Movements of Pelagic Dolphins (*Stenella* Spp.) in the Eastern Tropical Pacific as Indicated by Results of Tagging, With Summary of Tagging Operations, 1969-76

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ABSTRACT

Through 1976, 3,712 small cetaceans were tagged in the course of research cruises operating out of the Southwest Fisheries Center. These included 2,996 spotted dolphins, *Stenella attenuata;* 324 spinner dolphins, *S. longirostis;* 193 common dolphins, *Delphinus delphis;* and 113 bottlenose dolphins, *Tursiops truncatus.* Others tagged in small numbers included Pacific whitesided dolphins, *Lagenorhynchus obliquidens;* striped dolphins, *Stenella coeruleoalba;* and a short-finned pilot whale, *Globicephala macrorhynchus.* Several types of tags were used. Tags have been recovered from 97 spotted dolphins and 7 spinner dolphins. Time at liberty ranged from less than 2 h to more than 4 yr. Net distance traveled ranged from 7 to 582 n.mi. Average short-term movement in the spotted dolphin is 30-50 n.mi./day; range is 200-300 n.mi. in diameter, and seasonal onshore-offshore migrations may exist.

INTRODUCTION

Populations of pelagic dolphins are important to the purse seine fishery for yellowfin tuna in the eastern tropical Pacific and are affected by the fishery.[3] Adequate assessment of the impacts of the fishery on the dolphin populations requires knowledge of such aspects of life history as home range and seasonal migration. For this reason, we began a program of tagging dolphins in 1969. The tagging program was specifically designed to examine movements, but the tagging itself was largely opportunistic. In addition, research projects with other objectives but involving tagging have also yielded information on movements. The main purpose of this report is to summarize and to report the results of analyses of data on movements of spotted dolphins, *Stenella attenuata,* and spinner dolphins, *S. longirostris,* yielded by tag returns through 1976. A secondary purpose is to summarize and document all dolphin tagging operations carried out in conjunction with dolphin/tuna research at the Southwest Fisheries Center, La Jolla, Calif., from 1969 through 1976. This is necessary because of the possibility that tagged dolphins released by us may be recovered by other investigators not familiar with our program. We suspended field work in our tagging program in 1976, pending development of better tags and design of a plan for large-scale tagging aimed at estimating population sizes. The results of the expanded program will be the subject of future reports.

Many small marine odontocetes are thought to undergo migrations of varying scale in time and distance. Most published conclusions about movements have been based on sightings or strandings and have to do with season of the year or sea surface temperature. Fraser (1934) noted a possible intrusion of elements of the warm-temperate Atlantic cetacean fauna (including *Delphinus delphis*) into the North Sea during a year of anomalous sea-surface warming. Sightings and correlated oceanographic data suggest that the distributions of dolphins (*Lissodelphis peroni, Lagenorhynchus cruciger, Lagenorhynchus obscurus,* and *Delphinus delphis*) off the east coast of New Zealand are "closely associated with certain temperature ranges and consequently with specific water masses and convergence regions," causing different animals to be seen in summer than in winter (Gaskin 1968). Similarly, Kasuya (1971) found, on the basis of aerial sightings, that warm-water delphinids, including *Stenella attenuata,* in Japanese waters migrate north in the summer season as far as Hokkaido; whereas cold-water forms, such as *Phocoenoides dalli* and *Lissodelphis borealis,* migrate south in the winter. The northern extent of the distribution of the warm-water forms may vary seasonally as much as 13° of latitude (780 n. mi.) (Miyazaki et al. 1974). Evans (1975) demonstrated the existence of similar seasonal migrations by the common dolphin, *D. delphis,* off the coasts of southern California and Baja California. Several other similar studies have been carried out, and this review is not exhaustive.

Very little information has been available on home range of pelagic dolphins. As Norris (1967) noted, some dolphins seem quite sedentary. He found that herds of spinner dolphins, *Stenella longirostris,* are consistently found off limited stretches of coast; five such home ranges have been tentatively recognized off Oahu, Hawaii. On the other hand, some other dolphins are very

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[3]Report of the Workshop on Stock Assessment of Porpoises Involved in the Eastern Pacific Yellowfin Tuna Fishery. Unpubl. Manuscr., 109 p. SWFC Admin. Rep. No. LJ-76-29, Nat. Mar. Fish. Serv., La Jolla, CA 92038.

mobile. Herds of common dolphins off southern California and Baja California may move as far as 120 km in a 24-h period, following underwater escarpments (Evans 1971, 1974).

Preliminary results of our tagging program through early 1974 have been previously published (Perrin 1975). Time at liberty for tagged spotted dolphins ranged from 1.7 h to 502 days and minimum distance traveled from 13 to 532 km.[4] The tentative conclusion was that these data indicate a great deal of east-west and north-south movement within the eastern portion of the range of the offshore race of *S. attenuata*. Tag returns for *S. longirostris* showed less net movement.

[4]A maximum value for minimum distance traveled of 2,415 km was given in Perrin (1975). Subsequently, additional information has been acquired concerning the recapture of that tag, and the data are now considered to be unreliable and are not included in the analysis below.

MATERIALS AND METHODS

During the course of research on the dolphin/tuna problem, 3,712 small cetaceans were tagged (Table 1), including 2,996 spotted dolphins (Fig. 1) and 324 spinner dolphins (Fig. 2). One of us (Evans) carried out other dolphin-tagging operations during the period 1969-76, but these did not involve *Stenella* spp. and will be described in another report. Several types of tags and tag legends were used:

1. *Spaghetti tag with plastic dart.* This tag was described and figured by Nishiwaki et al. (1966). The

Table 1.—Dolphins and small whales tagged, 1969-76. Radiotags included.

Year	*Stenella attenuata*	*Stenella longirostris*	*Delphinus delphis*	*Tursiops truncatus*	Other	Unidentified	Total
1969	207	11	0	0	0	0	218
1970	618	94	10	0	0	[1]46	768
1971	147	18	50	12	[2]1	[3]15	243
1972	306	41	28	19	[2]7	0	401
1973	203	35	56	8	[4]2	1	305
1974	1,048	70	23	72	[2]7	1	1,221
1975	336	46	26	2	[5]4	[3]2	416
1976	131	9	0	0	0	0	140
Total	2,996	324	193	113	21	65	3,712

[1]Probability is high that these were either spotted dolphins, *Stenella attenuata*, or spinner dolphins, *S. longirostris*.
[2]Pacific white-sided dolphin, *Lagenorhynchus obliquidens*.
[3]Spotted or spinner dolphins.
[4]Striped dolphin, *Stenella coeruleoalba*.
[5]Two striped dolphins and two short-finned pilot whales, *Globicephala macrorhynchus*.

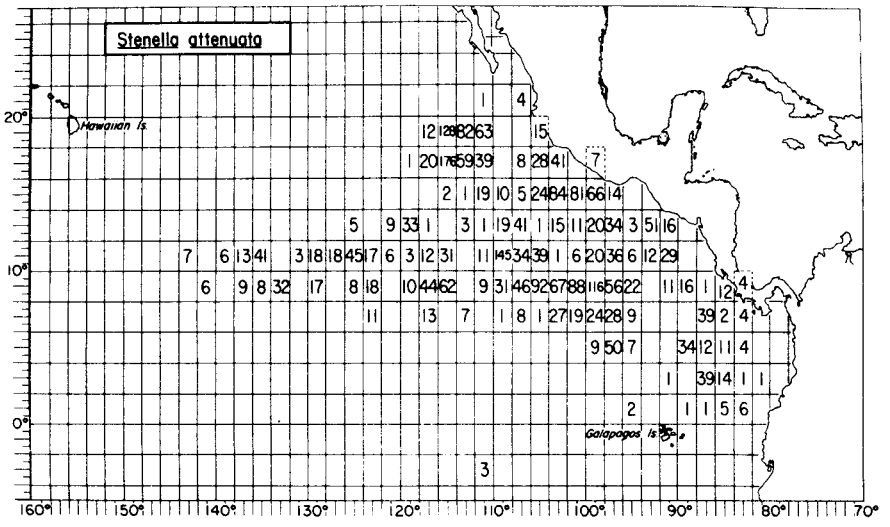


Figure 1.—Number of releases of tagged spotted dolphins, *Stenella attenuata*, by 2-degree area, 1969-76. Releases given in Table 1 for which precise localities are not available are not included.

