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Striped Marlin, *Tetrapturus audax*, Migration Patterns and Rates in the Northeast Pacific Ocean as Determined by a Cooperative Tagging Program: Its Relation to Resource Management

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Introduction

Since billfish cannot be captured in large numbers to study movements through tagging studies, marine anglers who will tag and release fish provide an effective, alternate way to obtain information on migration patterns. Billfish tagging by marine anglers in the Pacific began in the middle 1950's when tagging equipment, distributed to anglers by the Woods Hole Oceanographic Institution's (WHOI) Cooperative Marine Game Fish Tagging Program for tagging tunas and billfish in the Atlantic, was transported to fishing areas in the Pacific.

Sailfish, *Istiophorus platypterus*, were first tagged by billfish anglers in the northeast Pacific in 1954, and striped marlin, *Tetrapturus audax*, were first tagged in 1957. In 1961, black marlin, *Makaira indica*, were first tagged in the southwest Pacific (Coral Sea), and in 1963 blue marlin, *Makaira nigricans*, were tagged in the central Pacific (Squire, 1974). Cooperative billfish tagging programs with rod-and-reel anglers were developed to obtain an understanding of migratory patterns that could be useful in developing management plans for Pacific billfish stocks.

ABSTRACT—Migration patterns and rates for striped marlin, Tetrapturus audax, *tagged and recaptured in the northeast Pacific Ocean during 1957-81 are reported by time period and analyzed. Few long-range migrations and no trans-Pacific migrations were observed. Comparisons are made with other types of physical and biological data that might indicate seasonal movement (i.e., longline catch rates, areas of striped marlin spawning, movement of thermocline depth relative to fishing success). A tentative hypothesis describing the seasonal movement of striped marlin in the northeast Pacific and the total eastern Pacific is also proposed and presented in graphic form.*

In 1963, the U.S. Fish and Wildlife Service's Pacific Marine Game Fish Research Center, Tiburon Marine Laboratory, Tiburon, Calif., under the U.S. Department of Interior, assumed responsibility from WHOI for support of the Cooperative Marine Game Fish Tagging Program in the Pacific area. In 1970 a reorganization transferred the Tiburon Laboratory and the tagging program to the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) in the U.S. Department of Commerce. From 1963 to 1970 the State of California's Department of Fish and Game (CDFG) also provided tags to a select group of cooperating anglers to tag striped marlin (Squire, 1974).

The angler tagging programs have now accounted for nearly all the tagged billfish in the Pacific at a relatively modest cost compared to that which would have been incurred had the same fish been caught and tagged by more efficient longline gear from research vessels. These billfish were tagged mainly in areas that support active recreational billfish fisheries.

There is a major recreational fishery for striped marlin in the northeastern Pacific centered about the southern tip of Mexico's Baja California Sur peninsula, and it is very important to the economy of that area (Talbot and Wares, 1975). High catch rates are recorded in this area and surveys show the catch per angler day has ranged from 0.3 to 0.8 striped marlin since 1969 (Squire, 1986). Some striped marlin are also landed at Mazatlán, Mex., and others are occasionally taken off other west coast ports of Mexico and off Central and South America. High catch rates are observed again off Ecuador. In the northeast Pacific, high catch rates for striped marlin are recorded from January to March off Mazatlán, Mex., and later in the year (April-October) about the southeastern tip of the Baja California peninsula (Eldridge and Wares, 1974). The U.S. recreational fishing fleet off southern California lands striped marlin from July through October, with catches usually peaking in September; this area is the northern limit of the recreational fishery in the eastern Pacific.

Longline fishing for billfish and tunas has been conducted in the eastern Pacific (east of long. 130°W.) since the late 1950's (Suda and Schaefer, 1965) and in the northeastern Pacific, where it has targeted on striped marlin, sailfish, and swordfish, *Xiphias gladius*, since 1963 (Joseph et al., 1974). The catch rate for striped marlin in the high catch rate areas of the northeastern Pacific has declined from about 18 fish per 1,000 hooks fished in the early 1960's to about 9-11 fish per 1,000 hooks fished in 1980 (Anonymous, 1962-80). This decline came during the time tagging was conducted. Despite the substantial catch rate decline since the beginning of the fishery, the rate is among the highest in the Pacific, and this longline fishery provides in excess of 80 percent of the billfish tags recovered. From early 1977 to 1980 longline fishing for billfish and

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tunas was prohibited by the Government of Mexico within its 200-mile economic zone. The highest catch rates for striped marlin are about the southern tip of Baja California Sur, within the 200-mile zone. Joint-venture longline operations were resumed in 1980, providing a source of striped marlin tag recoveries.

