

## Tracking Pelagic Dolphins by Satellite

J. G. JENNINGS\* and W. F. GANDY\*\*

*\*National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, California 92038, U.S.A.*

*\*\*National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Center, National Fisheries Engineering Laboratory, NSTL Station, Mississippi 39529, U.S.A.*

*Abstract* - A satellite-linked tracking system is being designed for assessing numbers of dolphins involved in the yellowfin tuna fishery of the eastern tropical Pacific, U.S.A. Testing is via the NIMBUS-6 satellite. The transmitter has a 17.8 cm one-quarter wavelength stub antenna, operates at 401.2 MHz, has a power output of 0.5 W, and incorporates a seawater switch to regulate transmission. Preliminary tests in the laboratory and on captive dolphins revealed problems with the bit rate oscillator, the seawater switch, and frequency modulation. Field tests of prototype transmitters on wild Hawaiian spotted dolphins are scheduled for spring, 1979.

### INTRODUCTION

Under the U.S. Marine Mammal Protection Act of 1972, the National Marine Fisheries Service (NMFS) was made responsible for conservation of dolphins involved in the yellowfin tuna fishery of the eastern tropical Pacific, U.S.A. Regulations governing the fishery, including dolphin mortality quotas, are based on determinations of the status of the stocks. Assessment of animal populations requires data on distribution, migration, and mixing of the stocks, as well as on numbers. These data are combined with age, sex, and growth information obtained from sampling the kill to determine the status of the stocks.

The area involved in the fishery is substantial - 13 million km<sup>2</sup>. NMFS conducts aerial surveys, but the range of the relatively low flying planes limits coverage. A conventional tagging study is planned using highly visible disc tags placed on the dorsal fin. Cost of the tags is minimal, but charter cost for a tuna purse seiner (which is the only means of catching large schools of dolphins) is approximately \$10,000 per day. Tagging studies generally provide data at only two locations - the site of tagging and that of recovery. Radio tracking using standard HF and VHF equipment generally involves tracking one animal for a limited time and there is always the risk of losing the animal.

### PRELIMINARY TESTS

Initial development of the system concentrated on antenna selection. A 17.8 cm one-quarter wavelength stainless steel stub was chosen. Preliminary tests on a captive

dolphin were conducted at Sea World, San Diego, California, in June, 1977, using a modified engineering model of a satellite-linked transmitter developed for use on buoys. These tests, as well as all other work to date, have used the Random Access Measurement System (RAMS) on the NIMBUS-6 satellite. The purpose of the test was to assess the impedance match of the antenna, transmitter, and a live dolphin. The animal was trained to surface on command for transmission every 64 s. A minimum of four successful up-links (transmission to the satellite) per satellite orbit is required to accurately determine position. Of the 14 tests conducted from the live dolphin, only 2 tests were successful with the satellite receiving 4 and 5 up-links. Of 23 verification tests conducted with the transmitter on a roof, 10 were successful with as many as 15 up-links. Failure to achieve sufficient up-links was attributed to several factors: the satellite recorders were sometimes turned off; high satellite elevation angles may have occasionally been a problem; a defective battery cell caused the voltage to drop off after 36 h when it was designed to last 72 h; and the oscillator was not adequately temperature compensated. Most importantly, it was later discovered that the RF oscillator did not fully stabilize until 15 min after power was supplied. Since we did not turn on the unit until immediately before the satellite pass, the frequency drift was too great for reception by the satellite receiver. The test did successfully demonstrate that the concept is feasible and that geographic position of the platform could be determined (Gandy, Vanselow and Jennings, 1977).

#### MATERIALS AND METHODS

A new prototype transmitter pack is being designed and built. The engineering model consisted of: a power supply of 18 3-VDC organic lithium cells; main timing circuit; RF oscillator and power amplifier; seawater activation switch; one-quarter wavelength stub antenna; and aluminum (6061) housing. The system is currently packaged in two cylindrical tubes each measuring  $17.5 \times 5$  cm, which are connected by a 1.61 cm diameter neoprene tube. The pack weighs 907 g. The system operates at a frequency of 401.2 MHz with a transmission repetition rate controlled by the seawater switch. The transmission rate is one message per second if the switch circuitry is inhibited.