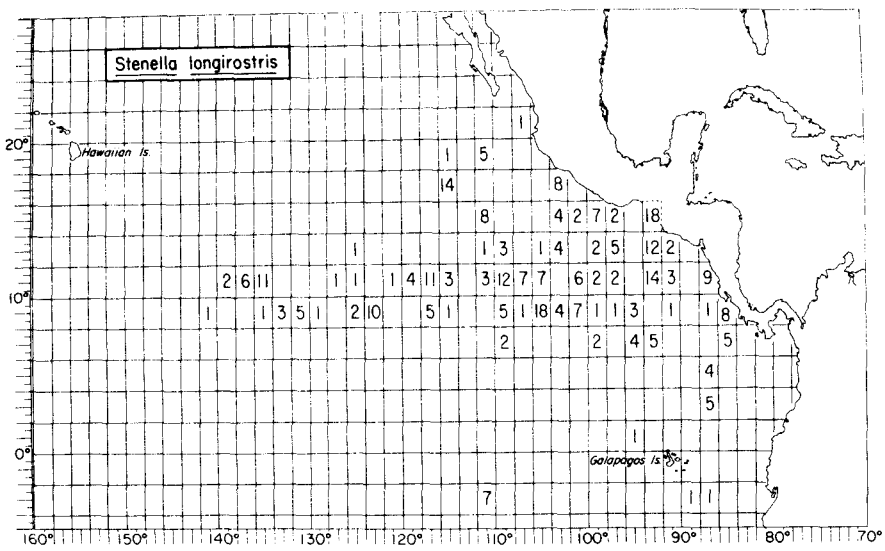


Figure 2.—Number of releases of tagged spinner dolphins, *Stenella longirostris*, by 2-degree area, 1969-76. Two dolphins given in Table 1 for which precise localities are not available are not included.

tags released in 1969 and 1970 were yellow and bore one of two legends (in addition to serial number):

a. RETURN TUNA COMM SAN DIEGO or
b. REWARD BU COMM FISHERIES SAN DIEGO.

2. *Spaghetti tag with steel dart.* This type of tag was developed for use on large pelagic fishes (Mather 1963) and was first used on cetaceans by Sergeant and Brodie (1969). It has been modified from its original design by addition of a clear plastic sleeve to protect the legend (Evans et al.1972). It is manufactured by Floy Tag and Manufacturing, Inc., Seattle, Wash. Four versions of the tag were used in the operations described here:

   a. 15-cm long, orange, with legend:
      REWARD U.S. BUR COMM FISH LA JOLLA, CALIF(CF)
   b. 12-cm long, yellow, with legend:
      REWARD NATL MARINE FISH SERVICE LA JOLLA, CAL
   c. 32-cm long, yellow, with legend:
      NUC-502 SAN DIEGO, CAL. 92132 REWARD
   d. 30-cm long, orange, with legend:
      NATIONAL MARINE FISHERIES SERVICE LA JOLLA, CA U.S.A. REWARD.

3. *Spaghetti tag with steel dart/braided.* These tags were designed at sea for use in underwater observations of tagged dolphins during the research cruise of the *Elizabeth C. J.* in 1976 (see following section on Chronological Account of Tagging Operations, 1969-76). Three-strand braids of spaghetti tubing of various colors were linked together in unique color/length combinations and fastened to steel-dart tags from which all but 1 in of tubing (bearing the serial number) has been removed. Six-inch lengths of ½-in wide flexible, bright orange plastic streamers were added to the ends of some of the tags to further increase visibility.

4. *Plastic deer ear tag.* This tag ("jumbo rototag") was described and figured by Norris and Pryor (1970). Tag and applicators are manufactured by Dalton, Henley, United Kingdom.

   a. Tags released in 1971 were yellow and bore the legend:
      DEVUELVA OF. DE PESCA PREMIO. 150 PESOS BU COMM FISH SAN DIEGO CON CABEZA
   b. Tags released in 1972 were yellow, with the legend:
      $15 DOLLAR REWARD FOR RETURN WITH HEAD BU COM FISH SAN DIEGO
   c. Tags released in 1973 were white and bore no legend other than the serial number.

5. *Radiotag.* Martin et al. (1971) and Evans (1971, 1974) described and figured the radiotags used.

CHRONOLOGICAL ACCOUNT OF TAGGING OPERATIONS, 1969-76

1. In 1969 and 1970, the Inter-American Tropical Tuna Commission (IATTC) conducted tuna-tagging operations on three cruises on the chartered tuna seiners, the *Connie Jean* and the *Anne M.* At NMFS' request, tuna tags (spaghetti tag with plastic dart—see discussion of tag types above) were also placed in dol-

phins captured with tuna (see Bayliff 1973 for description of tagging operations). Nine hundred and forty-nine dolphins were thusly tagged (Table 2).

2. In 1970, a crewman on the seiner *Conquest* volunteered to tag dolphins during fishing operations. He tagged 37 dolphins (probably spotted and spinner dolphins) with plastic-dart spaghetti tags.

3. Beginning in 1971, scientific observers from NMFS each year have accompanied some tuna seiners to the "porpoise-fishing" grounds. Through 1975, these observers tagged dolphins on an opportunity basis. The observers tagged 105 dolphins on 3 cruises in 1971, 316 on 9 cruises in 1972, 204 on 16 cruises in 1973, 1,221 on 25 cruises in 1974, and 416 on 22 cruises in 1975 (Table 3). Two short-finned pilot whales,

Table 2.—Tags released from commercial seiners, 1969-76. Releases by NUMFS observers aboard nonchartered seiners are detailed in Table 3. Tag type PD = plastic-dart spaghetti tag, MD = metal-dart spaghetti tag (see Table 3), DE = deer ear tag, and RX = radio-transmitter tag. Letters a, b, and c refer to tag type subcategories defined in text.

			Tagged							
Vessel	Cruise number	Cruise period	Spotted dolphin	Spinner dolphin	Common dolphin	Bottlenosed dolphin	Other	Unidentified	Total	Tag type
Connie Jean	1055	Oct-Nov 69	207	11	0	0	0	0	218	PD (a)
Anne M	1057	Jun-Aug 70	≥278	≥46	10	—	—	9	343	PD (61a, 278b)
Anne M	1058	Sep-Nov 70	340	48	0	0	0	0	388	PD (b)
Conquest	—	Mar-Apr 70	—	—	—	—	—	37	37	PD (b)
Queen Mary	13	Nov-Dec 71	≥105	—	0	0	0	[1]15	120	MD (107b, 24c)
			15	0	0	0	0	0	15	DE (a)
			3	0	0	0	0	0	3	RX
Independence	26	Sep-Oct 72	1	4	18	0	[2]1	0	24	MD (a)
			61	0	0	0	0	0	61	DE (b)
Trinidad	52	Oct-Nov 73	12	1	7	0	0	0	20	MD (a)
John F. Kennedy	53	Nov-Dec 73	59	0	0	0	0	0	59	MD (a)
			22	0	0	0	0	0	22	DE (c)[3]
Elizabeth C J	208	Oct-Dec 76	124	8	0	0	0	0	132	MD[4]
			7	1	0	0	0	0	8	RX
Total			1,234	119	35	0	1	61	1,450	

[1]Spotted or spinner.
[2]Pacific white-sided dolphin, *Lagenorhynchus obliquidens*.
[3]With 2-in disc.
[4]With braided tubing.

Table 3.—Tag releases (steel-dart spaghetti tags) by NMFS observers aboard commercial tuna seiners, 1971-75. Tag types defined in text.

		Tagged							
Cruise number	Year	Spotted dolphin	Spinner dolphin	Common dolphin	Bottlenose dolphin	Other	Unidentified	Totals	Tag type
6	1971	0	0	23	0	[1]1	0	24	(a)
8		8	18	17	11	0	0	54	(a)
9		16	0	10	1	0	0	27 105	(10c, 95a)
14	1972	18	0	0	0	0	0	18	(a)
15		43	0	2	0	0	0	45	(a)
16		22	21	0	0	0	0	43	(a)
17		6	0	2	9	[1]6	0	23	(a)
20		16	0	0	0	0	0	16	(a)
21		54	1	0	1	0	0	56	(a)
22		32	13	0	0	0	0	45	(a)
23		15	0	0	0	0	0	15	(a)
24		38	2	6	9	0	0	55 316	(a)
29	1973	2	4	7	0	0	0	13	(a)
30		12	5	0	0	0	1	18	(a)
31		1	0	0	0	0	0	1	(a)
32		1	0	0	0	0	0	1	(a)
33		1	0	0	0	0	0	1	(a)
34		9	0	0	0	0	0	9	(a)
38		4	1	0	0	0	0	5	(a)
39		1	0	0	0	0	0	1	(a)
40		1	0	0	0	0	0	1	(a)
41		12	10	6	0	0	0	28	(a)
43		5	1	4	0	0	0	10	(a)
44		11	1	4	0	[2]2	0	18	(a)
45		23	0	8	0	0	0	31	(a)
47		7	0	4	0	0	0	11	(a)
48		9	12	16	8	0	0	45	(a)

Table 3.—Continued.

