AN EVALUATION OF TECHNIQUES FOR TAGGING SMALL ODONTOCETE CETACEANS

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ABSTRACT

Ninety tags—various combinations of radio tags, spaghetti tags, Roto tags, freeze brands, and tags bolted to the dorsal fin—were placed on 47 Atlantic bottlenose dolphins, *Tursiops truncatus*, captured near Sarasota, Florida, between January 1975 and July 1976. In 18 months of field observation, 910 tagged dolphins were sighted; 781 were identifiable, and 129 were not. Twelve naturally marked dolphins were also observed. Radio tagged animals were tracked for as long as 22 days. Repeated observations of tagged animals permitted evaluation of effect on animals and relative merits of the various tags. Freeze brands were most readable from a distance (≤30 m), and most long lived (4.8 years). Other tags were too short lived (bolt tags) or too small to be identified from a distance (Roto tags and spaghetti tags), and all caused tissue destruction. Radio tags caused unexpected dorsal fin damage and were frequently lost prematurely. Taken together, the results suggest that freeze brands are least harmful, and that static tags should be tested on each species to be studied prior to attachment in the field.

Cetaceans are difficult to study in the field. Most individuals move almost constantly, rise to the surface only briefly to breathe, and are difficult to differentiate from conspecifics. To facilitate individual recognition, researchers have developed several tagging techniques and tested them on small odontocete cetaceans. Nishiwaki et al. (1966) placed streamer tags on captive rough-toothed dolphins, *Steno bredanensis*, and concluded that none were effective. On the other hand Perrin et al. (1979) recovered spaghetti tags, another type of streamer, from free-ranging dolphins, *Stenella* spp., in the eastern tropical Pacific up to 1,478 d after attachment. Roto tags were placed on the spotted dolphin, *S. attenuata*, and one marked individual was repeatedly identified from a semisubmersible over a period of 3½ yr (Norris and Pryor 1970). Evans et al. (1972) successfully used radio transmitters, large plastic "button" tags, spaghetti tags, and freeze brands on a total of five species in the Pacific Ocean and Gulf of Mexico. Leatherwood and Evans (1979) have recently reviewed developments and uses of radio tags on cetaceans. Irvine and Wells (1972) reported that an improved button tag was sighted 3 mo after attachment to a bottlenose dolphin, *Tursiops truncatus*, near Sarasota, Fla. Despite all these improvements in tagging technology, however, little information has been available about long-term effectiveness or affect on the wearers of any type of tag.

The tagging program of Irvine and Wells (1972) was reinitiated in the same area in January 1975, after a 4-yr lapse. Using radio transmitters, visual tags, and natural marks we studied the movements and activities of bottlenose dolphins. Between 29 January 1975 and 25 July 1976, 47 dolphins were captured, tagged, and released a total of 90 times. A summary of the tagging program and an evaluation of the tagging methods used are included below. Detailed analysis of the tagging program results is presented by Irvine et al. (1979,[4] 1981).

METHODS

The study was conducted along 40 km of coast south from Tampa Bay, Fla. The study area included shallow channels and bays bounded by a chain of barrier islands (NOS Chart No.

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[4]Irvine, A. B., M.D. Scott, R. S. Wells, J. H. Kaufmann, and W. E. Evans. 1979. A study of the movements and activities of the Atlantic bottlenose dolphin, *Tursiops truncatus*, including an evaluation of tagging techniques. Available National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22151 as PB-298042, 54 p.

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11425). Dolphins were captured by encircling one to nine animals with a 455 m × 4.5 m net dropped from a fast moving boat in shallow water. An inner circle enclosure method (Asper 1975) was used to minimize escapes. The inner circle was partitioned so that individual dolphins could be isolated and entangled without collapsing the entire net on remaining animals. Tangled dolphins were removed from the net and placed for tagging in a stretcher, usually held in the water alongside a boat. All animals were sexed, measured, and photographed before tagging. Previously tagged dolphins were examined and retagged as necessary before being released.

