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SHARKS, SKATES, AND RAYS

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THE JOHNS HOPKINS PRESS,
BALTIMORE, MARYLAND

Published in cooperation with the
American Institute of Biological Sciences
1967

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SHARK TAGGING IN THE EASTERN PACIFIC OCEAN, 1962–65

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This paper provides data on the movements and growth of several species of sharks from the eastern tropical Pacific Ocean and on the suitability of various types of tags. The data came from recaptures of sharks tagged by the Bureau of Commercial Fisheries Tuna Resources Laboratory, La Jolla, California, during 1962–65. Tagging was greatest in 1964, when the work was supported by a grant from the Office of Naval Research to the American Institute of Biological Sciences. Work under this grant was conducted jointly by the Bureau of Commercial Fisheries Tuna Resources Laboratory and the Instituto Nacional de Investigaciones Biologico-Pesqueras, Mexico.

Because only a year has elapsed since the majority of sharks were tagged, only preliminary data are presented.

Species and Study Areas

Sharks from three different habitats were tagged: offshore, from California to Peru; coastal, within and near the Gulf of California; and insular, at the Revillagigedo Islands. The species tagged and references which give their descriptions are listed in Table 6–1.

Five major shark-fishing centers, San Jose del Cabo, Mazatlan, Isla Maria Madre, Isla Isabela, and San Blas, are within or closely adjacent to the coastal tagging area. Sharks are fished by longline, handline, gillnet, and beach seine; shrimp trawlers also contribute to the catch. These sharks are used principally as bacalao (salted and dried flesh), although some

This work was supported by contract Nonr 4526(01) NR 104-832. We are indebted to Stewart Springer for his valuable advice, support, and encouragement. John Prescott and the late David Davies helped in preliminary studies on the suitability of different tags. The owners and captains of American and Mexican vessels allowed us to tag sharks during fishing cruises. Lee Palm permitted us to accompany one of his regular sport-fishing trips to Socorro Island on *Red Rooster*. He and the crew of the vessel have been of continuing aid throughout the study. Almirante Antonio Vasquez del Mercado, former Director of the Mexican Direccion General de Pesca, and Rodolfo Ramirez, Mauro Cardenas, and Hector Chapa aided by committing their agencies to cooperate in the study. Adolfo Torres May and Victor Tejeda of the government's shark-processing plant at Isla Maria Madre provided valuable information, as did Hector Ferreira. Advertisement of the tagging program was aided by members of the Inter-American Tropical Tuna Commission and California Department of Fish and Game.

TABLE 6-1. Species of sharks tagged.

Species	Reference
1. *Alopias vulpinus*	Bigelow and Schroeder, 1948
2. *Carcharhinus albimarginatus*[2]	Garrick and Schultz, 1963
3. *C. altimus*	Kato, 1964
4. *C. falciformis*[2]	Garrick et al., 1964
5. *C. galapagensis*	Rosenblatt and Baldwin, 1958
6. *C. limbatus*	Rosenblatt and Baldwin, 1958
7. *C. longimanus*	Bigelow and Schroeder, 1948
8. *C. porosus*	Rosenblatt and Baldwin, 1958
9. *C. velox*	Rosenblatt and Baldwin, 1958
10. *Prionace glauca*	Bigelow and Schroeder, 1948
11. *Rhizoprionodon longurio*	Springer, 1964
12. "Cazon" (=*R. longurio?*)	
13. *Ginglymostoma cirratum*	Bigelow and Schroeder, 1948
14. *Mustelus* sp.	
15. *Sphyrna lewini*	Garrick and Schultz, 1963
16. *S. zygaena*	Garrick and Schultz, 1963

[2] According to J. A. F. Garrick (personal communication) *C. albimarginatus* and *C. falciformis* are conspecific with *C. platyrhynchus* and *C. malpeloensis*, respectively.

small ones are sold fresh. The hides, livers, and fins of most large sharks are also sold. At least 19 species of sharks are found in this area (Kato, 1965), but the most common are *Carcharhinus limbatus*, *C. porosus*, *Rhizoprionodon longurio*, several species of *Sphyrna*, and one or two species of *Mustelus*. The ocean near the continental shore has a gently sloping mud bottom.

The insular tagging areas included Socorro Island and San Benedicto Island of the Revillagigedo Islands. The two islands are located about 250 miles south of the tip of Baja California. Unlike the nearly flat bottom of the Mexican coast, the sea floor around the islands is composed of volcanic rock and coral, with steep slopes, seamounts, and shallow banks. At least eight species of large sharks occur near the islands, but the dominant forms are juveniles of *Carcharhinus albimarginatus* and *C. galapagensis*. Fishing at the islands is limited to sailors stationed on Socorro Island, a few itinerant fishermen from the Mexican mainland, and United States tuna fishermen. Exploratory fishing vessels of the Mexican government and an American sport-fishing vessel, *Red Rooster*, also fish infrequently at the islands.

A third island in this group, Roca Partida, lies 65 miles west of Socorro Island. Since its shark fauna is different from that of the other islands, however, it is included in the offshore area.