Between 1964 and 1981, 155 tagged striped marlin were recovered—the majority by foreign commercial longline vessels. From recovery records it is possible to reconstruct migration patterns and rates. In this study I discuss the factors affecting tagging and recovery as they relate to migration, and the implications of the results for fishery management.

Tagging Methods and Results

Methods

According to the tagging instructions, when the billfish is brought alongside the boat the angler is to insert the dart tag beside the dorsal fin. Descriptive literature illustrating the suggested point of tag insertion is distributed with the tagging equipment. Because tagging of a large active billfish that cannot be lifted from the water or partially immobilized is a difficult task, it is probable that many tags have not been inserted as recommended.

When the tagging equipment is distributed to the angler, the tags are attached to a postcard (tag report card) which indicates the serial number of the tag (Fig. 1). After tagging a fish, the angler is requested to complete the tag information card with the date, location, species, estimate of marlin's weight and length, and the tagger's name and address; the angler is requested to return the card to the organization issuing the tag.

Tags used by billfish anglers participating in the Cooperative Marine Game Fish Tagging Program were described by Squire (1974). Four types of tags have been used for tagging striped marlin in the northeast Pacific Ocean (Fig. 1). For tagging conducted under NMFS sponsorship, less than 1 percent of the striped marlin were tagged with type "A" tags. About 7 percent were type "B" or FT-1, 37 percent type FM67, and 56 percent type FH69 or "H" type. The percentage of tag types used in the three areas of tagging was similar to the above distribution percentages, with one exception. A low percentage (4 percent) of FH69 tag were used at Mazatlán, due to a substantial reduction in tagging effort there in the early 1970's, at about the time the FH69 tag was introduced.

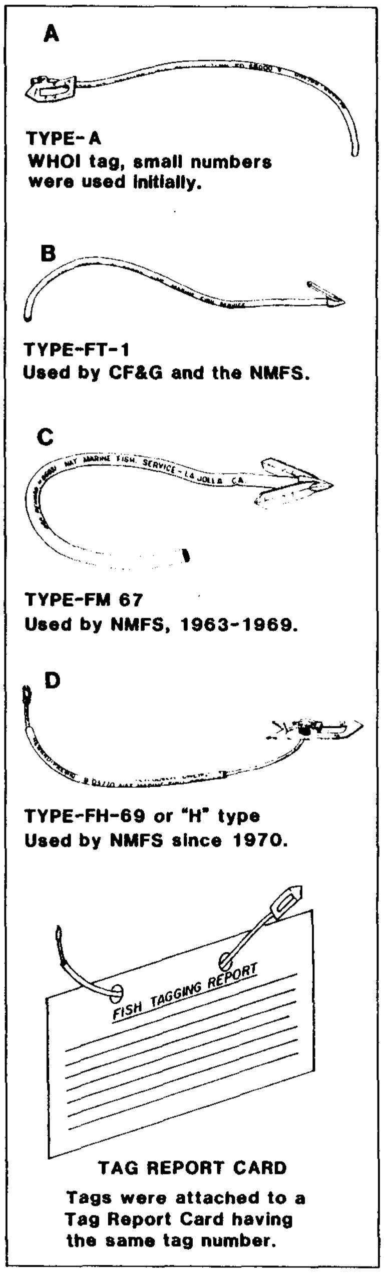

Figure 1.—Dart tags and tag report card used by the NMFS for the cooperative tagging program for tagging striped marlin in the northeast Pacific Ocean.

Table 1.—Annual number of striped marlin tagged by Cooperative Marine Game Fish Tagging Program Agency, 1957-81.

			NMFS			
Year	CDFG	WHOI	California	Baja Calif. Sur	Mazatlán	Total
1957		17	—	—	—	17
1958		13	—	—	—	13
1959		10	—	—	—	10
1960		2	—	—	—	2
1961		87	—	—	—	87
1962		76	—	—	—	76
1963	18	942	6	7	—	973
1964	329	113	9	243	8	702
1965	253	52	3	208	7	523
1966	186	47	13	365	15	626
1967	107	31	14	432	166	750
1968		29	17	749	59	854
1969	1	5	12	406	39	463
1970	2	6	24	617	54	703
1971		9	13	827	7	856
1972		—	7	804	1	812
1973		—	2	344	3	349
1974		—	54	603	3	660
1975		—	15	473	1	489
1976		—	46	576	9	631
1977		—	37	315	—	352
1978		—	24	557	—	581
1979		—	42	458	—	500
1980		—	22	1,142	—	1,164
1981		—	60	641	—	701
	896	1,439	420	9,767	372	12,894

Tagging Results

Between 1957 and 1981, 12,894 striped marlin were reported tagged in the northeast Pacific. This number represents only those tags for which a tag card was returned to the agency distributing the tags. Table 1 gives the number of striped marlin tagged by agencies that have provided tags to cooperating marine anglers. During 1963-81 the NMFS program accounted for 10,559 striped marlin tagged or 82 percent of the total number tagged. Maximum tagging effort was in 1980 (1,164 striped marlin tagged), and lowest effort in 1974 (349 striped marlin