Cruise number	Year	Tagged: Spotted dolphin	Spinner dolphin	Common dolphin	Bottlenose dolphin	Other	Unidentified	Totals		Tag type
49		11	0	0	0	0	0	11	204	(a)
54	1974	0	3	0	0	0	0	3		(a)
55		3	0	0	0	0	0	3		(b)
57		16	3	0	0	0	0	19		(a)
58		47	3	0	9	0	0	59		(a)
59		24	8	2	4	0	0	38		(a)
61		51	8	4	17	[1]3	0	83		(b)
65		17	0	4	0	0	0	21		(a)
66		29	0	0	0	0	0	29		(a)
67		0	1	0	0	0	0	1		(a)
68		20	1	7	0	0	0	28		(b)
71		2	5	0	0	0	0	7		(a)
72		1	0	0	0	0	0	1		(b)
73		3	2	0	0	0	0	5		(a)
74		34	1	0	0	0	1	36		(b)
75		2	0	0	0	0	0	2		(a)
76		1	1	0	0	0	0	2		(a)
78		8	0	0	0	0	0	8		(b)
80		10	0	0	0	0	0	10		(a)
81		2	0	0	8	0	0	10		(b)
82		34	0	0	0	0	0	34		(a)
87		91	5	6	32	[4]4	0	138		(b)
90		5	7	0	0	0	0	12		(a)
91		623	14	0	2	0	0	639		(a)
94		5	2	0	0	0	0	7		(a)
96		20	6	0	0	0	0	26	1,221	(a)
99	1975	1	0	0	0	0	0	1		(a)
100		16	0	0	1	0	0	17		(d)
102		43	2	0	0	[2]1	0	46		(d)
104		42	4	0	0	0	[3]2	48		(d)
105		18	2	0	0	0	0	20		(d)
106		45	3	0	1	0	0	49		(d)
110		3	0	0	0	[2]1	0	4		(d)
112		42	8	0	0	0	0	50		(d)
113		27	10	0	0	0	0	37		(d)
114		1	0	0	0	0	0	1		(d)
115		6	1	0	0	0	0	7		(b)
116		2	1	0	0	0	0	3		(d)
117		1	0	0	0	0	0	1		(d)
118		0	2	0	0	0	0	2		(d)
119		15	5	0	0	0	0	20		(d)
120		1	0	0	0	0	0	1		(d)
121		43	0	0	0	0	0	43		(d)
123		8	1	2	0	[4]2	0	13		(d)
124		1	0	0	0	0	0	1		(d)
125		5	0	0	0	0	0	5		(d)
129		16	7	24	0	0	0	47	416	(d)
	Total	1,762	205	158	113	20	4	2,262		

[1]Pacific white-sided dolphin, *Lagenorhynchus obliquidens*.
[2]Striped dolphin, *Stenella coeruleoalba*.
[3]Spotted dolphin or spinner dolphin.
[4]Short-finned pilot whale, *Globicephala macrorhynchus*.

Globicephala macrorhynchus, were also tagged in 1975. Before application, the tag heads were sprayed with Topazone, a topical antibiotic. The tags were applied in several different ways:

a. from the bow (when animals rode the bow wave), with a quick-release head (Beckett 1968) mounted on a long wooden pole or with a crossbow (as described by Kasuya and Oguro 1972, but using a rubber stop on the crossbow bolt rather than a brass stop);
b. from a skiff at the corkine of the seine during the dolphin-rescue maneuver called "backing-down" (see Perrin 1969 for details of fishing operation), using short (40 cm) wooden wands, with permanently mounted tag pins, as applicators; and
c. on the work-deck, when live dolphins were extricated from the net or the catch and then thrown overboard, using short applicators.

4. In late 1971, NMFS chartered the tuna seiner *Queen Mary* for a dolphin/tuna research cruise on the fishing

grounds. Three tagging operations were carried out on the cruise.

a. Radiotags were attached to spotted dolphins, to monitor herd movements, herd integrity, and recruitment of associated yellowfin tuna to the herd. The technique has been described by Evans (1971, 1974). Five dolphins were radiotagged and followed.
b. Fifteen spotted dolphins were measured, sexed, and injected with lead acetate and tagged with plastic deer ear tags placed in the dorsal fin. The animals were pulled into a small skiff for examination and tagging. Technique of application was described by Norris and Pryor (1970). The purpose of the injection of lead acetate was to lay down a time check in the hard tissues, so that growth rates in teeth and bone could be calibrated through examination of recaptured animals. The technique was developed by Nishiwaki and Yagi (1953). The tagged animals were also injected with an antibiotic to combat sepsis. Results of this experiment will be analyzed when tags are returned (none returned with sufficient data to date).
c. One hundred and twenty dolphins were also tagged with steel-dart spaghetti tags.

5. In late 1972, NMFS chartered the seiner *Independence* for a dolphin/tuna cruise. Sixty-one spotted dolphins were injected with lead acetate and tagged with plastic deer ear tags. Tagging was accomplished through use of an aluminum chute supported by two skiffs at the corkline of the seine (Fig. 3). In addition, 24 dolphins were tagged with steel-dart spaghetti tags.

6. Also in 1973, the seiner *Trinidad* was chartered by NMFS for technological research on dolphin rescue methods and equipment. During the cruise, 20 dolphins were tagged with steel-dart spaghetti tags.

7. In late 1973, NMFS chartered the seiner *John F. Kennedy*. The main purpose of the cruise was to conduct research on dolphin-rescue methods, but some tagging was also carried out. Twenty-two spotted dolphins in a single herd were tagged with white deer ear tags, inserted in the dorsal fin. A 2-in diameter thin red plastic disc was placed on the tag post on each side of the fin to increase visibility of the tag in the water. The objective was to tag dolphins in several herds, using a different color for each herd, and then to study herd structure and integrity through observation of tagged animals in the seine in subsequent hauls in the same area. Rough weather, however, prevented further use of the tagging chute (described above) and completion of the scheduled tagging. In addition to the 22 dolphins tagged with ear tags, 59 spotted dolphins were tagged with steel-dart spaghetti tags.

8. In late 1976, NMFS chartered the seiner *Elizabeth C. J.* for a combined dolphin/tuna behavioral research and gear research cruise sponsored by several governmental and private organizations. Two types of tags were used to mark dolphin schools so that they could be followed and recaptured and the tagged dolphins observed in the net. Radiotags were placed on seven spotted dolphins and one spinner dolphin. The radiotags failed after only a few hours, but two were subsequently recovered (the recoveries are treated below like other tag returns; the radio-transmitted data will be presented elsewhere). In addition, 124 spotted dolphins and 8 spinner dolphins were tagged with steel-dart spaghetti tags modified for greater underwater visibility (see 3. *Spaghetti tag with steel dart/braided* above).

ACCOUNT OF RADIOTRACKING EXPERIMENT

Transmitters were placed on one adult male (animal A) and two adult females (animals B and C) captured in a tuna seine on 21 November 1971. The object of the experiment was to track the school and set the net on what was assumed to be the same herd five times, at 24-h intervals and at about 1000. The initial set was in the afternoon, and the tagged animals were not released until almost sunset. The chronology of events (Fig. 4) may be summarized as follows:

After the release of the tagged animals it became increasingly obvious that the behavior of the male was quite different from that of the females. At first all animals appeared to stay on the same relative heading. After sunset the females began to move away from the male and the decision was made to stay with the male. After 6 h of tracking the females were separated from the male by an estimated 12 n.mi. and their transmitted signals were extremely weak. It was assumed the transmitter on at least one of the two animals (B and C) had failed.