The study area was surveyed as thoroughly as possible at least biweekly in a 7.3 m Wellcraft Fisherman[5] boat equipped with a 3 m tuna tower. All dolphin sightings were recorded during 228 surveys; photographs were taken to facilitate identification of tags and distinctive dorsal fins.

Radio Tags

An improvement (Model PT 219) of the radio tag developed for small pelagic cetaceans by Ocean Applied Research Corporation (Martin et al. 1971) had not been tested on *T. truncatus*. In our first efforts, the transmitter was attached with plastic straps to a foam-lined fiber glass saddle and secured to the dorsal fin with a stainless steel bolt through the fin. Because saddles provided by the manufacturer were too small for most *T. truncatus*, the transmitters were attached to fiber glass saddles molded by the authors (Fig. 1A, C). The saddles were lined with open cell foam to protect the animal from abrasion and to allow water circulation for thermoregulation.

Transmitter saddles were attached using techniques developed by other investigators (see review by Leatherwood and Evans 1979). The first seven saddles were attached with single bolts through the dorsal fin. The last three saddles were attached with bolts fore and aft to provide greater stability against water flow (Fig. 1C). Spring-loaded bolts with dissolving nuts were designed to release the saddle and transmitter from the dolphin sometime after the 1-2 mo life of the lithium batteries.

[5]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA, or the U.S. Fish and Wildlife Service.

Ten radio tags (designated RT-1 through RT-10) were attached to dolphins between 29 January 1975 and 9 June 1976. The RT-1 transmitter consisted of a single 35 cm long × 3.7 cm diameter tube with a 63 cm high spring steel antenna on the forward end. Transmissions from RT-1 gradually failed within 2 h, apparently due to saltwater leakage into the battery case. Cause of failure could not be confirmed because the transmitter was missing from the saddle when it was sighted 2 d after attachment. Transmitters on subsequent radio tags were attached to the saddle with bolted aluminum plates (Fig. 1A, C) instead of plastic straps.

The transmitter antenna on RT-2 was observed to be broken off at the base 5 d after attachment. Consequently, transmitter packages on RT-3 through RT-10 were modified to two tubes, 19.2 cm long × 3.8 cm diameter, connected by copper tubing at the forward end. A flexible 42.5 cm high whip antenna extended vertically from the rear of the starboard tube. The tubes, with transmitter assembly in one and batteries in the other, were bolted to either side of the saddle, and the connecting tubing was solidly encased in fiber glass (Fig. 1C).

Visual Tags

The button tags described by Evans et al. (1972) had proven not to be durable on *T. truncatus* (Irvine and Wells 1972). Therefore, we elected to try rectangular fiber glass "visual tags" (Fig. 2). These tags were 10 cm × 7.5 cm and made of 0.4 cm thick yellow laminated fiber glass with 5.1 cm high black tape numerals epoxied to the surface. Each tag was held in place by Teflon bolts with stainless steel washers and cotter pins. The bolts were placed near the anterior edge of the tag to produce a streaming effect as the dolphin moved through the water. The bolt hole was bored through the fin and cauterized with a heated rod, and sheathed with Plexiglas tubing in the same manner as for radio tags.

Double bolt tags, also yellow rectangles with black numerals, were cut from 0.2 cm thick fiber glass and varied in size from 9.0 cm × 12.9 cm to 10 cm × 15 cm, depending on the size of the dorsal fin to be tagged. The bolts were located near the anterior and posterior edges of the tag. Numerals were 7.7 cm high. Because cotter pins had sheared some of the Teflon bolts on single