The offshore area includes all offshore waters between southern California and Peru in addition to Roca Partida. The area coincides with fishing grounds for skipjack, *Katsuwonus pelamis*, and yellowfin, *Thunnus albacares*, tuna in the eastern Pacific; most sharks were tagged on United

States purse seine vessels. Although several sharks are caught by these vessels, *Carcharhinus falciformis* is by far the dominant species occurring with tuna (Kato, 1964). Returns of sharks tagged offshore are expected from American and Mexican tuna vessels, Japanese longline vessels, and a high-seas longline shark fishery of the Tres Marias Islands.

Materials and Methods

Tagging was conducted from tuna purse seine vessels, shrimp trawlers, sport-fishing vessels, and research vessels (Table 6–2). Shark tagging was not the principal objective of most of the cruises but was incidental to other operations. On the other hand, the sole objective of the cruises of the *Yaqui Queen* and *Red Rooster* in 1964 was to tag sharks. The gear and methods used during these cruises are described below.

Sharks were caught principally with handlines and rod and reel on small barbless hooks. Anchored setlines with barbed hooks buoyed off the bottom also had some success. Small sharks were lifted aboard with a dipnet and placed on a foam-rubber cushion, where they were tagged and measured. Large sharks were landed by a brail 5 feet (1.5 m) in diameter, in conjunction with an electric hoist mounted on an overhead monorail. The

Table 6–2. Summary of data on shark tagging, eastern Pacific Ocean, 1962–65.

Tagging date	Cruise	Locality	Tag type	No. tagged	Method of capture
1962					
1. March	*Royal Pacific*	Guatemala; Colombia	Strap	69	Purse seine
2. April	*Royal Pacific*	Nicaragua	Strap	3	Purse seine
3. July	*Royal Pacific*	Ecuador	Strap	1	Purse seine
4. August	*West Point*	Revillagigedo Islands	Strap	90	Purse seine, handline
1963					
5. January	*Royal Pacific*	Peru; Colombia	Strap	19	Purse seine
6. August	*Elsie A.*	Central Baja California	Strap Dart	8	Purse seine
1964					
7. July	*Yaqui Queen* (chartered)	Revillagigedo Islands	Strap Petersen Dart	47	Handline, longline
8. November	*Cerralro*	Mexican coast (Altamura)	Strap Petersen	2	Shrimp trawl
9. November	*Red Rooster* (chartered)	Mexican coast (Altata to San Blas); Revillagigedo Islands	Strap Rototag Petersen Dart	545	Handline, longline, rod and reel
1965					
10. May	*Red Rooster*	Socorro Island; Cape San Lucas	Strap Rototag	60	Handline, rod and reel
11. May	Shrimp trawler	Mexican coast (Altata)	Strap	2	Trawl
12. June	*Scofield* (research vessel)	Southern California	Strap	4	Handline
13. July	*Elsinore*	Ecuador	Strap	5	Purse seine
14. August	*Independence*	Ecuador	Strap	5	Purse seine

shark was retained in the net on deck during tagging. Body length (tip of snout to precaudal pit or base of caudal) and total length were measured with a metal tape rule while the head was held immobile with the aid of the iron rim of the brail and the tail was forcibly straightened.

A tag was needed which was conspicuous, would be retained by the shark for long periods with minimum effect on the health and behavior of the shark, and would withstand extended periods in sea water. Four different tags were used to learn which were suitable for tagging sharks (Table 6–3; Fig. 6–1).

In 1962 we used colored discs with strap tags to improve the visibility of the tags; we discontinued their use, however, when we learned that they were quickly shed.

Rototags, strap tags, and Petersen tags were usually attached on the first dorsal fin. Most tags were applied in pairs, consisting of a Petersen tag and either a strap tag or a Rototag. A few Rototags were paired with strap tags. A dart tag was attached to the back of a few large sharks as a third or fourth tag.

A tetracycline antibiotic salve was applied to the tagging wound.

Numbers, Sizes, and Sex Ratios of Sharks Tagged

A total of 860 sharks of 15 species were tagged (Table 6–4). The 1964 cruises of *Yaqui Queen* and *Red Rooster* accounted for 592 (69 percent) of the total. The localities of tagging extended from southern California to northern Peru (Fig. 6–2).

TABLE 6–3. Description of tags used.

Tag	Material	Size	Color	Lettering	Supplier
Petersen disc[a]	Laminated plastic	1-in diameter	Red with black lettering	One disc: DEVUELVA ESTA MARCA A LA OFICINA DE PESCA ANOTE FECHA Y LUGAR DE CAPTURA RECOMPENSA 15 PESOS Other disc: RETURN TO BUR. COMM. FISHERIES BOX 6317 SAN DIEGO 6	Floy Tag and Manufacturing, Inc.
Jumbo Rototag	Plastic	¾ x 1¾ in; shaft on male half ¼-in diameter	Yellow with black lettering	Male half: DEVUELVA OF. DE PESCA PREMIO 15 PESOS BU COM FISH SAN DIEGO Female half: None	Oberarch Patents (England)
Strap (cattle size ear tag)	Monel metal	⅜ x 1⅝ in; inside space ⅜ in	Metallic	Female side: DEVUELVA OF. DE PESCA CON FECHA Y LUGAR DE CAPTURA. 15 PESOS Male side: RETURN BUR COMM. FISH SAN DIEGO	National Band & Tag Company
Dart	Resinite tubing with hard nylon dart	⅛-in diameter; ½-in long	Yellow with black lettering	RETURN TAG TO AIBS SHARK RESEARCH 2000 P ST. N.W. WASH. D.C. 20036 U.S.A.	Floy Tag and Manufacturing, Inc.

