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Migration Patterns of Istiophoridae in the Pacific Ocean as Determined by Cooperative Tagging Programs

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ABSTRACT

Since 1954, billfish have been tagged by cooperative marine game fish tagging programs in many of the major sportfishing areas of the Pacific. Major locations of tagging have been off southern California, U.S.A., Baja California Sur and mainland Mexico, Panama, and Australia. Two cooperative marine game fish tagging programs have operated in the Pacific, 1) the Cooperative Marine Game Fish Tagging Program, sponsored jointly by the Woods Hole Oceanographic Institution and the National Oceanic and Atmospheric Administration, National Marine Fisheries Service, and 2) a cooperative program conducted by the California Department of Fish and Game.

During 1954-1971, 15,540 billfish were tagged. Records show 9,849 striped marlin *(Tetrapturus audax)*, 4,821 sailfish *(Istiophorus platypterus)*, 622 black marlin *(Makaira indica)*, and 248 blue marlin *(Makaira nigricans)* were tagged during this period. Ninety-seven tag recoveries have been made; these include 85 striped marlin, 10 sailfish, and 2 black marlin. Eighty-one percent of these recoveries were by longline fishing vessels, the remainder by marine sport fishermen.

The tag recovery rates were 0.88% for striped marlin, 0.32% for black marlin, and 0.24% for sailfish.

Four types of tags were used in the two programs. Two types of metal tip dart tags were used by the Woods Hole Oceanographic Institution; metal tipped single- and double-barbed plastic dart tags were used by the National Marine Fisheries Service; and a single-barb plastic dart tag was used by the California Department of Fish and Game. Tag types giving the best recovery rate for striped marlin and sailfish were the plastic single- and double-barbed dart tags.

Recovery data for striped marlin tagged in the eastern Pacific show a movement away from the tip of Baja California in a south to southwest direction in late spring and early summer. Some recoveries were made of fish tagged near the tip of Baja California and recaptured northwest of the tip of Baja California, Mexico. The migration pattern to the south and southwest at this time of the year may be related to spawning. Striped marlin tagged off southern California show a migration to the south in late summer and early fall. Recoveries of striped marlin in the eastern Pacific were generally short-term (average of 89 days) and covered short distances, averaging 281 nautical miles. Only three of 85 tagged striped marlin, and one of two tagged black marlin, were recovered 1,000 nautical miles or more from the site of tagging. The few recoveries of tagged black marlin (2) and sailfish (10) did not provide sufficient data to determine migration patterns for these species.

The tagging or marking of fish is an established method in the study of fish growth, migration, distribution and population structure (Schaefer, Chatwin, and Broadhead, 1961; Beckett, 1970). The concept of utilizing the services of marine anglers in the tagging of large marine game fishes, such as tunas and billfishes, was developed by Frank J. Mather III of the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. The first cooperative tagging of billfishes in the Pacific Ocean was in 1954 when tagging equipment was furnished by Mather to anglers fishing for billfishes and tunas. Interest in the tagging and releasing of billfishes in the Pacific increased and in 1961 arrangements were made with Mather for the then U.S. Fish and Wildlife Service's Tiburon Marine Laboratory to assume responsibility for the cooperative Marine Game Fish Tagging Program in the Pacific area. This program has recently been transferred to the Department of Commerce, National Marine Fisheries Service, Southwest Fisheries Center, La Jolla Laboratory, La Jolla, California. The Pacific phase of the Cooperative

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Game Fish Tagging Program was assisted by the International Game Fish Association and the Department of Fisheries, Mexico.

The State of California, Department of Fish and Game also participated in a cooperative tagging program for billfishes (striped marlin and sailfish) from 1965 through 1970 with the assistance of anglers representing the Oceanic Research Institute, San Diego, California.

The importance of the istiophorid billfishes, such as striped marlin *(Tetrapturus audax)* and sailfish *(Istiophorus platypterus)* in the eastern Pacific, blue marlin *(Makaira nigricans)* about the Hawaiian Islands (Strasburg, 1969), and black marlin *(Makaira indica)* off Queensland, Australia and throughout the Pacific, as species on which valuable sport fisheries are based upon, is well known. In addition to an extensive sportfishery, these species also assist in supporting an extensive commercial longline fishery throughout the subtropical and tropical Pacific.

The cooperative billfish tagging programs in the Pacific were developed to obtain an adequate understanding of the migratory patterns of billfishes so that ultimately the stocks can be properly managed. The migratory patterns of billfishes in the Pacific are little known. These fishes are caught in quantity primarily with hook and line, either by longlining or by rod and reel. Use of the more efficient longline gear from a research vessel for the purpose of tagging and releasing of billfishes would be costly, and in excess of any funds now available for billfish migration studies. The aid of the marine game fish angler was requested and to date the cooperative tagging programs have accounted for nearly all the billfishes tagged in the Pacific. Bayliff[2] reported tagging of billfishes by research agencies such as the National Marine Fisheries Service, Honolulu Laboratory and the Kanagawa Prefectural Fisheries Research Station in Japan. In 1968 the Honolulu Laboratory tagged 44 striped marlin, 1 blue marlin, and 10 shortbill spearfish. The Japanese Research Station reported tagging 33 striped marlin, 3 blue marlin, and 73 broadbill swordfish *(Xiphias gladius)*. No returns were reported from any of these taggings.

By furnishing tagging equipment to marine game fish anglers who have an interest in the rational conservation of the billfish resources, substantial numbers of billfishes can be tagged in areas of intensive sportfishing for a relatively modest cost. Marine game fishermen have been encouraged to tag and release billfishes through information in the form of written requests, talks before billfishing clubs, posters, and brochures. In addition, posters requesting both sport and commercial fisheries to return tags and advising of a reward are distributed in both the Spanish and Japanese languages.