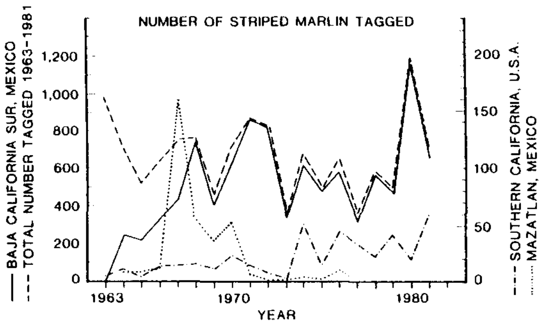

Figure 2.—Distribution of tagging effort, by year, for striped marlin off Mazatlán, Baja California Sur, and southern California, 1963-81.

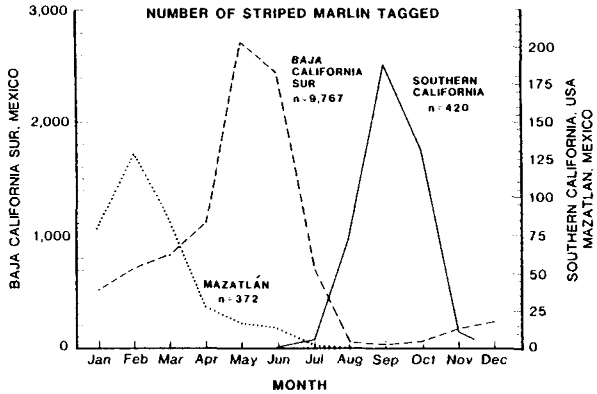

Figure 3.—Distribution of NMFS tagging effort, by month for tagging off Mazatlan, Baja California Sur, and southern California, 1963-81.

tagged); average tagging rate for 1963-81 was 668 striped marlin per year.

Distribution of tagging effort for the three major areas of tagging is given in Figures 2 and 3. Tagging effort increased off Mazatlán and Baja California Sur, Mex., in the middle 1960's. Through 1981, tagging effort levels ranged from 350 to 1,200 fish per year for Baja California Sur, and 30-80 fish for southern California.

The tagging program is a cooperative one and is dependent upon the active support of the anglers. Thus tagging frequency can fluctuate greatly, depending upon fishing success; tagging will be maximum during the peak of the fishing season and during seasons having better than average catches, and tagging will tend to be centered in specific geographical areas. Tagging of striped marlin in the northeast Pacific during any one year is not distributed randomly in time. High catch rate periods are evident for each of the three tagging areas. Figure 3 illustrates the timing of the releases for each of the three major tagging areas. The timing of tagging off Mazatlán and southern California is directly related to striped marlin availability occurring only during specific months. Striped marlin are available about the southern tip of Baja California Sur during most months of the year; however, because of a climate of high temperatures and humidity during the mid-summer through the fall there is much less fishing effort, and therefore less tagging.

There was little opportunity to recover tagged striped marlin in the eastern Pacific before the early 1960's. Prior to that time the Japanese longline fishery was expanding into the eastern Pacific, but the fishery had not yet concentrated in the northeast Pacific for the specific purpose of fishing striped marlin, sailfish, and swordfish. The recreational fishery continued to develop in the northeast Pacific but with a lower total estimated catch compared with current catches of an estimated 4,000-6,000 striped marlin per year. With the establishment in the early 1960's of an active commercial longline fishery in the northeast Pacific, the opportunity to recover tagged billfish increased (Ueyanagi, 1974). The Japanese longline fishery has recorded catches in the eastern Pacific (east of long. 130°W) of from 40,000 to 338,000 striped marlin annually during 1962-81. In 1963, the Japanese longline fishery for striped marlin, operating off the Baja California Sur peninsula (the major area of tagging), increased substantially and remained at a high level of effort until early 1977; catches from this area averaged about 30,000 striped marlin a year (Anonymous, 1962-80).

Recovery Rates of Tag Types

Of the striped marlin reported tagged during 1968-81, 12,689, 155 tags were returned for an overall return rate of 1.2 percent. The highest annual recovery rate was recorded in 1967—a 2.8 percent rate of recovery for 750 striped marlin tagged. The 1970 fishery (703 fish) yielded the second highest recovery rate—2.3 percent. These higher rates were recorded using FM67 tags. The recovery rate of the all-plastic double-barbed FM67 tag was 1.6 percent for 4,236 tags used. For 5,325 FH69 ("H" type) tags used, the recovery rate was 1.0 percent. A 38 percent greater tag return rate occurred with the FM67 tag compared with the FH69 tag.