[a] Flat head stainless steel needles (1.5 inches long x 0.035-inch diameter) used with Petersen tags were supplied by John Hassall, Inc.

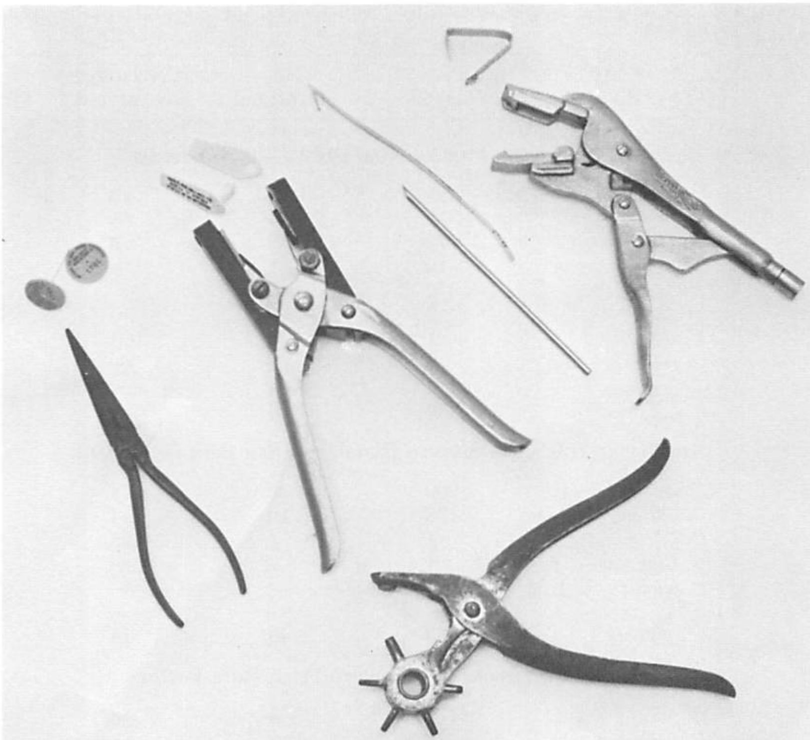

Fig. 6–1 Tags and applicators. *Top, left* to *right:* Petersen disc tag and needle-nose pliers; Jumbo Rototag and applicator; dart tag and applicator; Monel metal strap tag and applicator. *Lower right:* leather punch for use with Rototag.

Two or more tags were applied on 506 sharks (Table 6–5). Most of these (499) were tagged near the Mexican coast or at Socorro Island in 1964.

Some species of sharks in our catch appeared to be sexually segregated at particular times or localities (Table 6–6). Along the Mexican coast, we caught more male than female *Sphyrna lewini* and *Rhizoprionodon longurio;* on one occasion, 40 male *Rhizoprionodon longurio* were captured without a single female. At Socorro Island during one cruise, we caught more female than male *Carcharhinus albimarginatus,* but males outnumbered female *C. galapagensis.* The numbers of males and females were about equal in *C. limbatus, C. porosus,* and *C. falciformis.*

Our fishing methods and choice of fishing areas tended to select smaller individuals (Fig. 6–3). Except for *R. longurio,* no differences in size between sexes were evident; consequently, lengths for both sexes were combined.

TABLE 6-4. Number of sharks tagged by localities and species, and number and percentage recovered.

Species	No. tagged	No. recaptured	Percentage recaptured
Mexican coast: Altata to San Blas; Cabo San Lucas			
C. limbatus	155	19	12
C. porosus	77	6	8
R. longurio	73	2	3
S. lewini	19	1	5
Mustelus sp.	2	—	—
"Cazon"	2	1	50
G. cirratum	1	1	100
C. velox	1	—	—
Total	330	30	9
Revillagigedo Islands: Socorro Island, and San Benedicto Island			
C. galapagensis	209	29	14
C. albimarginatus	138	19	14
C. falciformis	4	1	25
C. limbatus	1	—	—
S. lewini	1	—	—
Total	353	49	14
Offshore: Southern California to Peru; Roca Partida			
C. falciformis	119	4	3
C. limbatus	28	—	—
C. galapagensis	6	—	—
P. glauca	5	—	—
S. lewini	5	—	—
S. zygaena	4	—	—
C. altimus	4	—	—
C. longimanus	3	—	—
A. vulpinus	2	—	—
C. albimarginatus	1	—	—
Total	177	4	2
Grand Total	860	83	10

The length distributions of *C. limbatus* (range 56–88 cm; mean 66) and *C. porosus* (range 48–89 cm; mean 64) were similar; each had a single exaggerated peak which probably represented a single age group. *C. limbatus,* the larger species, attains a body length of about 190 cm; *C. porosus* grows to about 110 cm. Three distinct modes were present in the length distribution of *R. longurio,* a small species with a maximum body length of about 90 cm. The sharks tagged ranged from 35 to 82 cm (mean 64 cm). The smaller-size groups included young males and females, but all sharks in the largest-size group were adult males.