The vessel followed the male (A) until 1040 on 22 November when the first recapture set was made (set 2). Net distance traveled between initial release and this recapture was 59 n.mi., in about 16 h. One of the females (C) rejoined the male (A) at 0800 but separated from him again at 0930 prior to the net set. An additional long-range transmitter was placed on another male (D) during set 2. Also, a long-life, short-range transmitter was placed on another female (E). After release, A and D stayed together and were rejoined by one of the females from the first set (C). Female B was not seen again following her separation from A and C after initial release in set 2. A, D, E, and C were followed until 1036 (set 3) on 23 November. Net distance traveled in 24 h was 28 n.mi. During this period, the males (A and D) were separated by some distance (3 n.mi.) from the school containing the females (C and E). The set (3) was made on the portion of the school containing the males A and D. They evaded capture by passing between the boat and the net skiff be-

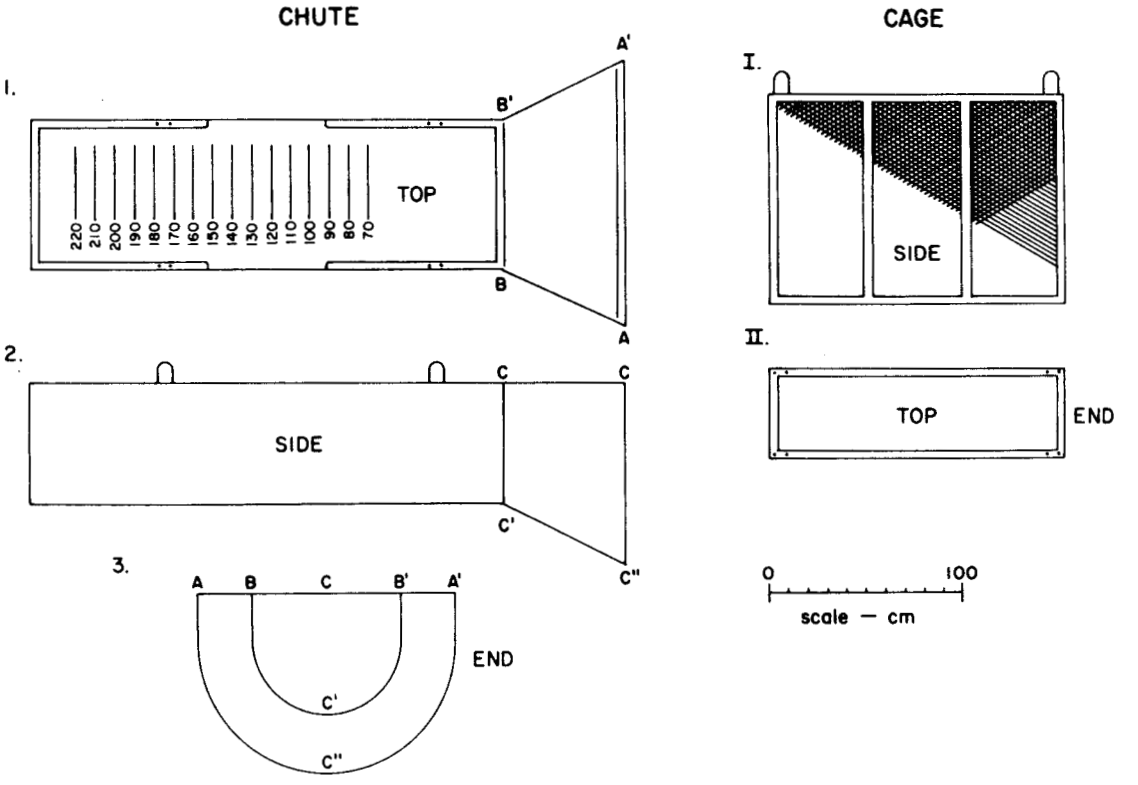
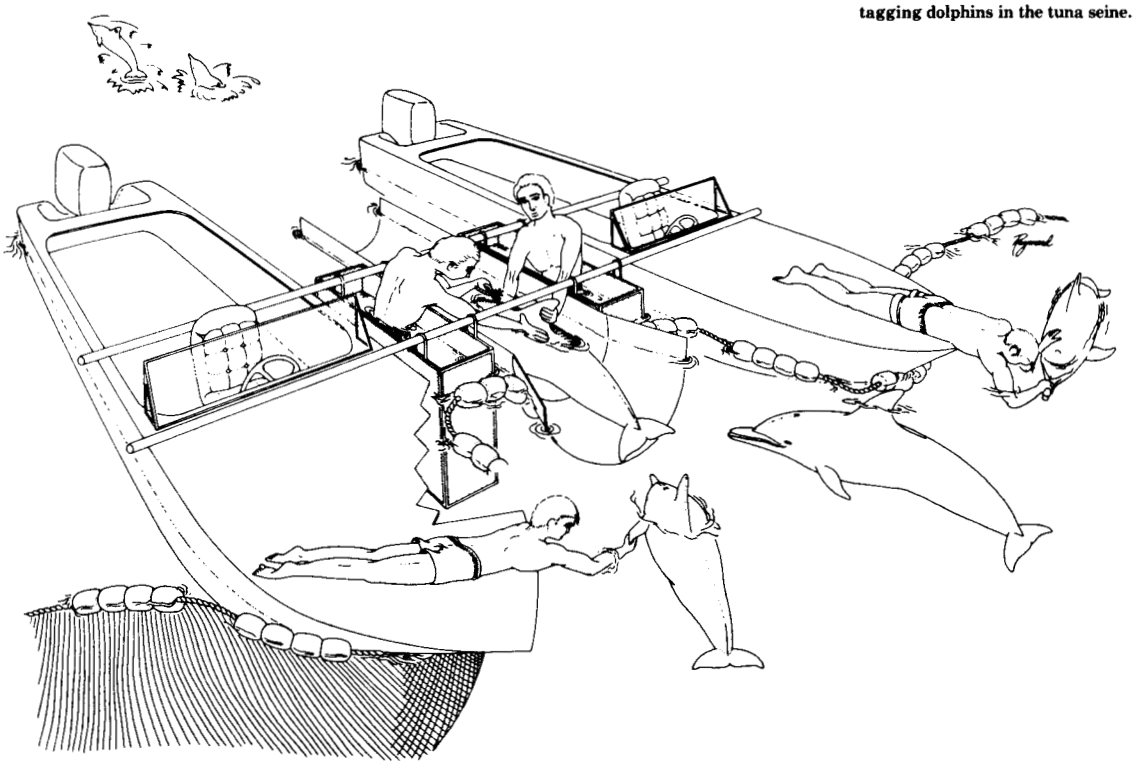


Figure 3.—Chute system used for tagging dolphins in the tuna seine.



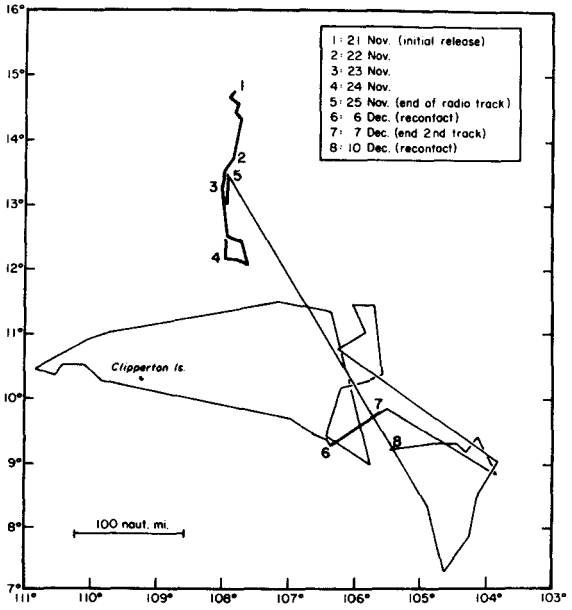


Figure 4.—Cruise track of chartered purse seiner *Queen Mary* while tracking movement of school of radiotagged spotted dolphins, *Stenella attenuata*, in November-December 1971. Heavy lines represent portions of the cruise track when radio contact was maintained with the school. The lines represent movements of the vessel, not necessarily the exact route of the radio-tagged animals.

fore completion of the net circle. After the set, A and D were followed until 2200 when they separated. Male D was followed, with a faint signal in the background from A, until 1020 on 24 November (set 5). Net distance traveled in this 24-h period was 69 n.mi., but actual distance traveled was about 110 n.mi. (Fig. 4). At this time, A and D had reconverged, but the set was made on the portion of the school containing D. Animal D again eluded capture in the seine. A and D rejoined after the set and were followed until 0700 on 25 November when the track was terminated because of an approaching storm. Net distance traveled during this 22-h period was approximately 75 n.mi. The school had doubled back and was heading north on almost exactly the same path it had followed south 3 days before. Total net distance traveled during the 110 h of the 5-day radiotrack was only about 75 n.mi., about one-fourth of the actual distance traveled. Maximum distance between any two points on the track was about 160 n.mi.

On 6 December, 11 days and approximately 285 n.mi. distance from termination of the first track, signals from both of the males (A and D) were picked up at 1255 and followed until 0750 on 7 December when strong signals were received from A in a school of <30 spotted dolphins. The school was chased to allow close approach and a good estimate of size, but no net set was made, and the school was not further followed. Net distance traveled during this 19-h second radiotrack was about 75 n.mi. Three days later, on 10 December, at 0925, signals were again received from A and D, and, this time, also from the female C, which had not been heard from since separating from the males on 23 November. The males and females were again segregated within the school. The school was not set on or followed after this recontact, and the research cruise ended shortly thereafter. Net distance traveled by the school between initial release and last contact (19 days) was 357 n.mi. (19 n.mi./day, south-southeast).