Release and tag recovery data are given in Table 2. The foreign commercial longline fleet has provided 77 percent of the striped marlin tag recoveries for the NMFS program, billfish anglers have accounted for 16 percent, and the remainder (7 percent) have come from either other types of commercial fishing boats or tags washed ashore.

Considerable variation in recovery rate by year was observed between tag types. Table 3 gives the total number of recoveries by year and tag types for 1963-81. Table 4 gives striped marlin tag recovery rates by year tagged and by the two major tag types used by NMFS—FM67 and FH69.

Angler Estimated Weight Data

The angler, upon tagging a billfish, is asked to record the estimated length and weight of the tagged striped marlin on the

Table 2.—Striped marlin tagging and recapture data, 1963-81.

	Tagging data				Recapture data		
Year	SWFC no.	Location[1]	Tagger	Date	Vessel or person	Distance[2] and direction from pt. of tagging	Days to recapture
1963	1	B	R. Fisher	6/6/63	Matsumoto maru #2	1,153/S	71
1964	2	E	G. Daley	2/24/64	Tosui maru #10	510/NW	59
1964	3	B	G. Myette	2/10/64	Okiya maru #8	162/SE	82
1964	4	B	B. Wilson	2/10/64	Seisho maru #11	140/SSE	56
1964	5	B	D. Cox	5/2/64	Kyowa maru #2	90/SSE	14
1964	6	B	C. Herrguth	5/26/64	Fukukyu maru #5	257/S	91
1964	7	A	C. Brignell	10/6/64	Kyowa maru #2	668/SE	26
1964	8	A	J. Koons	10/20/64	(Japanese longliner)	621/SE	34
1964	9	A	M. Freis	9/19/64	(Japanese longliner)	688/SE	87
1964	10	B	B. Hehr	2/7/64	(Japanese longliner)	320/SSW	154
1964	11	B	Unknown	3/15/64	Gemini/W. Kalayjiah	3/SE	40
1965	12	B	H. Chappell	3/1/65	Unknown (Mexican boat)	0 n.mi.	13
1965	13	B	J. Kott	6/10/65	Hakuyo maru #28	108/S	47
1965	14	B	C. Brignall	6/25/65	Shoei maru #7	116/NE	46
1965	16	B	R. Fredman	5/19/65	Bunyo maru #1	210/NW	82
1965	18	B	B. Nicholes	5/18/65	Syoei maru #12	361/S	64
1965	19	A	J. Mathiesen	9/6/65	Fujisei maru #3	560/SE	59
1966	20	B	R. Switzer	4/29/66	Keifuku maru #3	155/SE	13
1966	21	B	P. MacMahon	5/6/66	Keifuku maru #3	190/SE	6
1966	22	B	R. Farley	3/15/66	Keifuku maru #3	198/SE	61
1966	23	B	E. Spainard	5/3/66	Keifuku maru #3	186/SE	17
1966	24	B	O. Spainard	5/4/66	Keifuku maru #3	224/SE	19
1966	25	B	T. Munteen	3/27/66	Keifuku maru #3	226/SE	67
1966	26	B	Unknown	5/15/66	Syoei maru #7	138/S	110e[3]
1966	27	D	G. Heimpel	3/10/66	Syoei maru #7	252/W	146
1966	28	B	F. Bennett	4/14/66	(Sportboat) P. Testa	21/ESE	63
1966	30	B	P. Mackliz	5/6/66	Kyowa maru #2	161/SW	199
1966	31	B	N. Schwinn	4/7/66	Kyowa maru #2	63/S	225
1966	32	B	Unknown	Unknown	Kyowa maru #2	70/S	
1966	40	B	C. Hopton	4/15/66	Keifuku maru #7	100/NW	483
1967	34	B	H. Fink	6/9/67	(Sportboat) J. Ross	64/SW	18
1967	36	B	Unknown	2/13/67	Kaime maru #18	3,120/W	120
1967	37	B	J. Riberio	6/29/67	Koan maru #18	260/S	55
1967	38	D	G. Lyons	1/10/67	Keifuku maru #7	172/W	239
1967	39	D	L. Nelson	2/14/67	Keifuku maru #7	226/SW	213
1967	41	D	J. Sax	3/11/67	Kyowa maru #2	111/SW	45
1967	42	B	E. Horn	3/25/67	Kyowa maru #2	155/SE	30
1967	43	D	W. Milan	1/18/67	Kyowa maru #2	232/W	101
1967	44	D	M. Mernick	3/9/67	Kyowa maru #2	210/W	40
1967	45	D	K. Blacker	3/9/67	Kyowa maru #2	103/W	91
1967	46	D	H. Fait	6/21/67	Kyowa maru #2	233/W	28
1967	47	D	R. Daniels	3/3/67	Kyowa maru #2	276/W	206
1967	48	B	H. Ness	9/25/67	Kyowa maru #2	212/S	111
1967	49	D	B. Heimpel	7/14/67	Dyowa maru #2	169/W	88
1967	50	C	J. Binney	8/18/67	Dyowa maru #2	380/S	46
1967	51	D	Unknown	2/2/67	Kyowa maru #2	130/SW	93
1967	53	B	Unknown	~4/15/67	Shiyouei maru #12	280/S	150e
1967	54	B	Unknown	~4/10/67	Shiyouei maru #12	290/S	150e
1967	56	B	Unknown	Unknown	Sportboat/W. Werner, 2/2/68	Appx. same area	
1967	62	A	B. Devere	9/9/67	Kensei maru #26	2,090/WSW	179
1967	64	D	M. Olivetti	2/14/67	Syoei maru #12	285/SW	514
1968	57	B	J. McAleer	1/16/68	Anei maru #3	155/SE	27
1968	59	B	Unknown	Unknown	Anna Belle/T. Locke	< 10 n.mi.	
1968	61	B	G. Knudsen	3/16/68	Syoei maru #7	75/E	75
1968	65	B	R. Honeycutt	3/7/68	Chokyu maru #12	278/SW	183
1968	66	B	J. Warren	6/28/68	Hokucho maru #18	140/SW	65
1968	67	B	B. Enyart	4/26/68	Huckucho maru #18	241/S	166
1968	68	B	J. McTee	3/25/68	Fuku maru #8	374/SE	133
1968	70	B	R. Fansett	6/30/68	Fuku maru #8	366/S	40
1968	71	B	J. McDonald	7/22/68	Genkai maru #18	125/NW	43
1968	72	B	J. Grigsby	6/13/68	Genkai maru #18	285/SW	95
1968	73	A	D. Daley	10/5/68	(Beach) R. Armstrong	70/SE	
1969	75	B	B. Constantine	2/27/69	Sportboat/R. Jensen	12/N	1
1969	79	B	R. Taylor	2/2/69	(Japanese longliner)	285/SW	147
1969	80	B	L. Griffin	5/5/69	(Beach)/V. Wares	< 20 n.mi.	
1969	81	B	D. Sansome	2/11/69	Chokyu maru #12	81/NE	157
1969	108	B	P. McVay	12/29/69	Chokyu maru #12	156/SE	5
1969	119	D	Unknown	4/21/69	Shoei maru #38	13/W	22
1970	82	D	B. Heimpel	1/13/70	Chokyu maru #12	32/S	5
1970	87	B	J. Smith	3/1/70	Keifuku maru #7	120/E	20
1970	91	B	R. Hodgden	2/5/70	Fukuju maru #18	98/E	20
1970	93	B	R. Fadem	3/5/70	Keifuku maru #7	53/NNW	74
1970	94	B	C. Errega	5/28/70	Fukuju maru #18	195/S	36
1970	99	B	B. Ashby	1/22/70	Charter boat/T. Schiltz	210/E	57
1970	100	Unk.	D. Stone	Unknown	Shoei maru #12		
1970	101	B	Unknown	3/70e	Kyowa maru #2	180/S	40e
1970	103	A	R. Naftzger	8/2/70	(Beach)/D. Mullis	60/SE	
1970	104	B	W. Marcusson	6/16/70	Azuma maru #31	120/SW	49
1970	105	B	G. Robinson	5/26/70	Chokyu maru #15	60/S	135
1970	106	B	R. von Ottow	2/9/70	Chokyu maru #15	95/NW	225