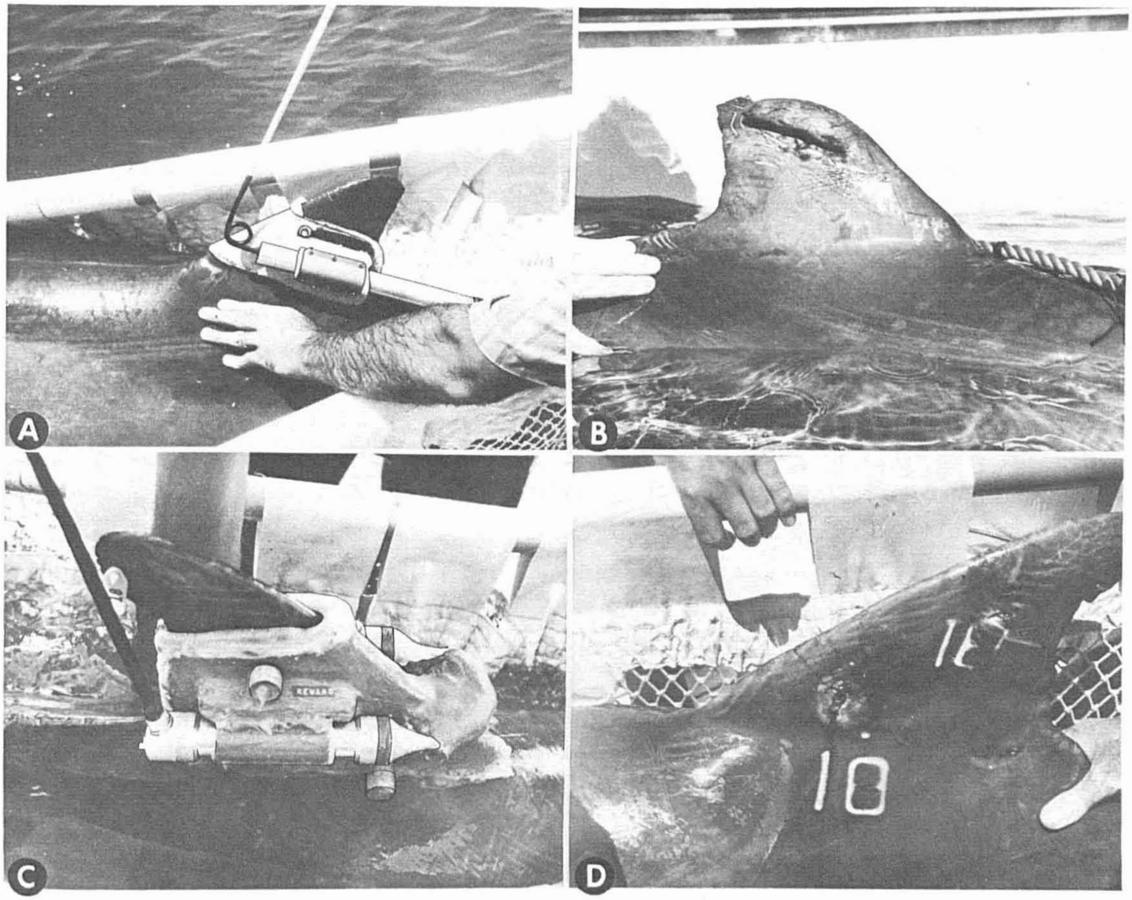

FIGURE 1.—A. Single tube transmitter with spring antenna forward (on dolphin RT-2). B. Dorsal fin 8 mo after transmitter in A was attached. C. Twin tube transmitter assembly with whip antenna aft. Dissolving nuts are top center and below the forward portion of the tube. D. Dorsal fin from C 22 d after the transmitter's installation. Note discolored, apparently necrotic, area around forward hole and apparent migration path of top bolt.

bolt tags, double bolt tags were attached with 0.64 cm stainless steel bolts and nuts.