RESULTS AND DISCUSSION

Of 3,712 tags released from 1969 through 1976, 104 had been returned as of 1 January 1977 (Tables 3, 4). Tags were recovered only from spotted dolphins (97) and spinner dolphins (7). Time at liberty ranged from 1 h and 40 min to 1,478 days for *S. attenuata* and from 15 h and 48 min to 776 days for *S. longirostris*. Minimum distance traveled (distance between release and recovery locations) ranged from 7 to 582 n.mi. for *S. attenuata* (Fig. 5) and 12 to 275 n.mi. for *S. longirostris* (Fig. 6). Details of returns are presented in Tables 4, 5. Returns are sufficient for the spotted dolphin to allow some analyses based on these and on the results of radiotagging.

Short-Term Movements

Twenty-six tagged spotted dolphins were recaptured within 2 days (48 h) after release (Fig. 7). Longer term recoveries were not included in the analysis because of the increasing potential for bias caused by the animals doubling back on themselves (see results of radiotagging experiment above). A linear regression line fitted to the data has a slope indicating an average movement rate of about 1.2 n.mi./h (about 30 n.mi./day).

The results of the radiotagging experiment indicate daily movement rates of similar scale (Fig. 4), yielding estimates of net daily travel rate ranging from 5 to 89 n.mi. and an average of 54 n.mi./day (Table 6), as compared with the estimate of about 30 n.mi./day based on short-term tag returns. The former can be assumed to be less affected by the "doubling back" factor.

Long-Term Movements

A plot of minimum distance traveled on time at liberty for all tag returns shows maximum movement of 500 to 600 n.mi. (Fig. 8). The data may have a periodic component. Average minimum distance traveled is 100 n.mi. for 10- to 50-day returns (n = 21) and 274 n.mi. for 50- to 200-day returns (n = 12) but only 93 n.mi. for 200- to 400-day returns (n = 15). A major question in interpreting these results is that of recovery effort. Tags are recovered during the fishing operation. Was there significantly more fishing effort in areas <200 n.mi. from areas in which tags were released 200 to 400 days earlier than in areas more than 200 n.mi. from areas of release? In other words, could the data reflect periodic fishing effort rather than periodic movement of dolphins? In an attempt to settle this question, we examined, for each of the 50- to 200-day returns (12) and each of the 200- to

Table 4.—Tag return data for spotted dolphin, *Stenella attenuata*, 1969-76. Recovered radiotags included. Tag type codes defined in text.

	Release				Recapture			Days at liberty (or h)	Minimum distance traveled (n.mi.)	Direction net movement		Tag type		Tag number
	Date	Cruise number	Position lat. N	Position long. W	Date	Position lat. N	Position long. W			°T	bearing			
1	1 Nov 69	1055	14°17′	98°58′	1970	—	—	60	—	—	—	PD	(a)	T3154
2	2 Nov 69	1055	13°49′	99°20′	25 Feb 70	15°39′	101°09′	114	152	316	NW	PD	(a)	T3160
3	4 Nov 69	1055	15°03′	101°42′	3 Mar 70	15°10′	100°41′	119	59	83	E	PD	(a)	T3193
4	17 Nov 69	1055	10°28′	107°40′	3 Apr 70	7°58′	98°10′	137	582	104	ESE	PD	(a)	A1171
5	18 Nov 69	1055	10°58′	107°34′	19 Nov 69	10°41′	107°08′	(24 h)	31	124	SE	PD	(a)	A1181
6	18 Nov 69	1055	11°09′	107°20′	5 Mar 70	13°20′	100°15′	107	435	72	ENE	PD	(a)	A1199
7	11 Sep 70	—	9°46′	140°50′	3 Dec 70	9°32′	134°15′	83	390	92	E	MD	(b)	P1019
8	24 Nov 71	13	12°11′	107°57′	11 Jan 72	11°37′	105°03′	48	174	101	E	MD	(c)	01667
9	7 Dec 71	13	9°49′	105°29′	12 Jan 72	10°40′	106°31′	36	67	320	NW	MD	(c)	00769
10	8 Dec 71	13	10°15′	104°32′	9 Dec 72	9°16′	104°26′	(15 h)	59	174	S	MD	(a)	00013
11	9 Dec 71	13	9°17′	104°48′	10 Feb 72	9°16′	98°40′	63	363	90	E	MD	(a)	00096
12	9 Dec 71	13	9°17′	104°48′	10 Feb 72	9°16′	98°40′	63	363	90	E	MD	(a)	00099
13	11 Dec 71	26	9°21′	105°50′	12 Jan 72	10°40′	106°13′	32	82	344	NNW	DE	(b)	116
14	11 Dec 71	26	9°21′	105°50′	8 Jan 72	8°50′	104°40′	28	76	144	ESE	DE	(b)	118
15	13 Jan 72	14	7°10′	102°30′	1973	—	—	—	—	—	—	MD	(a)	00609
16	21 Jan 72	17	10°30′	99°50′	10 Feb 72	9°50′	97°10′	20	162	104	ESE	MD	(a)	00591
17	30 Jan 72	16	6°15′	98°58′	31 Jan 72	6°07′	99°36′	(21 h)	40	252	WSW	MD	(a)	00434
18	24 Feb 72	16	14°54′	99°34′	4 Mar 72	14°40′	100°55′	9	80	260	W	MD	(a)	00457
19	25 Feb 72	21	9°45′	98°35′	28 Mar 72	10°35′	100°55′	32	147	290	WNW	MD	(a)	00475
20	27 Mar 72	22	9°28′	98°21′	11 Apr 72	13°16′	96°22′	15	256	27	NNE	MD	(a)	00111
21	8 Aug 72	26	12°30′	109°23′	21 Feb 74	12°55′	99°41′	501	568	86	E	DE	(b)	011
22	23 Oct 72	26	10°28′	104°03′	15 Nov 76	—	—	1478	—	—	—	DE	—	039
23	27 Mar 73	45	9°53′	96°17′	—	—	—	—	—	—	—	MD	(a)	01425
24	6 Feb 74	61	17°37′	112°41′	3 Aug 74	19°20′	113°25′	179	111	338	NNW	MD	(b)	02959
25	9 Feb 74	61	17°24′	102°24′	9 Feb 74	17°29′	102°19′	(2 h)	7	44	NE	MD	(b)	02986
26	18 Feb 74	59	11°05′	90°38′	29 Jan 75	12°45′	91°43′	345	119	328	NNW	MD	(a)	01457
27	18 Feb 74	59	9°37′	91°26′	6 Mar 74	11°20′	91°23′	16	103	2	N	MD	(a)	01461
28	18 Feb 74	59	9°37′	91°26′	6 Mar 74	11°40′	91°50′	16	125	349	N	MD	(a)	01469
29	20 Feb 74	58	14°46′	102°09′	20 Feb 74	14°39′	102°11′	(2 h)	7	188	S	MD	(a)	00837
30	25 Feb 74	66	14°15′	102°20′	27 Feb 74	14°38′	102°38′	(54 h)	32	328	NNW	MD	(a)	00073
31	4 Apr 74	82	5°10′	89°10′	4 Mar 75	4°22′	87°02′	334	136	111	ENE	MD	(a)	00059
32	19 Jun 74	91	18°16′	115°51′	7 Mar 75	16°32′	113°30′	260	170	127	SE	MD	(b)	02101
33	20 Jun 74	91	18°00′	114°50′	30 Jun 74	18°09′	115°49′	10	57	279	W	MD	(b)	02699
34	21 Jun 74	91	17°54′	114°02′	22 Jun 74	17°57′	113°38′	(14 h)	23	82	E	MD	(b)	02085
35	21 Jun 74	91	17°20′	114°23′	30 Jun 74	18°09′	115°17′	9	71	314	NW	MD	(b)	02691
36	21 Jun 74	91	17°20′	114°23′	1 Jul 74	18°19′	114°23′	10	39	356	N	MD	(b)	02694
37	22 Jun 74	91	18°27′	113°19′	13 Dec 74	20°07′	112°15′	174	117	31	NNE	MD	(b)	02032
38	22 Jun 74	91	18°27′	113°91′	20 Apr 75	17°23′	114°09′	302	80	217	SW	MD	(b)	02037
39	22 Jun 74	91	18°20′	113°17′	1 Jul 74	18°19′	114°23′	9	63	269	W	MD	(b)	02042
40	22 Jun 74	91	18°20′	113°17′	—	—	—	—	—	—	—	MD	(b)	02047
41	22 Jun 74	91	17°57′	113°38′	25 Jun 74	17°10′	115°00′	3	91	239	WSW	MD	(b)	02071
42	23 Jun 74	91	18°00′	113°00′	24 Jun 74	17°53′	113°06′	(14 h)	9	219	SW	MD	(a)	00395
43	23 Jun 74	91	18°00′	113°00′	15 Apr 75	18°17′	113°36′	296	38	297	WNW	MD	(a)	00398
44	23 Jun 74	91	18°00′	113°00′	8 Aug 74	18°12′	114°45′	46	101	277	W	MD	(b)	02029
45	26 Jun 74	91	17°50′	116°00′	20 Apr 75	17°23′	114°09′	298	109	104	ESE	MD	(a)	00376
46	28 Jun 74	91	17°45′	115°00′	3 May 75	18°12′	114°20′	315	47	55	NE	MD	(a)	00667
47	28 Jun 74	91	17°45′	115°00′	30 Jun 74	18°09′	115°49′	(45 h)	52	297	WNW	MD	(a)	01037
48	28 Jun 74	91	17°45′	115°00′	29 Jun 74	17°57′	115°22′	(18 h)	24	300	WNW	MD	(a)	01039
49	29 Jun 74	91	18°07′	115°08′	5 Aug 74	19°08′	116°00′	37	70	330	NNW	MD	(a)	01016
50	29 Jun 74	91	17°57′	115°22′	30 Jun 74	18°09′	115°49′	(25 h)	28	295	WNW	MD	(a)	01056
51	30 Jun 74	91	18°09′	115°49′	5 Aug 74	18°05′	114°10′	36	94	92	E	MD	(a)	01023
52	30 Jun 74	91	18°09′	115°49′	5 Aug 74	19°08′	116°00′	36	60	350	N	MD	(a)	01028
53	1 Jul 74	91	18°19′	114°23′	2 Jul 74	18°35′	114°40′	(17 h)	23	315	NW	MD	(a)	01043
54	1 Jul 74	91	18°19′	114°23′	2 Jul 74	18°35′	114°40′	(17 h)	23	315	NW	MD	(a)	01050
55	1 Jul 74	91	18°19′	114°23′	2 Jul 74	18°35′	114°40′	(17 h)	23	315	NW	MD	(a)	01093
56	1 Jul 74	91	18°19′	114°23′	2 Jul 74	18°35′	114°40′	(17 h)	23	315	NW	MD	(a)	01094
57	1 Jul 74	91	17°58′	114°36′	4 Aug 74	19°00′	114°26′	34	63	9	N	MD	(a)	01077
58	1 Jul 74	91	17°58′	114°36′	4 Aug 74	19°00′	114°26′	34	63	9	N	MD	(a)	01084
59	1 Jul 74	91	17°58′	114°36′	7 Jul 74	16°50′	114°15′	6	71	164	SSE	MD	(a)	01079
60	2 Jul 74	91	18°35′	114°40′	5 Jul 74	18°18′	114°12′	3	32	123	ESE	MD	(a)	01069
61	2 Jul 74	91	18°12′	114°26′	4 Aug 74	19°00′	114°23′	33	48	3	N	MD	(b)	02013
62	2 Jul 74	91	18°12′	114°23′	3 Aug 74	19°20′	113°25′	32	87	39	NE	MD	(b)	02018
63	5 Jul 74	91	18°23′	114°46′	9 May 75	18°12′	114°20′	308	27	114	ESE	MD	(b)	02060
64	5 Jul 74	91	18°18′	114°12′	20 Apr 75	17°23′	114°09′	289	55	117	S	MD	(b)	02117
65	5 Jul 74	91	18°18′	114°12′	3 Aug 74	19°20′	113°25′	29	76	36	NE	MD	(b)	02118
66	31 Jul 74	91	18°28′	111°00′	16 Nov 74	20°05′	109°39′	108	124	38	NE	MD	(b)	02534
67	1 Aug 74	91	19°40′	110°12′	24 Mar 75	16°00′	109°40′	235	222	172	S	MD	(b)	02745