The major geographical locations of cooperative tagging have been about the tip of Baja California, Mexico; Mazatlán, Mexico; and Cairns, Australia. Other locations where lesser numbers of tagged fish have been released are off southern California and the Hawaiian Islands, U.S.A.; Manzanillo and Acapulco, Mexico; Piñas Bay, Panama; Salinas, Ecuador; Tahiti; and New Zealand.

MATERIALS AND METHODS

The large size and active nature of billfishes require a tag that can be applied while the fish remains in the water. Dart tags were selected because they could be used effectively by billfish anglers inexperienced in tagging fish. All tagging, with the exception of a few striped marlin and swordfish, have been on hook and line caught fish. Some surface-swimming billfishes have been free-tagged by harpooning with a dart tag.

Four types of tags were used by the cooperative programs. The California Department of Fish and Game used the single nylon barb tag with yellow polyvinylchloride tubing bearing the legend, type FT-1 (Fig. 1A). The National Marine Fisheries Service's cooperative program used four types of dart tags: (i) In 1963 a number of type "C" tags (Fig. 1C) were issued. These tags had a stainless steel tip with yellow polyvinyl tubing for the legend and were similar to the type of tags used by the Woods Hole Oceanographic Institution program in the late 1950's and early 1960's. (ii) The FT-1 (Fig. 1A) with a slightly enlarged base on the dart head to prevent the tagging applicator tube from shearing the barb when pressure is applied to insert the tag into the billfish. This tag was recommended for tagging sailfish. (iii) A larger double barbed nylon tag FM-67 (Fig. 1B) with yellow polyvinyl tubing for information was used from 1963 to 1971. (iv) In mid-1971, the stainless steel dart tag, type "H" (Fig. 1D) was introduced. This tag has a nylon, monofilament line extending from the stainless steel barb with a yellow polyvinyl tubing sleeve over the

[2]Bayliff, William H., et al. 1972. Second interim report of the Working Party on Tuna and Billfish Tagging in the Pacific and Indian Oceans. FAO, unpublished.

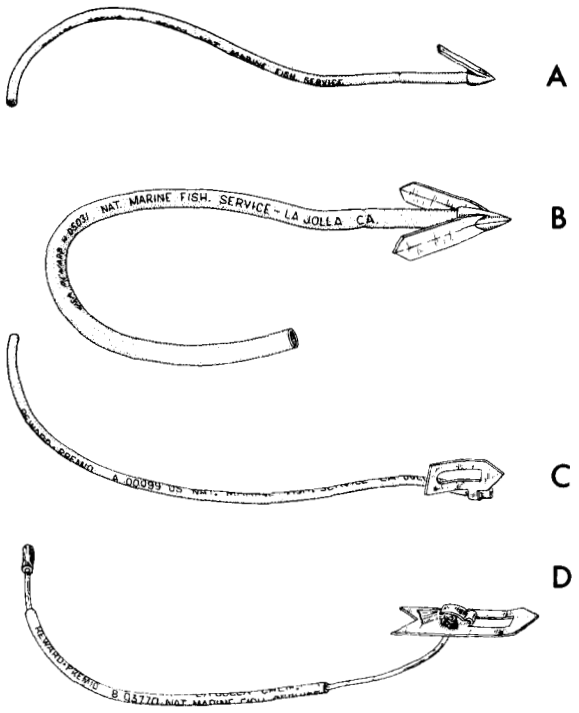

Figure 1.—Types of dart tags used by the cooperative tagging programs.

monofilament for printed information. All tags used by the National Marine Fisheries Service and the California Department of Fish and Game were manufactured by the Floy Tag Manufacturing Company, Seattle, Washington.[3] On all the tags, a serial number and a message are heat-embossed in black. The legend gives an address for return, together with a notice that a reward will be given. In the early years of the cooperative program the Woods Hole Oceanographic program used the type "C" tags (Fig. 1C) in the Pacific. In later years tags of an "H" type were used (Fig. 1D).

Upon bringing the billfish close to the boat the angler was instructed to insert the tag beside the dorsal fin, just posterior of the first dorsal ray, and at an angle so the tubing points in the general direction of the tail. This was done to provide a streamlining effect of the water flow over the tubing. After insertion, the leader was to be cut, thereby releasing the fish and leaving the hook and a portion of the leader attached. If necessary, it was recommended that the billfish be towed forward slowly before release to provide an additional supply of oxygen to assist in reviving the fish.

Tags were attached to a postcard having the serial number of the tag. After tagging the angler was requested to complete the information on tagging date, location, species, estimate of weight, tagger's name and address, and return it to the organization issuing the tag.

[3]Use of a trade name does not imply endorsement by the National Marine Fisheries Service.

TAGGING RESULTS

In the early 1960's, the Japanese longline fleet began fishing near the coasts of North, Central, and South America. The advent of this fishery has provided an invaluable source of billfish tag recoveries. Prior to 1963, a good source of recovery for billfish tags had not existed in the eastern Pacific.

Cooperating marine game fish anglers have tagged 15,540 billfishes in the Pacific since 1954.

Woods Hole Oceanographic Institution records for the period 1954 through 1971, show 3,618 tagged billfish releases (Mather, 1972). The National Marine Fisheries Service program resulted in the tagging and release of 10,964 billfishes. The distribution of tagging effort for the 14,582 billfish tagged by the Woods Hole Oceanographic Institution/National Marine Fisheries Service Cooperative Marine Game Fish Tagging Program included 8,953 striped marlin, 248 blue marlin, 622 black marlin, and 4,759 sailfish. The State of California Department of Fish and Game conducted a cooperative tagging program with selected billfish anglers and this program functioned during the period 1965-1970. Of a total of 958 billfishes tagged, 896 were striped marlin and 62 sailfish.

A total of 9,849 striped marlin, 622 black marlin, 248 blue marlin, and 4,821 sailfish was tagged by the cooperative programs. The totals and numbers of the four species of billfishes tagged per year and the number of recoveries (for each year's tagging) are listed by tagging organization in Table 1.