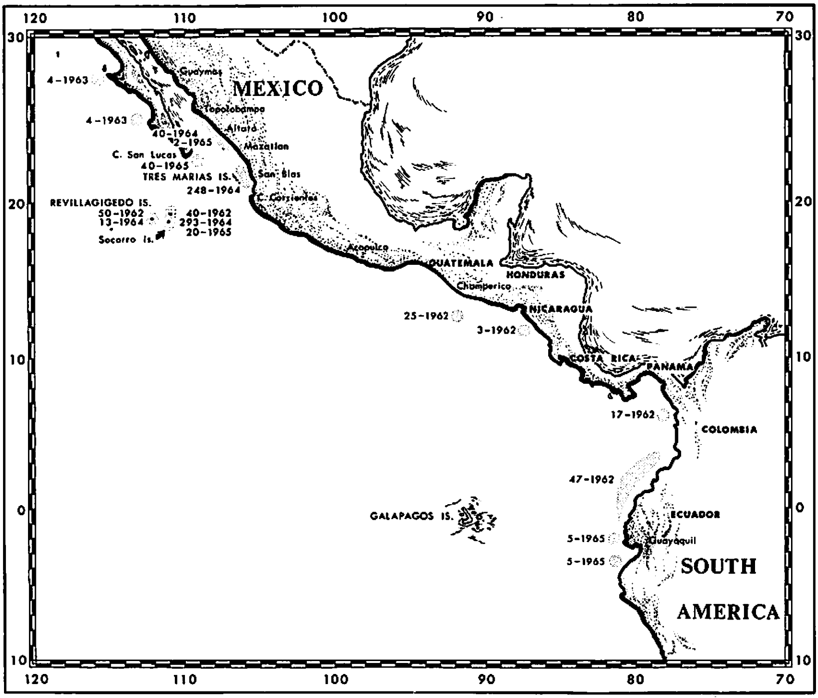

Fig. 6–2 Tagging localities (*shaded*), number of sharks tagged, and year of tagging.

Unlike the coastal sharks, both *C. albimarginatus* and *C. galapagensis*, which were tagged at the Revillagigedo Islands, lacked well-defined modes in their length distributions. The range for *C. albimarginatus* was 54 to 163 cm (mean 69 cm), and, for *C. galapagensis*, it was 44 to 136 cm (mean 79 cm). The former grows to about 225 cm in body length, and the latter may attain a length of about 250 cm. Umbilical scars were plainly visible on the smallest individuals of both species.

Measurements of 12 *C. falciformis* ranged from 140 to 165 cm (mean 152 cm). Most unmeasured ones had similar lengths. This species grows to a body length of about 190 cm.

Recoveries

By January, 1966, 83 (10 percent) of the 860 tagged sharks had been recaptured (Table 6–4). Tagged sharks were recaptured by shark, tuna, shrimp, and sport fishermen from Mexico, exploratory fishing vessels of the Mexican Government, a Japanese longline fisherman, and United States sport fishermen and commercial tuna fishermen.

TABLE 6–5. Types and numbers of tags used in different localities.

Tag types and combinations	Tagging locality: Mexican coast	Revilla-gigedo Islands	Offshore	Totals
Single tags				
Petersen	33	11	—	44
Strap	28	53	159	240
Rototag	51	19	—	70
Double tags				
Petersen, strap	110	138	4	252
Petersen, Rototag	106	87	—	193
Strap, Rototag	1	9	—	10
Strap, dart	—	—	5	5
Triple tags				
Petersen, strap, dart	1	6	2	9
Petersen, strap, Rototag	—	16	2	18
Petersen, Rototag, dart	—	2	—	2
Quadruple tags				
Petersen, strap, Rototag, dart	—	12	5	17
Totals	330	353	177	860

TABLE 6–6. Number of males and females tagged, and chi-square values testing deviation from a 1:1 sex ratio.

Species	Cruise	No. of males	No. of females	Chi-square[a]	p
C. limbatus	*Red Rooster*, 1964	74	80	0.23	>0.05
C. porosus	*Red Rooster*, 1964	35	39	0.22	>0.05
S. lewini	*Red Rooster*, 1964	14	5	4.26	<0.05
R. longurio	*Red Rooster*, 1964	23	10	5.12	<0.05
R. longurio	*Red Rooster*, 1965	40	—	8000.00	<0.001
C. albimarginatus	*West Point*, 1962	8	8	0	>0.05
C. albimarginatus	*Yaqui Queen*, 1964	4	2	0.66	>0.05
C. albimarginatus	*Red Rooster*, 1964	42	65	4.94	<0.05
C. albimarginatus	*Red Rooster*, 1965	5	5	0	>0.05
C. galapagensis	*West Point*, 1962	13	9	0.73	>0.05
C. galapagensis	*Yaqui Queen*, 1964	15	17	0.12	>0.05
C. galapagensis	*Red Rooster*, 1964	85	57	5.52	<0.05
C. galapagensis	*Red Rooster*, 1965	5	5	0	>0.05
C. falciformis	All cruises	50	61	1.09	>0.05

[a] Snedecor, 1956.