Laboratory tests were conducted in November, 1978 and February, 1979, using a RAMS satellite simulator, to evaluate the transmitter's operating characteristics such as frequency variation, phase modulation, proper message formatting and transmission timing.

Field tests on dolphins were conducted during 8-14 February, 1979, at Sea Life Park, Hawaii, using the engineering model. The package was attached with a nylon harness to the area of the dorsal fin of a captive dolphin. A receiver was located near the habitat pool, so that the operational status of the transmitter could be monitored. Satellite data were obtained by telephone through the NIMBUS Control Center at NASA's Goddard Space Flight Center, Greenbelt, Maryland, U.S.A. A test schedule was established, based on predicted times of overpasses and elevation angles of the satellite. Angles greater than  $23^\circ$  were chosen in order to have maximum time during the passes. The duration of these passes was about 20 min.

#### RESULTS

The engineering model failed the initial laboratory test in November, 1978 due to excessive frequency drift and improper phase modulation. The unit successfully interrogated the simulator during the second laboratory test in February. However, three problem areas were identified: (1) the frequency variation was  $1.5 \text{ Hz min}^{-1}$  versus a design specification of  $0.28 \text{ Hz min}^{-1}$ ; (2) the four data channels of the simulator received random messages; and (3) the seawater switch tended to lock in the 'on' position causing the transmitter to operate at the maximum repetition rate of one message per second.

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Eight tests of the engineering model were conducted on a captive dolphin. Sufficient up-links to determine geographic position were achieved during five overpasses (Table 1). The average error in calculated position was 23.33 km, reflecting frequency instability in the transmitter and possibly a larger longitudinal computation error at higher satellite elevation angles. The loss of data for two overpasses was due to the failure of the seawater switch in one case and the spacecraft recorder not being turned on in the other. The third failure is unexplained.

Table 1.  
Reported position of transmitter  
(Actual location was 21.32°N-157.66°W)

Date (calendar)	Time (GMT)	Reported position		Computed error (km)
		(Latitude)	(Longitude)	
2-11-79	2212	21.32°N	158.07°N	44.4
2-12-79	0934	21.14°N	157.46°W	29.6
2-12-79	2125	21.35°N	157.63°W	9.3
2-14-79	0941	21.34°N	157.96°W	33.3
2-14-79	2149	21.32°N	157.66°W	0

#### CONCLUSION

Tests have shown that it is feasible to acquire data on geographic positions of marine animals with a satellite-linked tracking system. Four design changes were implemented in recent tests: (1) RF shielding of the seawater switch circuit; (2) an inhibit circuit to prevent the transmitter from operating continuously when the animal is at the surface; (3) temperature compensation of the bit rate oscillator; and (4) frequency stability to within  $0.28 \text{ Hz min}^{-1}$ .

Two prototype units with these modifications will be tested on wild Hawaiian spotted dolphins (*Stenella attenuata*) in offshore Hawaiian waters in the spring of 1979. Successful tracking of these dolphins is prerequisite to placing transmitters on wild dolphins of the same species in the fishery. Placement on wild dolphins in the eastern tropical Pacific could begin in late 1979. Transition to the TIROS-N satellite is being evaluated which would require some modification of the electronics.

The tracking system is being designed to be applicable to other marine animals such as large whales and sea turtles. The pack will be reduced in size, and could be designed to incorporate oceanographic and physiological sensors.

#### REFERENCE

- Gandy W. F., Vanselous T. M. and Jennings J. G. (1977) Tracking marine animals by satellite. *Proceedings, ARGOS Meeting, Paris, France, November 3, 1977.*