Recoveries

Between 1954 and 1963, no returns were reported in the Pacific for the 945 billfishes tagged and released. From 1963 through 1971 a total of 97 tagged billfishes was recaptured. Foreign longliners recorded 79 recoveries or 81% of the total. One of these was by a Taiwanese longliner; the others were recovered by Japanese longliners. Marine game fishermen have accounted for 18 recoveries or 19%

Table 1.—Billfishes tagged and recaptured in the Pacific by cooperative marine game fish tagging programs.

Year	Organization	Species				
		Striped marlin	Black marlin	Blue marlin	Sailfish	Totals
1954	A_1	—	—	—	0/3	0/3
1955	A_1	—	—	—	0/9	0/9
1956	A_1	—	—	—	—	—
1957	A_1	0/17	—	—	0/35	0/52
1958	A_1	0/13	—	—	0/8	0/21
1959	A_1	0/10	—	—	0/124	0/134
1960	A_1	0/2	—	—	0/104	0/106
1961	A	0/87	0/8	—	0/188	0/283
1962	A_1	0/76	0/4	—	0/257	0/337
1963	A_1	1/942	0/37	0/30	0/266	0/1,275
	A_2	0/532	0/1	0/18	0/26	0/577
	B	0/18	—	—	—	0/18
1964	A_1	1/113	0/36	0/12	0/241	1/402
	A_2	4/281	—	0/3	0/268	4/552
	B	4/329	—	—	0/7	4/336
1965	A_1	1/52	0/26	0/4	0/233	1/315
	A_2	6/431	0/6	0/7	2/167	8/611
	B	0/253	—	—	0/18	0/271
1966	A_1	0/47	0/19	0/1	0/124	0/191
	A_2	10/735	—	—	2/283	12/1,018
	B	2/186	—	—	0/31	2/217
1967	A_1	0/31	0/27	—	0/62	0/120
	A_2	19/1,279	0/3	0/23	1/480	20/1,785
	B	0/107	—	—	0/1	0/108
1968	A_1	1/29	0/31	—	0/98	1/158
	A_2	13/1,119	0/13	0/32	2/432	15/1,596
	B	—	—	—	—	—
1969	A_1	0/5	0/36	—	0/78	0/119
	A_2	4/747	1/39	0/31	0/318	5/1,135
	B	1/1	—	—	—	1/1
1970	A_1	0/6	0/19	0/2	0/33	0/60
	A_2	16/989	0/82	—	2/501	18/1,572
	B	0/2	—	—	1/5	1/7
1971	A_1	0/9	—	0/12	0/12	0/33
	A_2	2/1,401	1/235	0/73	0/409	3/2,118
Also 1 shortbill spearfish *(Tetrapturus angustirostris)* tagged						
	B	—	—	—	—	—
Totals		85/9,849	2/622	0/248	10/4,821	97/15,540

NOTE: Releases (right of slash), returns (left of slash) by organization conducting the tagging. Returns are listed by year of recapture for WHOI, NMFS and CF&G lists recapture by year of tagging.

A. Cooperative Marine Game Fish Tagging Program.
A_1 Woods Hole Oceanographic Institution, from 1954.
A_2 National Marine Fisheries Service, from 1963.
B. California Department of Fish and Game.

of the total. The FM-67 and FT-1 tags are buoyant and a number of these have been returned after being picked up on the beach after being used to tag a billfish. These tags may have been lost overboard during the tagging process or may have been shed after tagging. Recoveries were considered valid only when the tag was taken from a recently caught fish.

The Cooperative Marine Game Fish Tagging program (National Marine Fisheries Service —Pacific) issued a conservation certificate to both the tagger and recoverer. A cash reward was paid to the tag recoverer by all three programs.

Table 2 gives the percentage rate of recovery by program, by year, and total recovery rate for each species and for all billfish tagged. Table 3 gives a summation of the rate of return for each of the three cooperative tagging programs.

Tag Performance

For the four types of tags used by the cooperative programs (FT-1, FM-67, C, and H) a comparison of tag performance can be made for the types FT-1 used by the California Department of Fish and Game, and the National Marine Fisheries Service and the Woods Hole Oceanographic Institution.

Recovery data for 10,777 tags used by the National Marine Fisheries Service Cooperative Tagging program and 958 tags used by the California

Department of Fish and Game to tag striped marlin, black marlin, and sailfish were analyzed for the purpose of giving some indication of tag performance. Eighty-two percent of the billfishes were tagged with FM-67 tags, 13.8% with FT-1 tags, 3.4% with the "H" tags, and 0.8% with the "C" tag. There were no recoveries of the "C" tag, and the "H" tag has been used only since mid-1971. The percentage recovery rate by tag type and tagging organization is listed in Table 4.

Hooking mortality undoubtedly accounts for a high tag loss, in addition to unknown losses that occur through tag shedding. The percentage of tag loss for the several types of tags is not known.

Table 2.—Rate of recovery of tagged billfishes.

Year	Organization	Species: Striped marlin	Black marlin	Blue marlin	Sailfish	Overall % recovery rate
1963	A_1	0.11%	0.00%	0.00%	0.00%	0.08%
	A_2	0.00	0.00	0.00	0.00	0.00
	B	0.00	—	—	—	0.00
				Annual Overall		0.05%
1964	A_1	0.88	0.00	0.00	0.00	0.25
	A_2	1.42	—	0.00	0.00	0.72
	B	1.21	—	—	0.00	1.20
				Annual Overall		0.70%
1965	A_1	1.92	0.00	0.00	0.00	0.32
	A_2	1.40	0.00	0.00	1.20	1.31
	B	0.00	—	—	0.00	0.00
				Annual Overall		0.75%
1966	A_1	0.00	0.00	0.00	0.00	0.00
	A_2	1.40	—	—	0.71	1.08
	B	1.07	—	—	0.00	0.92
				Annual Overall		0.91%
1967	A_1	0.00	0.00	—	0.00	0.00
	A_2	1.50	0.00	0.00	0.21	1.12
	B	0.00	—	—	0.00	0.00
				Annual Overall		0.99%
1968	A_1	3.44	0.00	—	0.00	0.63
	A_2	1.16	0.00	0.00	0.46	0.94
	B	—	—	—	—	—
				Annual Overall		0.91%
1969	A_1	0.00	0.00	—	0.00	0.00
	A_2	0.53	2.56	0.00	0.00	0.35
	B	100.00	—	—	—	100.00
				Annual Overall		0.40%
1970	A_1	0.00	0.00	0.00	0.00	0.00
	A_2	1.62	0.00	—	0.40	1.15
	B	0.00	—	—	20.00	14.28
				Annual Overall		1.16%
1971	A_1	0.00	—	0.00	0.00	0.00
	A_2	0.14	0.43	0.00	0.00	0.14
	B	—	—	—	—	—
				Annual Overall		0.13%
Totals						
1954-71		0.86%	0.32%	0.00%	0.21%	0.62%
1963-71		0.88%	0.32%	0.00%	0.24%	0.66%

