technology Society Journal 32:82–88.

MARTIN, A. R., AND V. M. F. DA SILVA. 2004*a*. River dolphins and flooded forest: Seasonal habitat use and sexual segregation of botos *Inia geoffrensis* in an extreme cetacean environment. Journal of Zoology (London) 263:295–305.

MARTIN, A. R., AND V. M. F. DA SILVA. 2004*b*. Number, seasonal movements and residency characteristics of river dolphins using an Amazonian floodplain lake system. Canadian Journal of Zoology 82:1307–1315.

MARTIN, A. R., V. M. F. DA SILVA AND D. L. SALMON. 2004. Riverine habitat preferences of botos (*Inia geoffrensis*) and tucuxis (*Sotalia fluviatilis*) in the central Amazon. Marine Mammal Science 20:189–200.

ROMMEL, S. A., D. A. PABST, W. A. MCLELLAN, J. G. MEAD AND C. W. POTTER. 1992. Anatomical evidence for a countercurrent heat exchanger associated with dolphin testes. Anatomical Record 232:150–156.

ROMMEL, S. A., D. A. PABST AND W. A. MCLELLAN. 1993. Functional morphology of the vascular plexuses associated with the cetacean uterus. Anatomical Record 237:538–546.

SCOTT, M. D., R. S. WELLS, A. B. IRVINE AND B. R. MATE. 1990. Tagging and marking studies on small cetaceans. Pages 489–514 *in* S. Leatherwood and R. R. Reeves, eds. The bottlenose dolphin. Academic Press, San Diego, CA.

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