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Table 3.—Recapture of striped marlin by year and tag.

	Recovery by ← tag type					
Year	A	FT-1	FM67	FH69(H)	Total	Percent recovery
1963	1				1	0.1
1964	1	4	5		10	1.4
1965	1		5		6	1.1
1966		2	11		13	2.1
1967		1	20		21	2.8
1968			12		12	1.4
1969			6		6	1.3
1970		1	15		16	2.3
1971			1	1	2	0.2
1972				6	6	0.7
1973				2	2	0.6
1974				8	8	1.2
1975				4	4	0.8
1976				5	5	0.8
1977				3	3	0.8
1978				2	2	0.3
1979				3	3	0.6
1980				23	23	1.9
1981			1	11	12	1.7
Totals	3	8	76	68	153[1]	

[1]Total = 155 (2 recaptures not identifiable as to year tagged).

Table 4.—Striped marlin tag recapture rates by year and tag (FM-67 and FH-69).

	FM 67			FH-69 ("H")		
Year	Tagged (no.)	Racaptured (no.)	Recaptured (%)	Tagged (no.)	Recaptured (no.)	Recaptured (%)
1963	9	0	0.0			
1964	232	5	2.15			
1965	200	5	2.50			
1966	370	11	2.97			
1967	683	18	2.53			
1968	818	10	1.22			
1969	450	6	1.33			
1970	646	14	2.16	1	0	
1971	639	1	0.01	194	1	0.05
1972	76	0		698	6	0.85
1973	8	0		334	2	0.59
1974	31	0		597	8	1.34
1975	7	0		481	2	0.41
1976	7	0		623	5	0.80
1977	5	0		347	3	0.86
1978				580	2	0.34
1979				500	3	0.60
1980				1,163	23	1.97
1981	1	1	100	701	10	1.42
Overall	4,236	71	1.57	5,325	55	1.03

tagging information card which is attached to the tag (Fig. 1). Because of their size and active nature, marlin caught by rod and reel are not removed from the water at the time of tagging, and thus only an estimate of weight is possible. Very few anglers gave estimates of length, although 96 percent of the tag cards included estimates of weights. The average estimated weight by year for

Table 2.—Continued.

	Tagging data				Recapture data		
Year	SWFC no.	Location[1]	Tagger	Date	Vessel or person	Distance[2] and direction from pt. of tagging	Days to recapture[3]
1970	107	B	J. Fiol	5/9/70	Shinko maru	70/E	152
1970	109	B	J. Recchardt	2/15/70	Chokyu maru #12	93/ESE	38
1970	110	B	C. Shattuck	3/20/70	Chokyu maru #12	125/SE	30
1970	111	D	B. Heimpel	Unknown	Chokyu maru #12	30/SW	
1970	115	B	K. Nefroney	3/18/70	Sportboat/W. Schreiner	110/NE	433
1971	117	B	G. Bruns	5/5/71	Gonei maru	213/NW	203
1971	118	A	H. Witherspoon	8/20/71	Kosho maru #11	675/SE	120
1972	121	B	J. Van Hove	4/22/72	Sportboat/A. Alvarez	<5 n.mi.	10
1972	126	B	W. Benson	5/1/72	Sportboat/G. Welton	70/SW	28
1972	138	B	A. Selby	5/19/72	Fukuju maru #32	95/SW	52
1972	139	B	T. Huls	6/2/72	Fukuju maru #32	240/NW	103
1972	197	B	R. Ayres	6/17/72	Keifuku maru #5	75/NW	670
1973	147	B	J. Birtcher	1/20/73	Kyowa maru #12	107/NE	64
1973	191	B	D. Rivoli	5/31/73	Kyowa maru #11	110/S	350
1974	187	B	Unknown	6/19/74	Chokyu maru #11	200/SW	11
1974	188	B	H. Shaw	5/27/74	Choyku maru #11	105/SE	10
1974	189	B	Unknown	1/26/74	Choyku maru #11	70/SE	124
1974	192	B	H. Moss	6/24/74	Kyowa maru #23	150/W	33
1974	193	B	Unknown	6/74	Kyowa maru #23	105/W	60e
1974	194	B	B. Guenter	6/3/74	Kyowa maru #23	50/NE	7
1974	195	B	F. Scroggs	6/8/74	Chokyu maru #12	50/E	20
1974	196	B	T. McConville	6/9/74	Keifuku maru #5	55/NW	30