A_1 = Cooperative Marine Game Fish Tagging, Woods Hole Oceanographic Institution.
A_2 = Cooperative Marine Game Fish Tagging, National Marine Fisheries Service.
B = Cooperative Billfish Tagging, California Department of Fish and Game.
— = no billfish tagged.
1954 through 1962 no recoveries reported.

MIGRATORY PATTERNS

Eastern Pacific

Figures 2, 3, 4, and 5 show the tagging and recovery points by quarters for both striped marlin and sailfish in the eastern Pacific. The recovery data from the longline fleet have not been adjusted for fishing effort in the various geographical areas. The commercial longline fishery has expanded to the limits of the fishery in the eastern Pacific and the seasonal distribution of fishing effort is assumed to

Table 3.—Rate of recovery (left figure refers to number of tag recoveries; right figure refers to number of fish tagged and released).

Year	Striped marlin	Black marlin	Blue marlin	Sailfish	Total
Program A_1—Woods Hole Oceanographic Institution					
1954-1971	4/1,439 = 0.28%	0/243 = —%	0/61 = —%	0/1,875 = —%	4/3,618 = 0.11%
Since 1963	4/1,234 = 0.32%	0/231 = —%	0/61 = —%	0/1,147 = —%	4/2,673 = 0.15%
Program A_2—National Marine Fisheries Service					
1963-1971	74/7,514 = 0.98%	2/379 = 0.53%	0/187 = —%	9/2,884 = 0.31%	85/10,964 = 0.78%
Program B—California Department of Fish and Game					
1963-1970	7/896 = 0.78%	—/— = —%	—/— = —%	1/62 = 1.6%	8/958 = 0.84%

Rates of recovery for striped marlin and sailfish combined, 1963-1971:
Program A_1 4/2,673 = 0.15%
A_2 85/10,964 = 0.78%
B 8/958 = 0.84%

Table 4.—Percentage recovery rates for tag types used by the California Department of Fish and Game (CF&G), and National Marine Fisheries Service (NMFS), fish tagged through 1971.

Species	Agency	Type tag	% recovery	
Striped marlin	NMFS	FM67	1.06%	
	NMFS	FT-1	0.42	>0.66%
	CF&G	FT-1	0.80	
	NMFS	H	0.40	
Black marlin	NMFS	FM67	0.32%	
	NMFS	H	1.20	
Sailfish	NMFS	FM67	0.30%	
	NMFS	FT-1	0.60	>0.86%
	CF&G	FT-1	1.60	

be located in areas of greatest concentration and maximum yield.

January, February, March.—During this period striped marlin are commonly taken by the sportfishery off Mazatlán, Mexico, and in lesser numbers off Cabo San Lucas, the southern tip of Baja California Sur, Mexico. Sailfish are not common in the area about the mouth of the Gulf of California during the winter and early spring. The longest distance recovery of a striped marlin was for a fish tagged near the tip of Baja California Sur, Mexico, and recovered 200 nautical miles southwest of the Hawaiian Islands, a distance of 3,120 nautical miles in a period of 3 mo (2/67-5/67). Recoveries of striped marlin tagged off Mazatlán, Mexico, show a west to southwest movement towards the tip of Baja California Sur, and the Revillagigedo Islands, Mexico, respectively. Recoveries of striped marlin tagged about the tip of Baja California Sur, Mexico, show some movement toward the northwest and northeast; however the direction of the movement as indicated by tag recoveries from this area is south through southeast (reference, Fig. 2).

April, May, June.—During late spring and early summer the sportfishery striped marlin catch decreases off Mazatlán and increases about the tip of Baja California Sur, Mexico. Sailfish becomes the dominant species off Mazatlán during this season. A pattern of striped marlin movement, indicated by recoveries, is from about the tip of Baja California southward toward Las Tres Marias and Revillagigedo Islands, Mexico. Striped marlin tagged