Table 4.—Continued.

	Release				Recapture			Days at liberty (or h)	Minimum distance traveled (n.mi.)	Direction net movement		Tag type	Tag number
	Date	Cruise number	Position lat. N	Position long. W	Date	Position lat. N	Position long. W			°T	bearing		
68	3 Aug 74	91	19°20′	113°25′	20 Apr 75	17°23′	114°09′	259	124	200	SSW	MD (b)	02618
69	4 Aug 74	91	19°00′	114°26′	14 Apr 75	17°07′	113°33′	252	123	156	SSE	MD (b)	02622
70	4 Aug 74	91	19°00′	114°26′	20 Apr 75	17°23′	114°09′	258	98	171	S	MD (b)	02646
71	8 Aug 74	91	18°12′	114°45′	22 May 75	17°20′	114°55′	287	53	190	S	MD (b)	02152
72	9 Aug 74	91	18°40′	113°55′	10 Apr 75	17°10′	114°15′	244	92	192	SSW	MD (b)	02155
73	17 Aug 74	91	11°15′	109°05′	18 Aug 75	11°34′	108°16′	(19 h)	52	68	ENE	MD (b)	02275
74	17 Aug 74	91	10°54′	109°13′	18 Aug 75	11°34′	108°16′	(25 h)	71	52	NE	MD (b)	02784
75	17 Aug 74	91	10°54′	109°13′	17 Aug 75	11°15′	109°05′	(5 h)	22	20	NNE	MD (b)	02786
76	17 Aug 74	91	10°54′	109°13′	17 Aug 75	11°15′	109°05′	(5 h)	22	20	NNE	MD (b)	02792
77	17 Aug 74	91	10°54′	109°13′	17 Aug 75	11°15′	109°05′	(5 h)	22	20	NNE	MD (b)	02799
78	7 Jan 75	99	20°14′	110°32′	13 Jan 75	19°35′	110°20′	6	41	164	SSE	MD (a)	01321
79	21 Jan 75	100	13°35′	100°35′	30 Mar 75	12°59′	103°00′	68	146	256	WSW	MD (d)	04509
80	30 Jan 75	102	14°47′	99°09′	3 May 75	15°31′	109°00′	93	572	276	W	MD (d)	04227
81	31 Jan 75	112	13°08′	91°50′	1 Feb 75	13°12′	91°38′	(16 h)	12	71	ENE	MD (d)	04366
82	31 Jan 75	112	13°08′	91°50′	1 Feb 75	13°12′	91°38′	(16 h)	12	71	ENE	MD (d)	04391
83	31 Jan 75	112	13°08′	91°50′	18 Feb 75	12°23′	91°38′	18	47	165	SSE	MD (d)	04377
84	18 Feb 75	112	9°25′	95°15′	5 Aug 75	9°13′	99°18′	168	240	267	W	MD (d)	04389
85	19 Feb 75	113	9°20′	95°43′	21 Feb 75	9°08′	96°55′	2	72	261	W	MD (d)	04407
86	21 Feb 75	113	9°01′	97°57′	23 Feb 75	8°32′	98°28′	2	42	227	SW	MD (d)	04413
87	21 Feb 75	113	9°01′	97°57′	23 Feb 75	8°32′	98°28′	2	42	227	SW	MD (d)	04414
88	22 Feb 75	119	12°10′	92°10′	2 Mar 75	12°48′	92°37′	8	46	325	NW	MD (d)	04963
89	14 Apr 75	121	17°07′	113°33′	21 Apr 75	17°29′	114°11′	7	42	301	NNW	MD (d)	04264
90	14 Apr 75	121	17°07′	113°33′	21 Apr 75	17°29′	114°11′	14	54	152	WNW	MD (d)	04266
91	21 Apr 75	105	14°48′	109°15′	5 May 75	14°00′	108°49′	14	54	152	SSE	MD (d)	04467
92	21 Apr 75	105	14°48′	109°15′	5 May 75	14°00′	108°49′	14	54	152	SSE	MD (d)	04468
93	24 Oct 76	208	9°33′	104°46′	26 Oct 76	9°11′	105°01′	(15 h)	26	214	SW	MD[1] —	05194
94	25 Oct 76	208	9°33′	104°46′	26 Oct 76	9°11′	105°01′	(15 h)	26	214	SW	MD[1] —	05200
95	25 Oct 76	208	9°33′	104°46′	26 Oct 76	9°11′	105°01′	(15 h)	26	214	SW	MD[1] —	05217
96	25 Oct 76	208	9°33′	104°46′	26 Oct 76	9°11′	105°01′	(15 h)	26	214	SW	RX —	—
97	25 Oct 76	208	9°33′	104°46′	26 Oct 76	9°11′	105°01′	(15 h)	26	214	SW	RX —	—

[1]With braided tubing.

Table 5.—Tag return data for spinner dolphin, *Stenella longirostris*, 1969-76. Tag type codes defined in text.