1974	224	B	I. Lewis	5/13/74	Chokyu maru #25	340/S	194
1975	230	B	P. Sadkr	7/28/75	Sportboat/C. Taylor	180/SE	152
1975	263	B	C. Weiner	6/23/75	Sportboat/E. Landsaw	<5 n.mi.	987
1976	215	B	J. Carpenter	5/24/76	Keifuku maru #12	300/SW	112
1976	221	B	C. Bradfield	4/6/76	Kyowa maru #28	15/S	10
1976	225	B	Unknown	5/19/76	Chokyu maru #25	280/S	30
1976	229	B	A. Jensen	5/30/76	(Marlin on beach)	B/W	2
1976	247	A	E. Martin	11/11/76	Kotoshiro maru #15	2,520/S	80
1977	248	B	H. Consley	5/31/77	Sportboat/H. Sherman	3 n.mi.	7
1977	276	A	E. Martin	9/3/77	Sportboat/S. Nesbitt	35/E	398
1977	277	A	R. Barrett	10/12/77	Sportboat/C. Husfar	83/SE	358
1978	285	B	Unknown	6/78	El Indomable (tuna seiner)	60/SE	305
1978	306	B	F. Gilbert	12/30/78	Sportboat/L. Clinkenbeard	20/NE	475
1979	283	B	P. Locke	6/1/79	Fukuju maru #32	390/SW	81
1979	284	B	T. Sheehan	5/1/79	Fukuju maru #32	390/SW	81
1979	291	B	Unknown	4/79	Sportboat/J. Clarke	10/SE	<20
1980	299	B	W. Jossey	3/28/80	Horso maru #21	207/S	257
1980	300	B	J. Collins	12/2/80	Hosyo maru #21	110/S	13
1980	301	B	N. Ruston	3/15/80	Chidori #86	110/SSW	240
1980	302	B	A. Williamson	4/14/80	Chidori #86	120/SW	211
1980	303	B	J. Crowson	7/8/80	Chidori #86	240/W	160
1980	304	B	L. Schonert	10/14/80	Chidori #86	230/W	28
1980	305	B	S. Stevenson	5/20/80	Fukutoku maru #18	720/SE	148
1980	307	B	M. Bryant	6/9/80	(Commercial diveboat)	800/NW	130
1980	308	B	K. Johnson	5/9/80	Japanese longliner	80/SSW	90
1980	309	B	J. Cunningham	5/19/80	Japanese longliner	105/SSW	90
1980	314	B	J. Lee	6/30/80	Sportboat/M. Barks	70/SE	118
1980	315	B	S. Jacobson	4/9/80	Japanese longliner	250/S	189
1980	316	B	J. Brandes	4/9/80	Japanese longliner	300/S	180
1980	318	B	Unknown	7/15/80	Sportboat/M. Brett	<5 n.mi.	12
1980	319	B	Unknown	5/80	Sportboat/Unknown	<5 n.mi.	<10
1980	323	B	L. Wiczai	7/15/80	Hosyo maru #21	410/SW	411
1980	327	B	H. Kameron	4/2/80	Sportboat/E. Bishop	12/SW	352
1980	328	B	C. Ackerman	5/23/80	Sportboat/R. Fraser	60/S	301
1980	329	B	H. Kameon	7/17/80	Sportboat/E. Cohen	60/SW	205
1980	334	B	N. Yoshihara	5/6/80	Sportboat/A. Aguayo	180/SE	324
1980	342	B	R. Martin	6/13/80	Chidori #88	260/NW	553
1980	343	B	E. Clark	6/5/80	Chidori #88	260/NW	560
1980	344	B	T. Gillen	12/26/80	Chidori #7	240/S	337
1981	322	A	C. Herberts	8/30/81	Sportboat/B. Feldhorn	50/E	13
1981	324	B	Unknown	Unknown	Sportboat/E. Miller	<5 n.mi.	
1981	325	B	J. Brown	2/28/81	Sportboat/G. Carter	<5 n.mi.	38
1981	326	B	N. Braemer	4/4/81	Sportboat/F. Appling, Jr.	12/E	39
1981	330	B	P. Gillen	1/5/81	Sportboat/T. Gillen	20/E	5
1981	335	Unk.[4]	Unknown	Unknown	Korean longliner, 12/24/81		
1981	336	B	M. Abbott	12/26/81	Korean longliner	155/S	50
1981	337	B	P. Torre	6/15/81	Hosyo maru #21	360/S	183
1981	338	B	K. Defieore	10/23/81	Hosyo maru #21	240/NW	53
1981	339	B	E. Martin	11/30/81	Hosyo maru #21	241/NW	20
1981	340	B	D. Lyddon	7/2/81	Mosyo maru $21	360/S	166
1981	341	–	Unknown	Unknown	Hosyo maru #21		
1981	345	A	E. Martin	9/25/81	Fukujyu maru #32	600/SE	57
1981	346	B	W. Feldhorn	3/9/81	Fukujyu maru #32	30/W	210