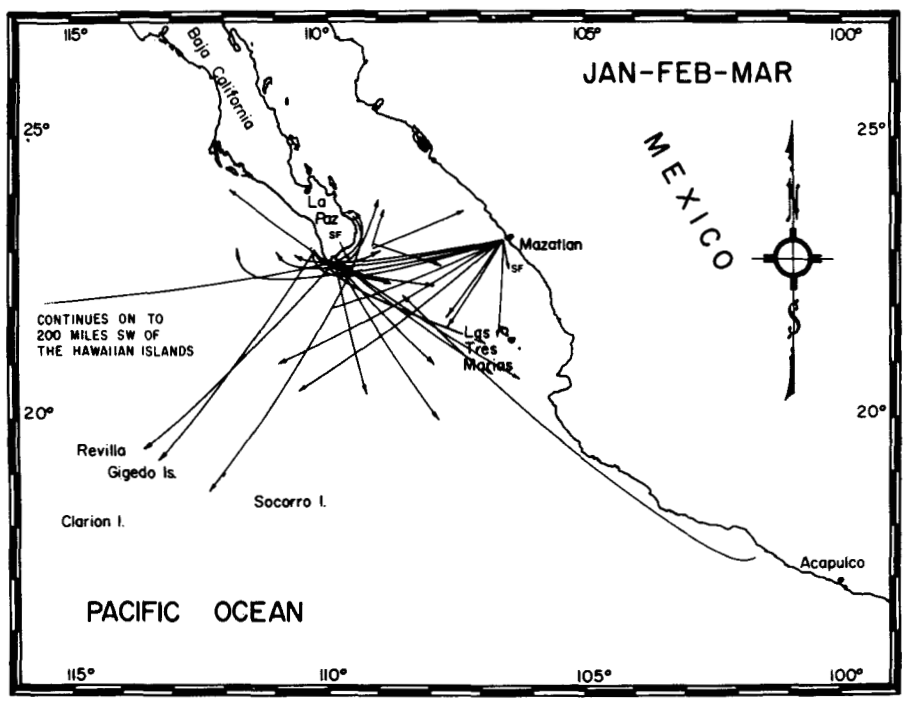

Figure 2.—Movements of billfishes from tagging conducted during the months of January, February, and March. Striped marlin unless otherwise noted as SF (sailfish).

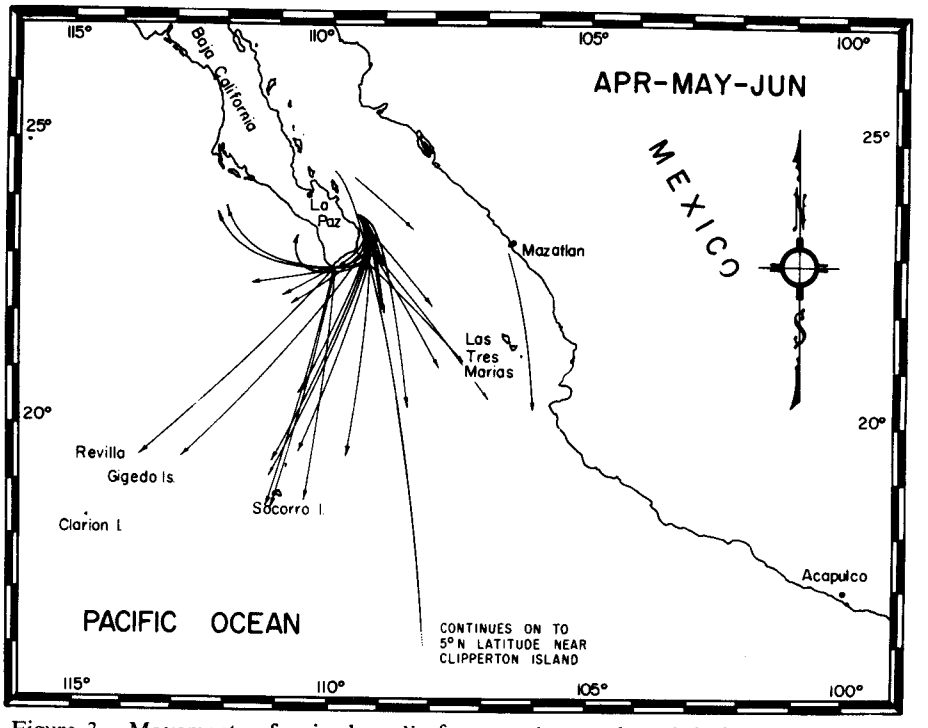

Figure 3.—Movements of striped marlin from tagging conducted during the months of April, May, and June.

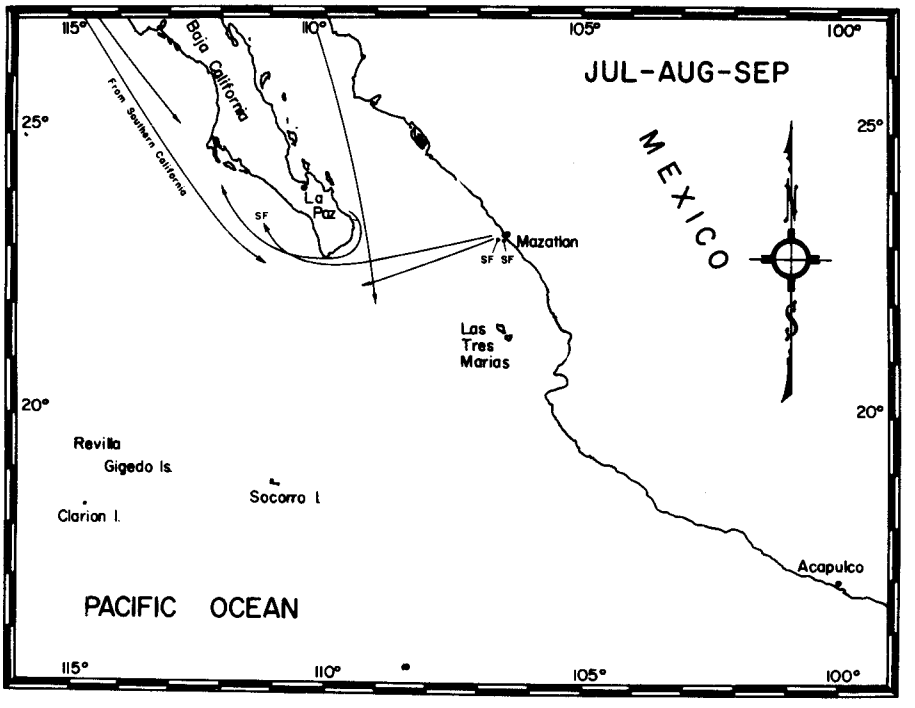

Figure 4.—Movements of billfishes from tagging conducted during the months of July, August, and September. Striped marlin unless otherwise noted as SF (sailfish).