	Release				Recapture			Days at liberty (or h)	Minimum distance traveled (n.mi.)	Direction of net movement		Tag type	Tag number
	Date	Cruise number	Position lat. N	Position long. W	Date	Position lat. N	Position long. W			°T	bearing		
1	18 Aug 70	26	10°47′	127°48′	17 Sep 71	11°17′	123°09′	395	275	83	E	PD (a)	A6242
2	23 Nov 71	13	13°20′	108°00′	8 Jan 74	11°44′	105°32′	776	172	124	SE	MD (a)	01116
3	8 Dec 71	13	10°15′	104°32′	28 Feb 72	11°01′	101°15′	82	199	76	ENE	MD (a)	00741
4	8 Dec 71	13	10°15′	104°32′	28 Feb 72	11°01′	101°15′	82	199	76	ENE	MD (a)	00016
5	10 Jan 72	16	9°04′	105°01′	6 Feb 72	9°35′	108°10′	37	189	280	W	MD (a)	00413
6	31 Jan 75	112	13°08′	91°50′	1 Feb 75	13°12′	91°38′	(16 h)	12	71	ENE	MD (d)	04363
7	13 Apr 75	105	6°38′	93°21′	16 Apr 75	6°54′	94°43′	3	83	281	W	MD (d)	04464

Table 6.—Net distance traveled and net travel rates for radiotrack segments <50 h long.

Track segment (Fig. 4)	Duration (h)	Minimum distance (n.mi.)	N.mi. h	N.mi. day
1-2 (set)	16	59	3.7	89
2-3 (set)	24	28	1.2	29
3-4 (set)	24	69	2.9	70
4-5	22	75	3.4	82
1-3 (set)	40	70	1.8	43
2-4 (set)	48	80	1.7	41
3-5	46	10	0.2	5
6-7 (chase)	19	60	3.2	77
Average	—	—	2.3	54

400-day returns (15), the logged take of yellowfin tuna[5] within a radius of 250 n.mi. and a radius of 250 to 600 n.mi. during the period after 50 days following release and before capture, or after 200 days and before recapture, respectively (Table 7) (catch of yellowfin tuna is the closest correlate of actual tag recapture effort (i.e., number of dolphins captured) for which data of sufficient geographical and temporal precision are available). For both groups of tag returns, the catch of yellowfin tuna in each instance was greater in the 250- to 600-

[5]Unpublished data furnished by J. Joseph, Inter-American Tropical Tuna Commission, P.O. Box 271, La Jolla, CA 92038.

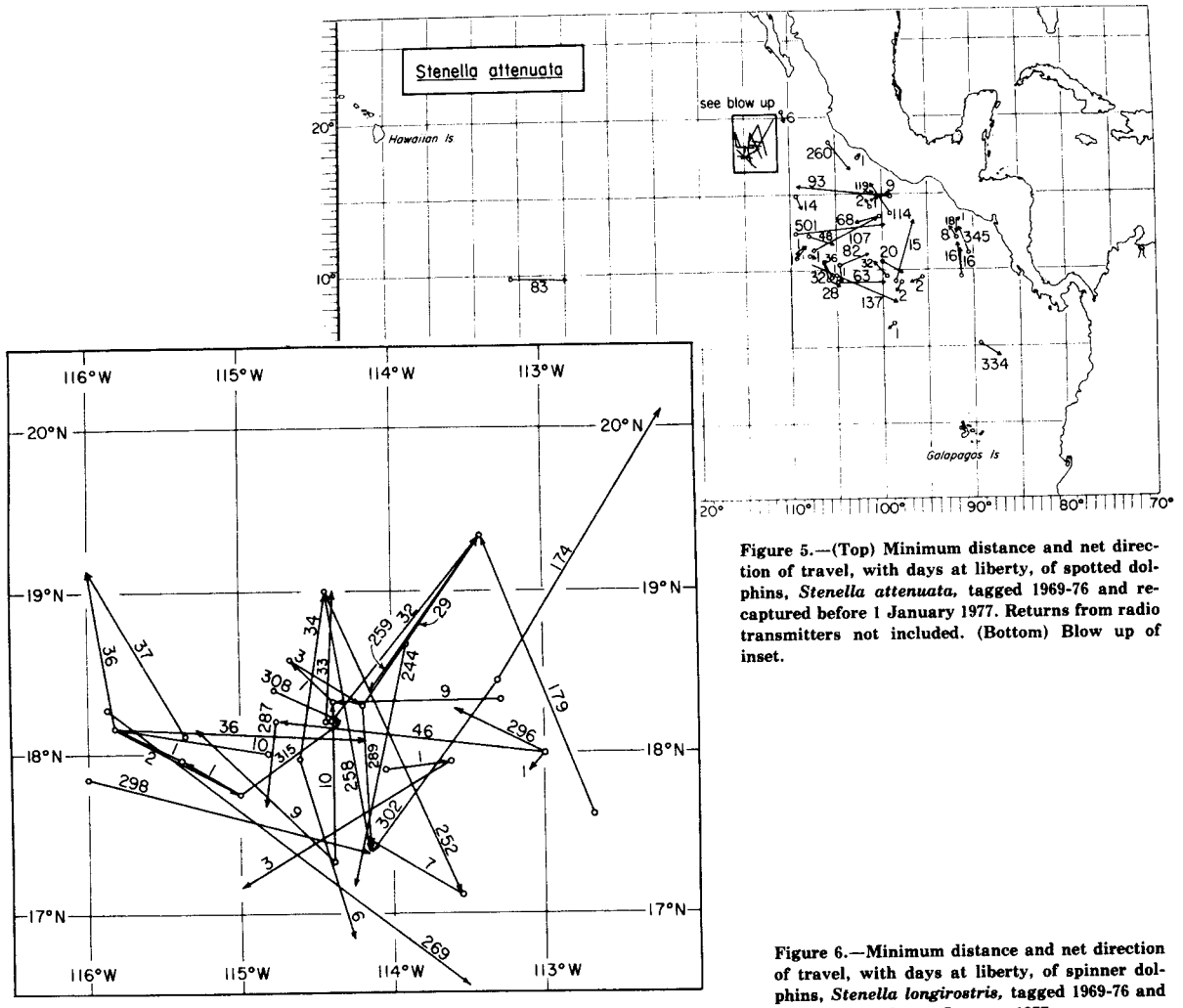
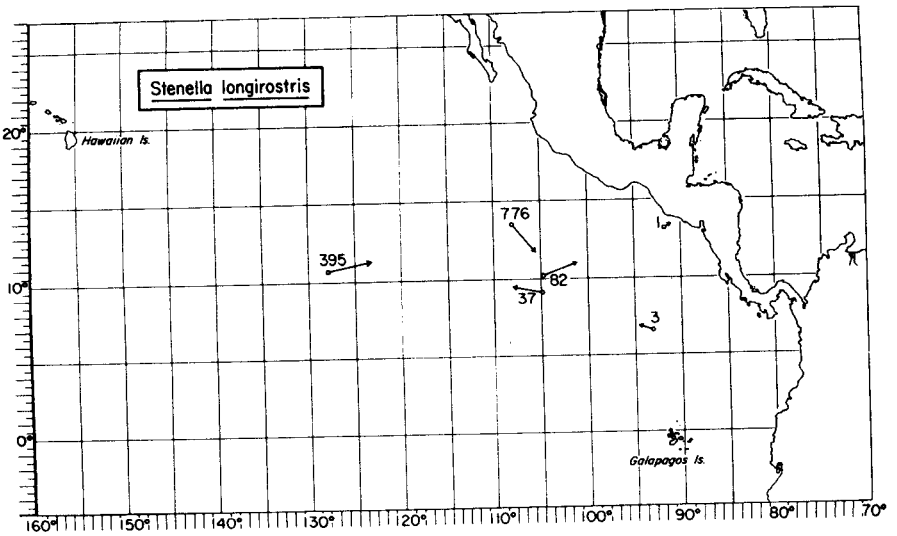


Figure 5.—(Top) Minimum distance and net direction of travel, with days at liberty, of spotted dolphins, *Stenella attenuata*, tagged 1969-76 and recaptured before 1 January 1977. Returns from radio transmitters not included. (Bottom) Blow up of inset.

Figure 6.—Minimum distance and net direction of travel, with days at liberty, of spinner dolphins, *Stenella longirostris*, tagged 1969-76 and recaptured before 1 January 1977.