[1]A = Southern California, B = Baja California Sur, C = Guaymas-Kino area, D = Mazatlan, and E = Acapulco

[2]Distance is listed in nautical miles.

[3]e = estimate.

[4]Unk. = unknown.

Table 5.—Average estimated weight for striped marlin tagged off Mazatlan and Baja California Sur. Mexico and Southern California, U.S.A., by year as recorded on the tag card report. Weights in parentheses represent the yearly average weight of landed striped marlin as recorded by the Balboa Angling Club, Balboa, California, and the Marlin Club, San Diego, California.

Year	Mazatlán	Southern California		Baja California Sur,
1963		135.0	(132.8)	127.8
1964	145.0	127.8	(134.9)	150.6
1965	147.1	126.7	(141.6)	136.1
1966	125.7	131.9	(129.1)	149.1
1967	117.1	130.4	(128.4)	137.7
1968	127.7	143.8	(136.8)	148.0
1969	117.9	150.0	(146.3)	132.1
1970	101.2	115.4	(138.8)	133.7
1971	106.6	132.2	(144.6)	125.9
1972	135.0	142.9	(146.4)	131.5
1973	146.7	125.0	(149.1)	135.6
1974	140.0	133.4	(144.4)	138.4
1975	160.0	88.0	(151.7)	143.2
1976	159.9	139.1	(142.6)	154.8
1977		135.5	(153.2)	148.3
1978		140.3	(148.0)	150.6
1979		142.7	(145.6)	138.6
1980		135.5	(153.2)	133.9
1981		166.2		144.7

striped marlin tagged off southern California, Baja California Sur, and Mazatlán is given in Table 5.