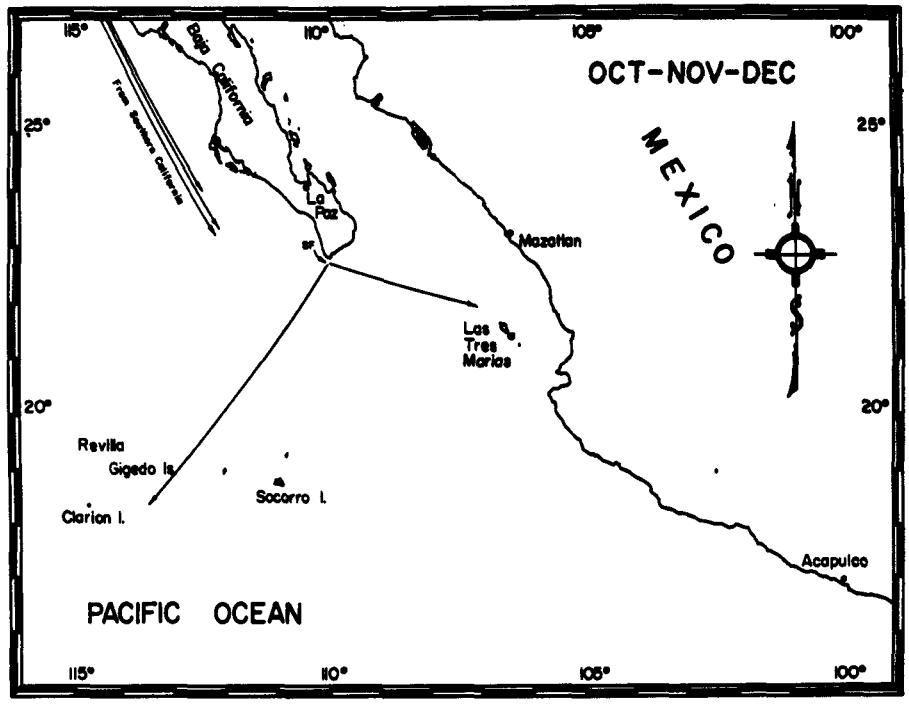

Figure 5.—Movements of billfishes from tagging conducted during the months of October, November, and December. Striped marlin unless otherwise noted as SF (sailfish).

along the east side of the tip of Baja California have shown some movement about the tip to the west and northwest. The longest southward migration of any tagged striped marlin was recorded during this period; the marlin's total straight line migration was 1,153 nautical miles from near the tip of Baja California to near Clipperton Island in 71 days (reference, Fig. 3).

July, August, September.—A reduction in tagging effort due to fewer sportfishermen traveling to the tip of Baja California and the west coast of Mexico during the warm season is reflected in the numbers of billfishes tagged and later recovered. Short distance sailfish recoveries were made near Mazatlán. A sailfish, tagged during this period off Mazatlán, was recovered northwest of the tip of Baja California, a distance of 250 nautical miles, after 457 days. This sailfish recovery was the greatest in distance and time (reference, Fig. 4).

Striped marlin fishing becomes productive off southern California in late August and two recoveries were made off the southern west coast of Baja California of striped marlin tagged off southern California in September. One recovery was made of a striped marlin tagged off Guaymas, Mexico, which is located on the east coast in the upper Gulf of California, and recaptured south of the tip of Baja California 17 days later.

October, November, December.—This is a period of reduced tagging throughout all eastern Pacific sportfishing areas. A limited amount of tagging off southern California has yielded returns, one being the second longest return recorded, 2,090 nautical miles to the southwest in 179 days. Three recoveries of striped marlin tagged off southern California were recovered northwest of the tip of Baja California 1 to 4 months later (reference, Fig. 5).

As in any conventional tagging or marking program only two points in the migration are known —the location of tagging and the tag recovery point. The geographical migratory course of the billfish between these two points is unknown.

Southwestern Pacific

Through the cooperation of anglers fishing for black marlin near Cairns, Queensland, Australia, recoveries of two tagged black marlin have been recorded (Fig. 6). One was recovered by a Japanese

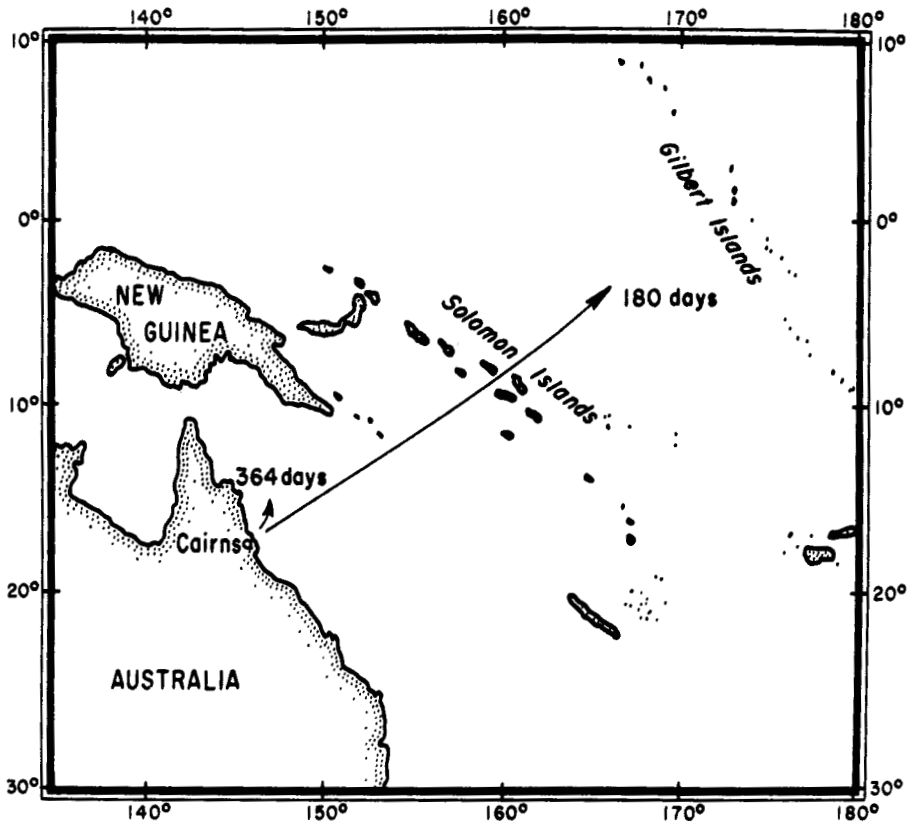

Figure 6.—Movements of black marlin tagged off Queensland, Australia.

longliner 364 days after tagging about 90 nautical miles north from the point of tagging near Hope Reef, Queensland, Australia. The second was recovered 180 days after tagging by a Taiwanese longliner 1,440 nautical miles northeast of the tagging site at Escape Reef, Queensland, Australia.