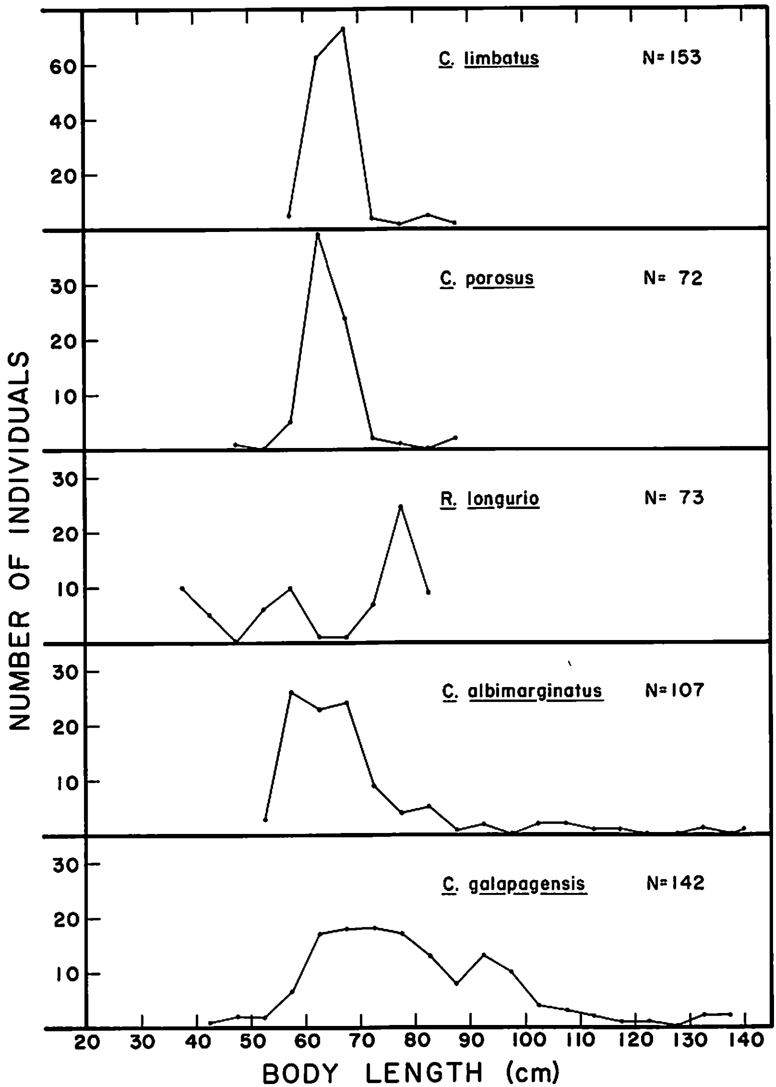

FIG. 6–3 Length-frequency distribution of five species tagged, in 5-cm groups.

Thirty sharks (9 percent of those tagged) were recaptured from the Mexican coast, 49 (14 percent) from the Revillagigedo Islands, and only 4 (2 percent) from the offshore area.

The length of time tagged sharks were at liberty before recapture varied widely for the different tagging localities (Table 6–7). Within the coastal area, the variation was probably due to fluctuations in fishing intensity and movements of sharks away from the fishing grounds. The time at

TABLE 6-7. Number of sharks recaptured after different periods of liberty.

Tagging locality	Months at liberty				
	<1	1–3	3–5	5–7	>7
Mexican coast	3	15	6	4	1
Revillagigedo Islands	1	3	18	17	10
Offshore	1	1	1	1	—

which tagged sharks were recaptured at the Revillagigedo Islands, however, depended primarily upon cruises to this area by Mexican Government fishing vessels, by *Red Rooster*, and by us.

Nearly all sharks tagged at the Revillagigedo Islands were recaptured near the tagging locality (Table 6–8). One *C. galapagensis* tagged at San Benedicto Island, however, traveled 32 miles over deep water to Socorro Island.

Sharks from the coastal and offshore areas, on the other hand, showed considerable movement. Most coastal sharks moved northward from San Blas, where they had been tagged in December. Two *C. limbatus* tagged at Altata in November moved southward, but six tagged at San Blas in December moved northward (Fig. 6–4). One *R. longurio* tagged in May at Cape San Lucas was recaptured 4 months later after it had traveled 600 miles northward on the western side of Baja California.

Four *C. falciformis* were recaptured from the offshore area. Three of them were tagged at Roca Partida; one was recaptured there after 10 weeks, the second traveled 65 miles to Socorro Island where it was recaptured after 4 months, and the third traveled 95 miles to San Benedicto Island in 5 months. The fourth shark was recaptured 50 miles from the tagging locality off Guatemala, 3 or 4 days after it had been tagged.