Freeze Brands

When first captured, all dolphins were freeze branded with 5 cm high numerals on both sides of the dorsal fin and on the body below the fin (Figs. 1D, 2C, D). Recaptured animals were rebranded as necessary to improve visibility of existing brands. Application times of 15 s with irons cooled in a mixture of Dry Ice and alcohol were used to brand the dolphins captured before August 1975. Thereafter, liquid nitrogen was used as the coolant. The application time remained 15 s. When possible, the skin was rubbed with an alcohol swab to lower the skin temperature by evaporative cooling prior to branding. Before April 1976, the branding irons were applied to the skin with a gentle rocking motion to assure even contact. After that time the irons were held firmly against the skin without motion, and brand visibility was greatly improved. In some cases, however, parts of the brand did not show because of uneven contact (Figs. 1D, 2C, D).

Roto Tags

Numbered Roto tags (NASCO Inc., Ft. Atkinson, Wis., Jumbo size) were attached to the trailing edge of the dorsal fin of all dolphins handled after January 1976. Red tags were attached to females and yellow tags to males. The

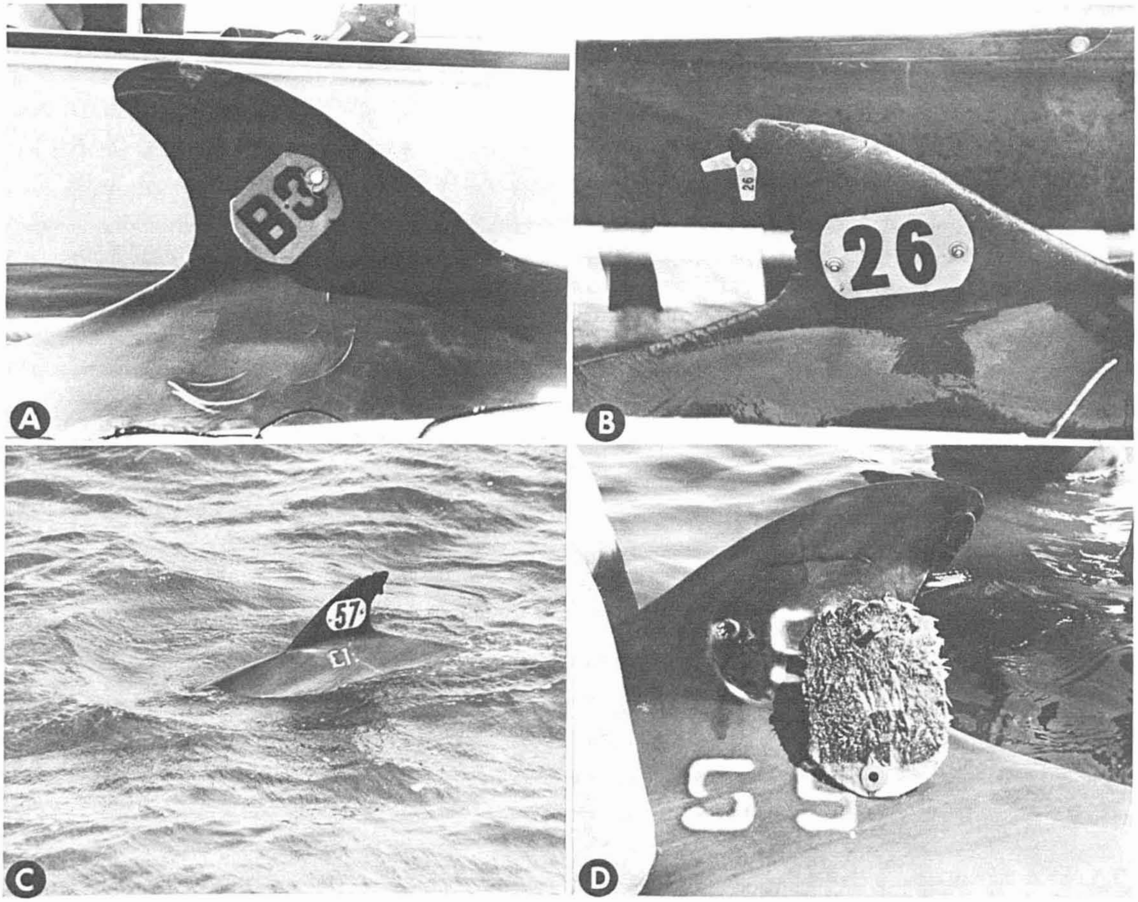

FIGURE 2.—A. Single bolt visual tag held by Teflon bolt and cotter pin. Note tag bolt scar from 1970-71 study. B. Double bolt tag, Roto tag (at top rear of fin), and spaghetti tag (lower right). C. Double bolt tag on free-swimming dolphin. Note freeze brand with incomplete left digit on body below fin. D. Algae-covered tag 2 mo after initial installation. Note indented area of skin where water flow against tag on opposite side of fin caused pressure on near side. Note also discolored tissue around forward bolt hole.

TABLE 1.—Comparison of tagging techniques.

Tag no.	No. tags installed	Tag longevity[1]	No. sightings/tag mean	No. sightings/tag total	No. identifications/tag mean	No. identifications/tag total	% identifiable sightings-other observers	No. tags of known fate	Tags of known fate lost, broken, or removed %	Tags of known fate lost, broken, or removed total no.	Tags of known fate obscured by fouling %	Tags of known fate obscured by fouling total no.	Tags of known fate removed because of tissue damage %	Tags of known fate removed because of tissue damage total no.
Visual tags (single bolt)	16	<5 min to >2 mo	4.88	78	2.00	32	6	14	86	12	14	2	14	2
Visual tags (double bolt)	19	<2 wk to >2 mo	10.00	190	9.84	187	16	16	63	10	31	5	25	4