MIGRATION RATES AND TIMES

The speed of migration of striped marlin, expressed in nautical miles per day projected on a straight line/time basis, varies considerably between local and distant water recoveries (Fig. 7). For billfishes tagged off the Baja California/ Mazatlán area the average time at liberty was 94 days. An average distance of 176 nautical miles traveled equals 1.9 nautical miles per day. Striped marlin tagged off southern California recovered near the tip of Baja California had an average release time of 52 days and a migration rate of 12.3 nautical miles per day. Other long distance migration rates are as follows; southern California to southwest of the Hawaiian Islands, 26.0 nautical

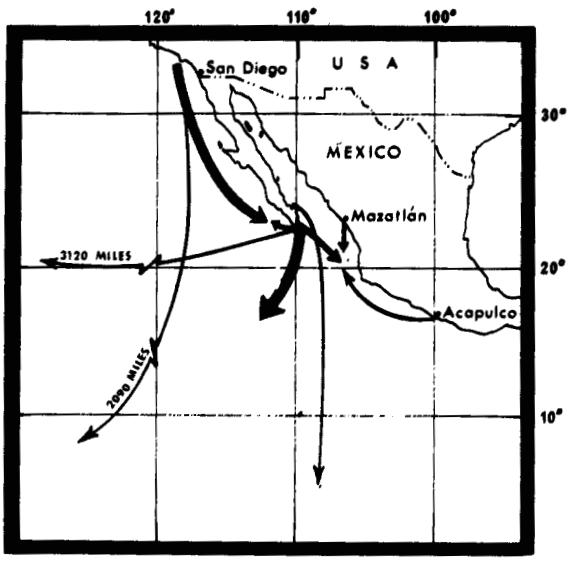

Figure 7.—General migration patterns of striped marlin tagged off southern California and Mexico.

miles per day; tip of Baja California to ⅔ the distance to the Hawaiian Islands, 11.7 nautical miles per day; tip of Baja California to near Clipperton Island, 16.3 nautical miles per day.

For all striped marlin recoveries having accurate records, the average days out is 89; the average migration 281 nautical miles, and average distance per day out, 3.16 nautical miles.

For the limited number of sailfish recaptured the average number of days out was 113, the migration rate was 0.4 nautical miles per day. The longest distance recorded for any sailfish was 250 nautical miles in 457 days out. This was the longest release-recapture time of any billfish tagged in the Pacific.

Two black marlin were recovered, one near the point of tagging in the Coral Sea 364 days after tagging, the other 180 days after tagging, 1,440 nautical miles northeast of Queensland, Australia. This billfish averaged 8 nautical miles per day.

The greatest migration rate in nautical miles per day for any billfish was a short-term recovery of a striped marlin tagged off the tip of Baja California which averaged 31.6 nautical miles per day.

DISCUSSION AND SUMMARY

The concept of utilizing cooperating marine game fish anglers to tag and release billfishes has proven to be a practical approach to the study of billfish migration patterns.

Experience indicates that accurate estimates of weights and lengths of tagged fish cannot be expected.

After tagging, the angler is requested to return the tag card. In 1968 a comparison was made of the number of tags returned with a matching tag card on file, with those that did not have a tag card. This indicated that about 17% of the tag cards were not being returned. As a result, an active campaign to have the angler return the cards was begun.

The number of billfishes tagged annually in the Pacific has steadily increased since 1954, reaching a total of 2,118 in 1971. The annual rate of billfish recoveries rose to above the 0.90% level from 1966 through 1968, dropped to 0.40% in 1969, increased to a peak of 1.16% in 1970, and dropped to a very low 0.13% in 1971. The reason for the sharp decline in recoveries in 1971 cannot be explained. The only change in operation of the National Marine Fisheries Service program was the introduction of the "H" type tag. During the latter half of 1971, 317 "H" tags were used, which equalled only 14.7% of the total tags used by the National Marine Fisheries Service program during 1971.

The recovery rate from FM-67 and FT-1 tags used by the National Marine Fisheries Service and California Department of Fish and Game in the Pacific for striped marlin were comparable. The California Department of Fish and Game program obtained a 0.80% recovery rate using the FT-1 and the National Marine Fisheries Service program obtained a 0.42% recovery rate using the same tag, giving an overall average of 0.66%. The California Department of Fish and Game program restricted its tag distribution to a limited number of experienced anglers fishing from private boats. On an average these anglers were more experienced in tagging billfish than most of the anglers participating in the National Marine Fisheries Service program. The FM-67 tag used for striped marlin shows a greater recovery rate (1.06%) than any of the four types of tags used. The recovery rate of the California Department of Fish and Game FT-1 tag (0.80%) was near that of the FM-67.

The National Marine Fisheries Service program changed to the metal-plastic "H" type tag in mid-1971 because of the recovery record (recovery percent and time out) for white marlin *(Tetrapturus albidus)* and sailfish in the Atlantic Ocean experienced by the Woods Hole Oceanographic Institution program.