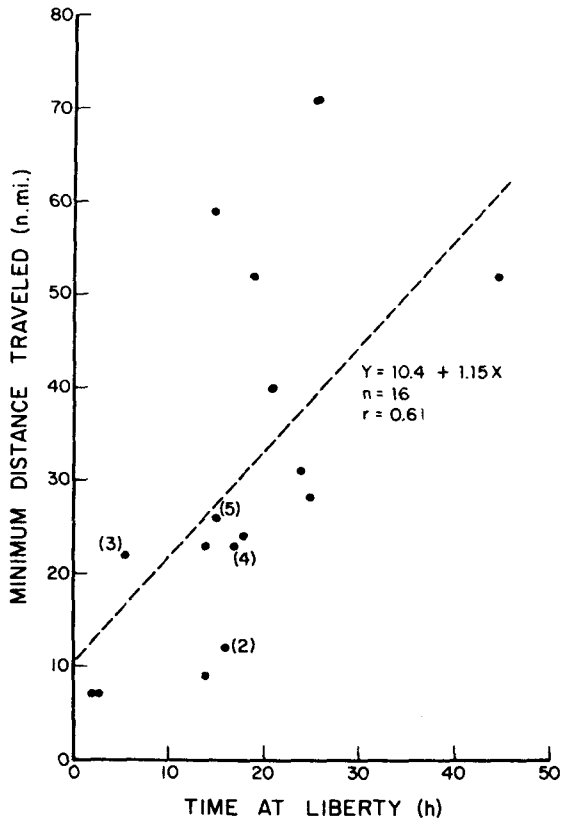


Figure 7.—Movement of tagged spotted dolphins, *Stenella attenuata*, recaptured within 48 h of release. When more than one dolphin was tagged and recovered from the same school at the same time, the number is indicated in parentheses. Dashed line is linear regression line fitted to unweighted data points.

n.mi. area than in the 250-n.mi. area. This result shows that the pattern in Figure 8 of apparent annual migration or dispersal of at least some of the tagged animals is real and not an artifact of the distribution of recapture effort.

The net direction of movements of <300 n.mi. was essentially random, but movements >300 n.mi. had a very strong east-west component (Fig. 9). This apparent predominance of longitudinal movement in long-distance returns is probably not due to chance. If it is assumed that the distribution of deviations in Figure 8 would be random, given that neither longitudinal nor latitudinal movement predominate, the probability that all seven of the over 300 n.mi. net movements would have deviations of <20° is described by a binomial probability distribution. If $n = 7$ and $P = 90$, then the probability is 2.6×10^{-5}. The data, therefore, show that, if seasonal migration or dispersal does indeed exist, it is primarily onshore-offshore. The time-of-year data for the few tag returns indicating movements >300 n.mi. indicate that movement may be generally onshore (E) in fall and winter and offshore (W) in late spring and summer

Table 7.—Estimated catch of yellowfin tuna within 250 n.mi. and within 250-600 n.mi. of point of tag release for 12 tagged dolphins recovered between 50 and 200 days after release and traveling up to 582 mi (average 174 mi) and 15 tagged dolphins recovered between 200 and 400 days after release and traveling <223 mi (average 93 mi). Catches for the first group are between 50 days after release and before recapture and for the second group between 200 days and recapture.

Tag returns		Estimated yellowfin tuna catch: Within 250 n.mi. (short tons)	Within 250-600 n.mi. (short tons)
Group 1			
(50-200 days):	1.	886	14,041
	2.	9,363	25,908
	3.	4,858	35,508
	4.	4,728	30,119
	5.	76	657
	6.	2,065	11,906
	7.	2,365	4,562
	8.	745	1,529
	9.	516	1,501
	10.	1,202	7,885
	11.	1,436	4,497
	12.	4,737	6,605
Group 2			
(200-400 days):	1.	5,108	6,224
	2.	2,396	26,142
	3.	470	6,325
	4.	4,656	14,737
	5.	4,523	16,180
	6.	3,277	12,389
	7.	3,893	14,452
	8.	3,893	13,126
	9.	4,485	13,573
	10.	1,955	3,177
	11.	3,051	6,746
	12.	952	3,611
	13.	3,214	6,377
	14.	5,390	13,312
	15.	759	3,944

Table 8.—Time of year at liberty and net direction of movement for seven tagged spotted dolphins, *Stenella attenuata*, traveling more than 300 n.mi. before recapture.

At liberty	Net movement: Direction	Distance (n.mi.)
1. Jan-May	W	572
2. Aug-Feb	E	568
3. Sept	E	390
4. Nov-Mar	ENE	435
5. Nov-Apr	ESE	582
6.[1] Dec-Feb	E	363

[1]Two dolphins.

(Table 8). This hypothesis must be considered as highly tentative, however, pending availability of more data.

In summary, home range at any particular season is roughly circular, on the order of 200 to 300 n.mi. in diameter, and may move seasonally several hundred miles onshore (possibly in fall and winter) and offshore (possibly in spring and summer). Average short-term net movement is on the order of 30 to 50 n.mi./day.

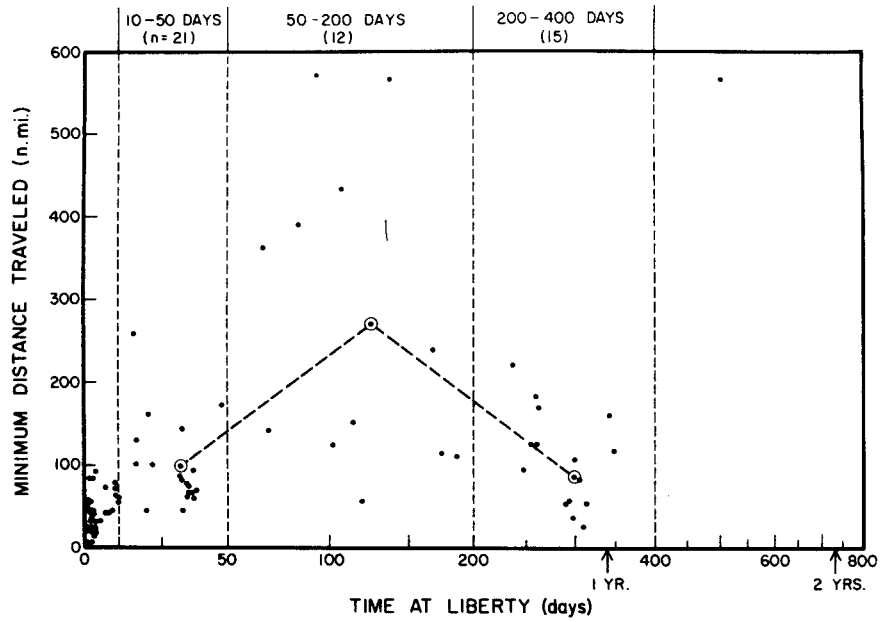


Figure 8.—Plot of minimum distance traveled on time at liberty (logarithmic scale) for tagged and recaptured spotted dolphins, *Stenella attenuata*. Circled means are for 10- to 50-, 50- to 200-, and 200- to 400- day returns.

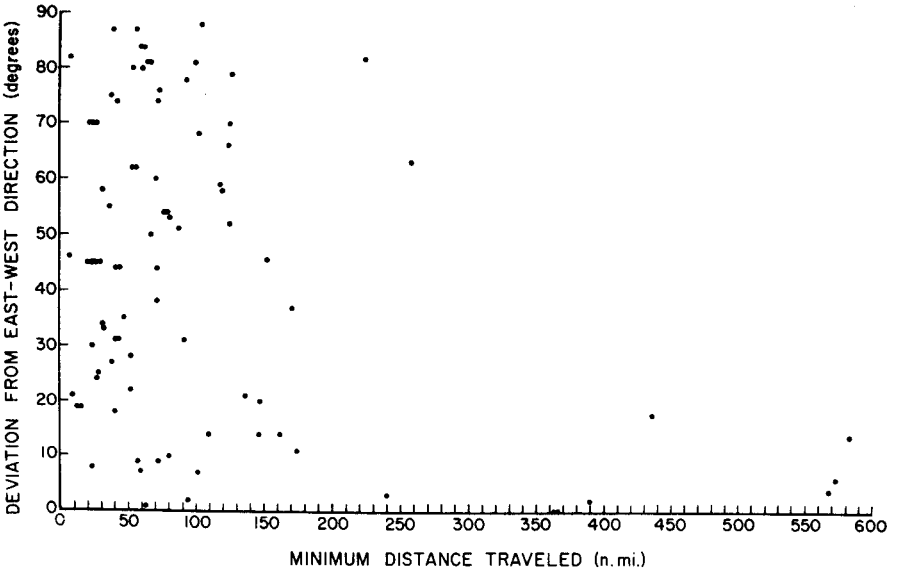


Figure 9.—Deviation from E-W direction of net movement plotted on minimum distance traveled for tagged and recaptured spotted dolphins, *Stenella attenuata*.

ACKNOWLEDGMENTS

We thank the hundreds of people (scientists, technicians, crew members, and vessel owners and operators) who helped get the tags out and the recoveries in. Some are mentioned in the text; others (including the many "tunaboat observers" who released the tags listed in Appendix 2) are not. We thank W. H. Bayliff who proposed the initial design of the tagging shute. We also thank J. G. Jennings, J. M. Coe, T. Quinn, V. I. Gallucci, R. L. Brownell, Jr., and W. H. Bayliff, for criticizing the manuscript. Unpublished data were furnished by the Inter-American Tropical Tuna Commission through the courtesy of C. J. Orange. R. Butler and N. K. Wiley provided invaluable assistance with data processing.

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