Roto tags	53	<1 d to >5.5 mo	6.45	342	0.53	28	0	48	40	19	10	5	4	2
Spaghetti tags	17	<1 mo to >13 mo	2.53	43	0		0	12	50	6	0		25	3
Freeze brands	[2]47	>4.8 yr	6.57	309	5.89	277	2	39	—	—	—	—	—	—
Natural marks[3]	12	>6 yr	7.25	87	7.25	87	1	12	—	—	—	—	—	—

[1]Length of time tag was attached and identifiable.
[2]Many were redone or "touched up."
[3]Recognizable dorsal fins.

numbers on the tags were too small to be read from the observation boat, but the color codes were useful for recognition of sex, and the positions of a tag often indicated identity.

Spaghetti Tags

Spaghetti tags (Floy Tag and Manufacturing, Inc., Seattle, Wash., Model FH 69A) were tested on some dolphins captured from April through June 1976. The attachment technique was similar to that described by Evans et al. (1972), except that the tags were applied to animals in a stretcher.

Natural Marks

Some dolphins had disfigured or uniquely shaped dorsal fins. A photo catalog of these recognizable untagged animals was compiled as a reference for field identification.

RESULTS

Nine hundred ten tagged dolphins were sighted; 781 were identifiable, and 129 others were not. When field identification was uncertain, photographs of combinations and locations of tags or tag remnants were often examined to verify individual identities. A compilation of tagging and sighting results is presented in Table 1.

Radio Tags

Ten dolphins were radio tagged and tracked for up to 22 d (Table 2). Eight of these were later recaptured and examined. In five instances, the saddle was lost, apparently because the bolt ripped through the fin (for example, see Figure 1B). Fin damage was apparent 3 to 6 wk after tagging by which time saddles no longer fit snugly over the leading edge of the fin. When loosened, the saddles titled backwards creating an obvious drag; this shifting caused the bolts to migrate dorsoposteriorly. When RT-8 was recaptured after wearing a transmitter for 22 d, the two bolt holes had not healed nor appeared infected. The forward bolt had migrated dorsoposteriorly about 1.5 cm (Fig. 1D), and the saddle was fouled with algal growth and monofilament line. When RT-9 was recaptured after 46 d, the saddle and rear bolt were missing, but the front bolt was still present but bent, with part of the dissolving nut attached. The partially healed wounds appeared discolored and necrotic, but showed no obvious signs of infection. Only RT-6 showed no fin damage from the radio tag, but the tag (with malfunctioning transmitter) was removed <8 h after attachment.