Although many factors such as seasons and areas of fishing and economic value of billfishes influence catch rates in the Atlantic and eastern Pacific, a gross comparison of catch rates between the two oceans can be made. Catch and effort data given by the Japanese for Japanese longline operations in the Atlantic and eastern Pacific Oceans and plotted by Gottschalk (1972), show that the total effort in hooks fished was only slightly greater in the Atlantic than in the eastern Pacific for the period 1962 through 1970 (478×10^6 for the Atlantic and 442×10^6 for the eastern Pacific). Charts outlining longlining areas for striped marlin and sailfish in the eastern Pacific by Joseph et al (1973) and for sailfish and white marlin in the Atlantic by Wise and Davis[4] show that these areas are near equal in geographical extent. However, the catch-per-unit-effort (catch/hook) for striped marlin in the eastern Pacific has remained about three times greater over the years than the catch-per-unit-effort for white marlin

[4]Wise, John P. and Charles W. Davis. 1971. Seasonal distribution of billfish in the Atlantic. Prepared for 22nd Tuna Conference, NMFS, Miami, Fla., 28 p. (mimeo.).

in the Atlantic, a species that is similar in many respects to the striped marlin. The catch-per-unit-effort for sailfish in the eastern Pacific has averaged about four times the catch rate for the same species in the Atlantic.

These wide variations in catch rates between the Atlantic and eastern Pacific indicate a possibility of a lower density level or of a much smaller white marlin population, or both, in the Atlantic when compared with striped marlin in the eastern Pacific and sailfish in both oceans. If this is true, given approximately the same fishing effort, a greater percentage of tag recoveries of these species could be expected in the Atlantic.

The recovery rate of striped marlin tagged in the eastern Pacific using the FM-67 plastic tag was slightly less than for the metal tip tags used by the Woods Hole Oceanographic Institution Atlantic program for white marlin (1.06% eastern Pacific, 1.22% Atlantic). The plastic FT-1 tag gave near equal recovery rate results for sailfish in the Atlantic and the eastern Pacific (0.86% eastern Pacific, 0.80% Atlantic). The recovery rate for striped marlin tagged with metal tip "H" tags in the eastern Pacific has been 0.40%.

From the limited amount of data available, no definite conclusions can be reached. However, it appears that the plastic dart tag is as satisfactory as the metal tip dart tag. When the possible differences in population levels and projected recovery rates are considered, the plastic dart tag actually may prove to be superior.

In the northeastern Pacific there have been enough striped marlin tag recoveries to make some observations regarding their migration. Striped marlin usually are available during the first 3 months of the year off Mazatlán, Mexico. Movements of tagged fish from this area are toward the southwest and west, to and beyond the tip of Baja California. In late spring the principal component of the fishery changes to sailfish dominance.

Striped marlin are usually available about the tip of Baja California from late spring through fall. Migrations of tagged fish to the south and some to the west and northwest have been recorded. During late spring and early summer the reproductive activity of striped marlin increases in this area (M. Eldridge and P. Wares,[5] pers. comm.; Kume and Joseph, 1969). Thus the migrations away from the tip of Baja California in a southerly direction may be related to spawning activity of striped marlin in the general vicinity of the Revillagigedo Islands. Some spawning activity has been reported in this area by the Japanese longline fleet during the period late June through October (G. Adachi,[6] pers. comm.). Gonad indices for striped marlin collected in areas of reported spawning have been several times higher than the index found about the tip of Baja California (M. Eldridge,[5] pers. comm.).

Since the amount of longline fishing becomes less as one proceeds north of Magdalena Bay, Baja California, Mexico, the number of returns of striped marlin tagged about the tip and migrating northwest of the Magdalena Bay area would be reduced in proportion to the amount of fishing effort. However, some recoveries have been recorded northwest from the tip of Baja California toward southern California, immediately prior to the movement of striped marlin into the southern California fishery. An increase in catch per effort is noted in this area during the second and third quarters of the year. The southern California sportfishery takes only a small number of striped marlin during late August through October (usually less than 500); the Japanese longline fleet does not operate in this area. Therefore the chance of recovering a striped marlin off southern California is remote. However, from the limited number of striped marlin tagged off southern California and recovered a short time later near the tip of Baja California, indications are that a southerly migration from southern California exists in the fall.

The rates of migration for striped marlin about the tip of Baja California-Mazatlán-Revillagigedo Island area was 1.9 nautical miles per day. Two westward records of long distance migrations from the coast of North America toward Hawaii show rates of 12.3 and 26.0 nautical miles per day. From southern California to near the tip of Baja California, four records show an average migration of 12.3 nautical miles per day. A southward migration from the tip of Baja California to near Clipperton Island was recorded at 16.3 nautical miles per day.

Distant water migrations from southern California and about the tip of Baja California show a much higher migration rate in nautical miles per day when compared with those recaptured near the tip of Baja California, Mexico.

Sailfish recoveries indicate little movement, the

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[6]G. Adachi, P.O. Box 240, Manzanillo, Colima, Mexico.

longest being 250 nautical miles. Figure 7 represents a summation of the major migrations of striped marlin in the eastern Pacific as determined by the cooperative tagging program. In general, recoveries of striped marlin in the eastern Pacific were short-term (89 days average) and the average migration distance was 281 nautical miles.

Certain recommendations can be made regarding the future conduct of cooperative tagging programs in the Pacific for billfishes. These are as follows:

1. Encourage and develop billfish tagging (sport and commercial) throughout the entire Pacific for a better understanding of the migration patterns over the entire area for the major commercial and sport species. In the eastern and central Pacific additional tagging should be conducted off the Hawaiian Islands, southern California, Acapulco, Panama/Ecuador/Peru, Galapagos Islands, Tahiti, and Samoa.

2. Attempt to free-tag (harpoon method) or tag billfishes caught by non-injurious fishing techniques in sufficient numbers to determine hooking mortality.

3. Consider development of improved tags and tagging equipment and experimentally test both the metal tipped and plastic dart tags for histological compatibility and differential shedding by double-tagging billfishes or double-tagging large pelagic species in aquaria tests.

4. If additional tagging programs are to be undertaken in the Pacific in the future the programs should be coordinated between countries with regards to types of tags used, locations and seasons of tagging, publicity, recovery and reward procedures, to achieve the greatest return of information.

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