Most sharks whose life histories have been studied have shown extensive

TABLE 6–8. Number of tagged sharks recovered at different distances from the tagging locality.

Tagging locality, and species	Miles traveled				
	<1	1–5	6–10	11–19	>20
Mexican coast					
C. limbatus	2	1	2	6	8
C. porosus	—	—	1	3	1
R. longurio	2	—	—	—	1
S. lewini	—	—	—	—	1
G. cirratum	—	—	—	—	1
Revillagigedo Islands					
C. albimarginatus	14	5	—	—	—
C. galapagensis	16	7	2	3	1
C. falciformis	—	—	1	—	—
Offshore					
C. falciformis	1	—	—	—	3

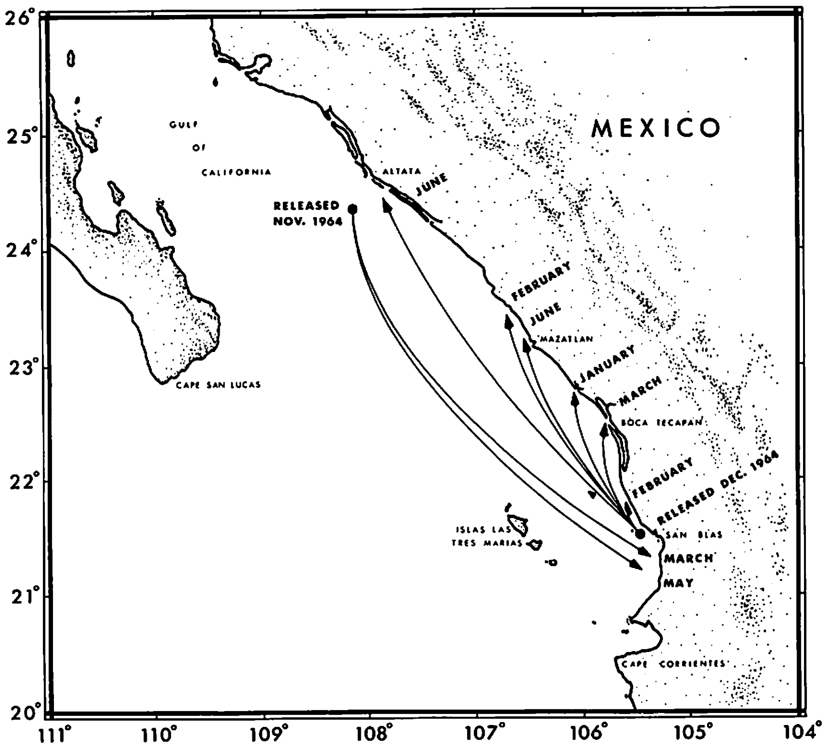

FIG. 6–4 Movements of tagged *C. limbatus.*

movement. This was true not only for inshore species like *G. australis* (Olsen, 1954), *S. acanthias* (Holland, 1957), and *E. milberti* (Springer, 1960) but also for pelagic species, e.g., *Prionace glauca* (Suda, 1953). Movements and distribution of sharks are generally related to reproductive activity, seasonal changes in environmental conditions, or both.

Our tag recoveries indicated that young *C. limbatus*, and possibly *C. porosus*, made seasonal north-south migrations within and near the Gulf of California. Oceanographic conditions within the Gulf of California provide clues to the causes of such movements. At Puerto Penasco, near the head of the Gulf, the sea-surface temperature varies from 14.9C in January to 31.2C in August, a range of 16C (Roden, 1964). At Mazatlan, near the mouth of the Gulf, the temperature varies 9C annually, from 21.1C in February to 30.1C in September (Roden, 1964). Just below Cabo Corrientes, which is located slightly south of San Blas, oceanic conditions are more stable; temperatures change only 5C annually, from 25C to 30C (Renner, 1963). Salinity within the Gulf varies only slightly from Puerto Penasco to Mazatlan and shows little seasonal variation (Roden, 1964). Fluctuations in temperature then are probably the chief factors influencing seasonal movements of sharks within the Gulf. Thus we expect *C. limbatus*, which is generally a warm-water species (Bigelow and Schroeder, 1948), to move southward during winter and northward into the Gulf as the waters warm in late spring.

Large *C. limbatus* are scarce in inshore waters except during late spring and early summer, when there is an influx of pregnant females. Adults are taken regularly by purse seine fishermen on the high seas (although always fairly close to shore) and by the shark fishery at Islas Las Tres Marias; they are apparently present throughout the year near Manzanillo, Mexico, which is south of Cabo Corrientes. The distribution and movements of *C. limbatus* are similar in many respects to those found for *C. milberti*, by Springer (1960).

Unlike the Gulf of California, the Revillagigedo Islands provide a stable oceanic environment; temperatures range from 24C in March to a high of about 28C in August (Renner, 1963). Our tag returns indicated that juveniles of both *C. albimarginatus* and *C. galapagensis* were restricted to the shallow water surrounding the islands. Large sharks of both species were also near shore, but they were rarely found with the juveniles. Adults of *C. albimarginatus* appeared to be more abundant than adults of *C. galapagensis*, at least at Socorro Island. On the other hand, more large *C. galapagensis* than *C. albimarginatus* were taken by purse seines in offshore waters, both near the islands and on the high seas (Kato, 1964).