Two dolphins, RT-9 and RT-10, developed aberrant swimming behavior after 10 and 17 d, respectively. Both animals were observed to respire without bringing the dorsal fin to the surface in a typical cetacean rolling motion, although each could move rapidly under water. Evaluation of the problem was impossible because RT-9 evaded recapture attempts during this period, and RT-10 was not sighted during capture operations.

One animal, RT-7, died 17 d after tagging, apparently of causes unrelated to the radio tag. Necropsy results implicated pulmonary damage from parasitism as a cause of death. It could not be determined if the capture-tagging process contributed to the cause of death. Tissue autolysis precluded histopathological examination, and no parasites were found.

TABLE 2.—Radio tagging results.

Tag no.	Tag description	Dolphin sex	Dolphin length (cm)	Date attached	Duration of transmission	Probable reason for cessation of transmission
RT-1	Single cylinder; forward spring antenna	Male	251	29 Jan. 1975	2 h	Water leak (?)
RT-2	Single cylinder; forward spring antenna	Male	210	28 Apr. 1975	5 d	Broken antenna
RT-3	Twin cylinder; aft spring antenna	Male	249	15 Jun. 1975	20 h[1]	Seawater switch failure (?)
RT-4	Twin cylinder; aft flexible antenna	Female	252	1 Aug. 1975	6 d[2]	Unknown
RT-5	Twin cylinder; aft flexible antenna	Female	257	2 Oct. 1975	7 d[3]	Seawater switch failure (?)
RT-6	Twin cylinder; aft flexible antenna	Male	226	15 Dec. 1975	7 h	Seawater switch malfunction; transmitter removed
RT-7	Twin cylinder; aft flexible antenna	Male	239	14 Feb. 1976	17 d	Functioning transmitter removed from dead dolphin after 21 d
RT-8	Twin cylinder; aft flexible antenna	Male	221	15 Apr. 1976	22 d	Functioning transmitter removed because of fin damage
RT-9	Twin cylinder; aft flexible antenna	Female	256	8 May 1976	10 d	Unknown. Dolphin did not bring fin above the surface
RT-10	Twin cylinder; aft flexible antenna	Female	250	9 June 1976	17 d	Unknown. Dolphin did not bring fin above the surface

[1]Inconsistent signals during the last 6 h.
[2]Direction finder malfunction after 6 d.
[3]Inconsistent signals during the last 3 d.

Visual Tags

Sixteen single bolt tags were attached between January and December 1975. One was lost within seconds, and three others were lost within 24 h. Two tags had twisted after 2 mo, damaging the fin and requiring removal of the tag. Another tag was believed to have ripped through the fin of a third animal. Two recaptured dolphins had bolt migration scars, and the tags were lost. Of 32 single bolt tags identified in the field, only 3 were sighted more than 2 wk after tagging.

From December 1975 through May 1976, 19 dolphins were tagged with double bolt tags. Tags were identified on free-ranging dolphins 187 times through July of 1976, and one tag was sighted 2 mo after attachment. Broken tags were observed eight times, and nine sightings were unidentified due to algae and barnacle fouling (Fig. 2D). Several tags were observed to have only the upper anterior edges broken, implying that breakage was from physical contact. During recaptures, four intact tags were removed because barnacles on the inner surface of the tag caused skin abrasions. Six broken tags were removed. Bolt migration was not as common as with single bolt tags, probably because of the stability offered by the rear bolt. Although none of the bolt wounds appeared fully healed, none appeared infected when the animals were recaptured and examined.

Visual tags were often discernible up to 200 m away. The numerals were rarely readable at distances >50 m, but even broken tags, tag bolts, and tag scars were useful for identification of some dolphins.

Freeze Brands

Freeze brands were recognizable on marked animals at distances of <30 m, although photographic analysis was often necessary to confirm identification. Some brands were difficult to identify because they were incomplete or because of the relatively poor color contrast of the brand against the skin (Figs. 1D, 2C).

One of the dolphins captured by Irvine and Wells (1972) in March 1971 and freeze branded (on both sides of the dorsal fin) was captured again in December 1975. The animal had a readable freeze brand on only one side of the fin. On another dolphin branded in the same manner in March 1971 and additionally recognizable because of a deformed lower jaw, the brand was readable in May 1971 (Evans et al. 1972), but the brand was no longer visible upon recapture in February 1976.

Roto Tags

From February 1976 through July 1976, 53 Roto tags were placed on 38 dolphins, including 3 animals released with 2 tags. Roto tags were known to be lost from 17 animals and were replaced on 10 of them. A healed indented notch on the trailing edge of the fin was the only evidence of tag loss. Two Roto tags were replaced due to barnacle fouling on the inner surfaces. Brown algae and/or barnacles obscured the tag numbers on most recaptured dolphins, but the tags were still readable on close examination.

Roto tag color could be observed from up to 70 m in calm seas. When examined photographically, position of the tag on the fin or placement in relation to other tags or marks helped verify identity. No dolphins were identified exclusively with Roto tags.

Spaghetti Tags

Seventeen spaghetti tags were attached to 13 dolphins, including 4 dolphins initially released with two tags. None of the animals reacted noticeably to the attachment process. Six tags were missing from four animals recaptured 10 wk after tagging. Three tags were removed from three other dolphins because the entry wounds appeared to be festering.

Animals that had lost their tags bore healed but discolored scars that were similar in size to the festering entry wounds described above. No scratches or other evidence that the dolphins may have attempted to remove the tags by rubbing were noted. The wounds, up to 1.9 cm in diameter, apparently were created by movement of the base of the tag streamer on the skin.

One spaghetti tag was observed in May 1977, 345 d after attachment. Several orange colored spaghetti tags became faded within 4 wk, an observation not reported by other investigators.

Natural Marks

Twelve untagged dolphins with recognizable natural marks were identified a total of 87 times. Photographs of an individual taken first in 1970-71, then during this study in 1976, and by Wells et al.[6] in 1980 suggest that natural marks are relatively permanent.

DISCUSSION

The most obvious shortcoming of tags attached to the dorsal fin was the short longevity. Water drag, tissue rejection, and attempts by dolphins to shed tags may have contributed to tag loss and fin damage. We had hoped that tissue would grow tightly around the bolt sheaths and insulate the wound from bolt-induced tissue irritation; however, healing apparently never occurred while bolts were in place. Since tag wounds did not heal, different attachment methods or new designs are needed. Transmitter packages on two killer whales, *Orcinus orca*, were held for 6 mo by pins implanted diagonally to the plane of the leading edge of the fin (Erickson[7]), and may offer an alternative method of attachment. The relatively larger fin of a killer whale (vs. a dolphin) may, however, have increased chances of success. Carbon bolts attach human prosthetic devices,[8] and are another attachment method yet to be tested on marine mammals.

Radio tags have proved useful to study the ecology of small odontocetes (Evans 1971, 1974; Evans et al. 1972; Gaskin et al. 1975; Würsig 1976), but the configuration used in this study is not recommended for use on *T. truncatus*. The fin damage, premature transmitter loss, and unusual swimming behavior which we observed, may influence study results. These factors have not been previously documented. Radio tags caused no obvious behavioral effects during captive tests on *Delphinus delphis* (Martin et al. 1971). In field studies, however, the radio tagged animals have been infrequently sighted and never recaptured, so possible long-term effects of the tags on the animals are unknown.