Although juveniles of the two species seemingly occupied the same ecological niche, close examination of the catch data suggested that *C. albimarginatus* was dominant on parts of the eastern shores of Socorro Island, and *C. galapagensis* was more abundant at all other areas fished.

Growth of Tagged Sharks

The growth rate of both *C. albimarginatus* and *C. galapagensis* was extremely slow (Table 6–9). We recaptured and measured 17 sharks which we had tagged at Socorro Island about 5½ months previously. Measurements of the longer-term recoveries (9½ and 14 months at liberty, Table 6–9) were made by crew members of *Red Rooster* who used our measuring methods. The growth data on male *C. albimarginatus* were inconsistent; four had negative increments and two grew at a faster rate than all other sharks (possibly we made errors in measuring these two sharks). Our data indicated an average annual increment of 31–54 mm for juvenile *C. albimarginatus* and 41 mm for juvenile *C. galapagensis*.

Little is known about the growth rate of large sharks. Three large *Somniosus microcephalus* tagged by Hansen (1963) grew 10 mm in 2 years, 150 mm in 14 years, and 80 mm in 16 years, an average increment of 7.5 mm per year. Springer (1960) estimated from indirect evidence that *Carcharhinus milberti* grew from about 60 cm at birth to 200 cm in 2 years, an average growth rate of about 700 mm per year.

Holland (1957) reported an average growth increment of 30 mm per

TABLE 6–9. Length increments of tagged sharks recaptured at Socorro Island.

Sex and body length at tagging (mm)	Increase in length at recapture (mm)	Time at liberty (months)	Length increment (mm/year)
	C. albimarginatus		
Female			
555	20	5.5	47
565	0	5.5	—
650	20	5.5	47
680	20	5.5	47
755	15	5.0	39
1,050	5	9.5	6
			Average 31
Male			
605	−10	5.5	—
665	10	5.5	23
665	35	5.5	83
685	135	14.0	116
690	−5	5.5	—
690	80	5.0	208
710	−5	5.5	—
1,135	−15	5.5	—
			Average 54
	C. galapagensis		
Female			
495	15	5.5	33
Male			
640	10	9.5	13
740	25	5.5	59
780	70	9.5	88
865	10	5.5	23
880	70	14.0	60
905	35	14.0	30
955	5	5.5	12
970	95	14.0	81
1,110	−5	5.0	—
			Average 41

year from tagging studies of *Squalus acanthias*, a small species. Olsen (1954), in studies of the larger *Galeorhinus australis*, used length-frequency and tagging data to calculate average annual length increments for different age groups that ranged from 130 mm for 1-year-old sharks to 30 mm for 12-year-old sharks.

Shedding Rates and Condition of Tags and Tag Wounds

Returns from multiple-tagged sharks indicated that Petersen and dart tags were shed at much higher rates than Rototags and strap tags (Table 6–10). Because of the high shedding rate of Petersen tags, it is difficult to

TABLE 6–10. Shedding rates of tags, from recaptures of 70 multiple-tagged sharks.[a]

Locality and tag type	No. of tags attached	No. of tags shed	Percentage shed
Mexican coast			
Petersen	25	20	80
Rototag	8	0	0
Strap	18	1	6
Revillagigedo Islands			
Petersen	42	21	50
Rototag	21	2	10
Strap	28	1	4
Dart	2	2	100
Offshore			
Petersen	1	1	100
Rototag	1	0	0
Strap	1	0	0
Dart	1	1	100
Totals			
Petersen	68	42	62
Rototag	30	2	7
Strap	47	2	4
Dart	3	3	100

[a] The 70 sharks included 64 with 2 tags, 4 with 3 tags, and 2 with 4 tags.

assess the loss of rototags and strap tags; most double tags consisted of a Petersen tag paired with a rototag or strap tag (Table 6–5). Our data are inadequate for estimating the probabilities of loss of both tags. Consequently, the shedding rates given here are minimal.

The percentages of strap tags and Rototags returned from the Revillagigedo Islands were equal, but at the Mexican coast the percentage of Rototags recovered was only one-half that of strap tags (Table 6–11). Recoveries of Petersen tags were also fewer in proportion to recoveries of strap tags from the Mexican coast. These differences may be due to species

TABLE 6–11. Comparison of recovery rates of sharks from the Mexican coast and Revillagigedo Islands, after tagging during the 1964 *Red Rooster* cruise.

Locality and tag type	No. of tags released	No. of tags recovered	Percentage recovered
Mexican coast			
Petersen	248	5	2.0
Rototag	129	9	7.0
Strap	126	19	15.1
Revillagigedo Islands			
Petersen	231	17	7.4
Rototag	131	21	16.0
Strap	139	22	15.8

differences or to incomplete reporting of recaptured sharks. We consider the recovery rates from the Revillagigedo Islands reliable because nearly all the recaptures were made by us, by fishery vessels of the Mexican Government, or by crew members of *Red Rooster*.