Freeze branding proved the most durable marking method. The variability of marks on the animals captured 5 yr after branding indicates that tissue response to the branding process is inconsistent. Freeze brands have remained readable after several years in captivity, but optimal coolants, application times, and pressures have yet to be determined (Cornell et al.[9]). Our resighting, after almost 5 yr, is the longest yet reported. Twenty-one of 26 of the dolphins originally tagged in this study were observed during 1980 and had freeze brands that were either completely readable in photographs or were legible enough to confirm identifications indicated by other characteristics (Wells et al. footnote 6). Maximum longevity of freeze brands is still unknown, however.

The comparatively high incidence of spaghetti tag loss reported here is noteworthy because this tagging method has been previously used with no reports of rejection or abscess (Sergeant and Brodie 1969; Evans et al. 1972; Perrin et al. 1979). Recent tests on captive dolphins have shown, however, that tag loss may be related to tissue rejection, attachment impact, or to the angle of dart entry (Jennings[10]).

Recognition of natural marks provided useful supplementary information in our study, and has been used to study bottlenose dolphins in Texas (Gruber 1981; Shane and Schmidly[11]) and Argentina (Würsig and Würsig 1977). Close approach to the animals is usually required for field recognition, however, and we felt that photoidentification was necessary to verify most of our sightings.

This tagging study has demonstrated that repeated sightings of tagged dolphins are possible and can provide substantial amounts of information about the behavioral ecology of small cetaceans (Wells et al. 1980; Irvine et al. 1981). Selection of the tags to be used should, however, involve consideration of tagging and resighting effort, tag visibility and durability, and potential harm to the tagged animal. Visual

[6]Wells, R. S., M.D. Scott, A. B. Irvine, and P. T. Page. 1981. Observations during 1980 of bottlenose dolphins, *Tursiops truncatus*, marked during 1970-1976, on the west coast of Florida. Report to National Marine Fisheries Service, Contract No. NA80-GA-A-195, 21 p. Available Center for Coastal Marine Studies, University of California, Santa Cruz, CA 95064.

[7]Erickson, A. W. 1977. Population studies of killer whales (*Orcinus orca*) in the Pacific Northwest: a radio-marking and tracking study of killer whales. Available National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22151 as PB-285615, 34 p.

[8]Anonymous. 1977. The application of high purity carbon technology for Rehabilitation Engineering Center at Rancho Los Amigos Hospital. John F. Kennedy Space Center (NASA) Report SED-77-100, 146 p. Kennedy Space Center, Cape Kennedy, FL 32899.

[9]Cornell, L. H., E. D. Asper, K. Osborn, and M. J. White. 1979. Investigations on cryogenic marking procedures for marine mammals. Available National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22151 as PB-291570, 24 p.

[10]J. G. Jennings, Fishery Biologist, Southwest Fisheries Center, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, CA 92038, pers. commun. October 1978.

[11]Shane, S. H., and D. J. Schmidly. 1978. Population biology of Atlantic bottlenose dolphin, *Tursiops truncatus*, in Aransas Pass, Texas. Available National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22151 as PB-283393, 130 p.

tags are most detectable, but are not durable and may damage the dorsal fin tissues. Freeze brands are durable, but not highly visible. Roto tags are of limited use for field identification except in unusual close range situations (e.g., Norris and Pryor 1970), although a combination color and location of the tag can identify an individual. For free-ranging dolphins, spaghetti tags are the only current tagging option, but identification of these tags usually requires collection of the animal. If animals are to be captured initially, combinations of tag types and use of natural marks can provide effective field identification.

Although radio tagging and tag or mark identifications are valuable tools for ecological studies of cetaceans, more development and testing of tags and attachment techniques are needed. Investigators should realize that tagging methods which are successful on one species may not work well on another species. Prior to field studies, tags should be tested on the species to be studied. We also recommend intensive follow-up sighting surveys to maximize data return and to determine the effect of tags and marks on free-ranging animals.

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