The percentages of Petersen tags that were shed ranged from 50 (Revillagigedo Islands) to 80 (Mexican coast). We examined the fins of 20 multiple-tagged sharks that had shed their Petersen tags after they had been at liberty from 11 to 34 weeks (average 20 weeks). In most fins, we saw a dark line caused by the pin as it cut through the fin. The original tag wound had healed completely, but in a few sharks the trailing edge of the dorsal fin was still split. In 14 sharks which had retained their tags from 8 to 28 weeks (average 17 weeks), the tag wounds were swollen and the skin under the discs was abraded. Neither the stainless-steel pins nor the plastic discs showed any deterioration after 1–28 weeks (average 14 weeks) at sea. Some discs had organisms attached, but the lettering was unaffected.

The high shedding rate of Petersen tags—50 percent or more in 6 months—leads us to conclude that these tags are unsuitable for the species studied. Olsen (1953) double-tagged *Galeorhinus australis* with Petersen and Nesbit internal tags and found a similar 50-percent loss of Petersen tags. Hansen (1963) obtained a return of 6.8 percent when he tagged 411 *Somniosus microcephalus* with Petersen tags. Holland (1957) recovered a similar 6.7 percent of 9,705 tagged *Squalus acanthias*. Many of the recaptures reported by both authors were long-term recoveries, up to 16 years after tagging. Neither Hansen nor Holland, however, obtained estimates of the shedding rate.

Only two Rototags were shed; one of these was attached to the small second dorsal fin. The tag wounds of 17 sharks which had been at liberty from 11 to 38 weeks (average 18 weeks) were not severe, although the tissue was slightly swollen and inflamed. The Rototags were often completely covered with barnacles and other organisms. Apparently, the deep imprint of the numbering facilitated the attachment of invertebrates. The lettering of one Rototag recovered after 11 months was abraded and partially illegible, but that of four others recovered after 9 to 14 months was in good condition.

We consider Rototags superior to all others used in this study, particularly because they caused less damage to the fin than strap tags and because of their low shedding rate. Davies (1965) recovered 27 percent of 1,006 sharks tagged with Rototags within 8 months. In preliminary studies with captive sharks, he found that wounds healed well when the tag was attached to the first dorsal fin (personal communication). Rototags could be improved by inscribing the lettering more deeply. On attachment, the numbers and lettering should face inward.

Of 56 recaptured sharks that were tagged with strap tags, only 2 had shed their tag. One tag was lost after 1 week, probably because of faulty attachment. The sharks were at liberty from 1 to 121 weeks (average 22 weeks). We were able to examine 25 sharks that were recaptured after 8–121 weeks (average 24 weeks). The tag wounds on all were swollen and inflamed. Tags attached to the pectoral fin or very close to the fleshy base of the first dorsal fin caused especially severe wounds. Pinching and constant abrasion of tissue is inevitable with this tag, but the wounds were not as severe when the tag was attached well above the fleshy base and near the trailing edge of the first dorsal fin. Most of the tags were in good condition, and no corrosion of the Monel metal was apparent except at the point of attachment in some of the long-term recoveries. We found a thin layer of algal or bryozoan growth on some tags, but all lettering was plainly legible. One tag was deeply pitted after 11 months at sea, however. Proper clinching of the tag was difficult with large sharks unless a hole was punched prior to attachment.

We consider the strap tag usable for tagging sharks because it does not deteriorate badly and is retained over extended periods. In preliminary studies with strap tags, John Prescott (personal communication) found that tags attached to the leading edge of the first dorsal fin of captive *Triakis semifasciata* caused severe wounds.

We consider the dart tags used in this study unsuitable for tagging sharks. Dart tags were applied on 22 sharks in multiple-tag experiments. Three of these were recovered, and all had shed their dart tags after 10, 20, and 22 weeks at liberty. Further evidence of rapid shedding was provided by David Davies (personal communication) who attached dart tags to a few captive sharks and found that they were quickly shed.

Future Tagging

Results of this study have pointed out the possibilities and limitations of acquiring information on the movements and growth of sharks. To obtain information on growth, trained personnel must be on hand to measure freshly caught tagged sharks. Although impractical for most situations, the restricted movements of sharks at the Revillagigedo Islands makes such an approach feasible. Investigators could make periodic cruises to the islands and with reasonable confidence expect to capture tagged sharks. The nonmigratory juvenile sharks at the islands also present opportunities for experiments ordinarily restricted to laboratories and small ponds.

Future tagging along the Mexican coast should be complemented with catch statistics of the shark fishery. Data on species and size-frequency distributions at different seasons and years would facilitate interpretation of tagging data.

Attempts should be made to study the effects of tags and tagging on the growth rates of sharks. This work could be accomplished by other marking procedures, including internal tags, branding, or mutilation, or possibly by applying the Petersen method to length-frequency data.

Rototags, properly modified, should be used exclusively as the external tag. To obtain information on rates of shedding, they should be attached in pairs. Chapman et al (1965) described a method for estimating shedding rates by double-tagging fish with a single type of tag. Internal tags can also be used to determine shedding rates of external tags (Olsen, 1953).

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