Longline vessels sometimes submitted weight data on recaptured marlin and occasionally biological information. A total of 74 striped marlin recoveries had usable weight data. The weights from the commercial longline fishery were with the bill and portion of head removed at about the area of eye orbit, and less gills and internal organs. The reported or dressed weight must therefore be increased by a factor of 1.2 to give the approximate round weight of the fish.

I compared the estimated weights at tagging and their calculated weights at recovery within release time periods; the results are given in Figure 4. For a release time of 0-60 days, the average recovery weight of 31 marlin was 0.3 kg less than the initial weight estimated by the angler at tagging. Variation is extensive between tag and recovery weights for 0-60 days, ranging from an overestimate of 12.7 kg (28 pounds) to an underestimate of 19.0 kg (42 pounds). For recoveries made 61-120 days after release, the average recovery weight was 1.5 kg (3.3 pounds) less than had been estimated by the angler. Weight at recovery would be expected to increase as time of recovery increased. Average weight estimated at time of tagging compared with average weight at recovery appears to show a positive growth increase for the recovery period 121-240 days after tagging. On Figure 4, only 44 percent of the recoveries (30 fish) showed an increase in weight and 56 percent (38 fish) were reported caught at weights less than estimated at tagging. Five recoveries (7 percent) indicated the same weight as tagged, some having release times of 1-2 years. These data indicate that angler estimated weight data lacks the precision necessary for striped marlin growth studies. Similar conclusions were made for black marlin resulting from our Coral Sea studies (Squire and Nielsen, 1983).

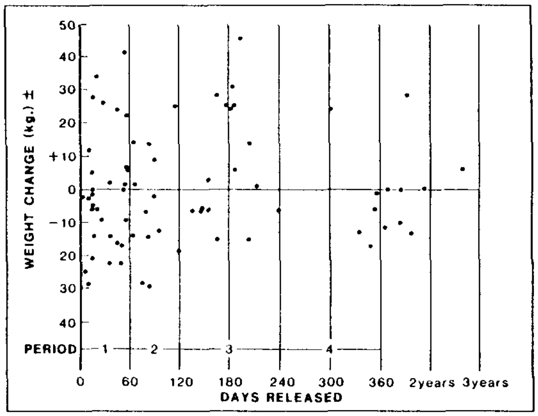


Figure 4.—Comparison of angler-estimated weights of striped marlin at tagging with weight at recovery, by release time and weight at recovery.

Migratory Patterns and Rates

The season and geographical locations of tagging must be considered in evaluating the migratory patterns and rates determined from tagging results. Striped marlin occur throughout the Pacific Ocean between about lat. 45°N to 35-40°S and are common to the tropical and temperate waters of the Pacific and Indian Oceans (Fig. 5). Based on longline catch data, the distributional pattern of this species in the Pacific is horseshoe-shaped with the base located along the central American coast (Nakamura, 1974). Striped marlin tagging in the northeast Pacific Ocean has been concentrated in two areas about the southern tip of Baja California: Off Cabo San Lucas and about 60 miles to the northeast off Bahia de Palmas in the Gulf of California (Fig. 5). Most of the striped marlin were tagged in the Bahia de Palmas area from April to August. Only a few striped marlin have been tagged in the Gulf of California north of Bahia de Palmas. Other areas of tagging were off Mazatlán from January through March, and off the southern California coast from August to October (Fig. 3).

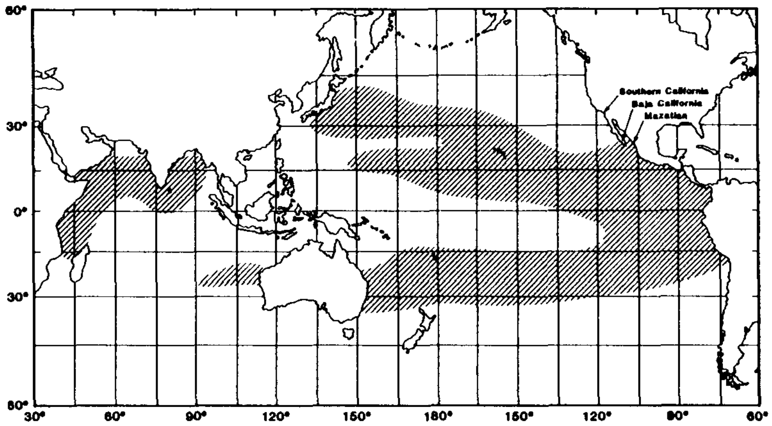


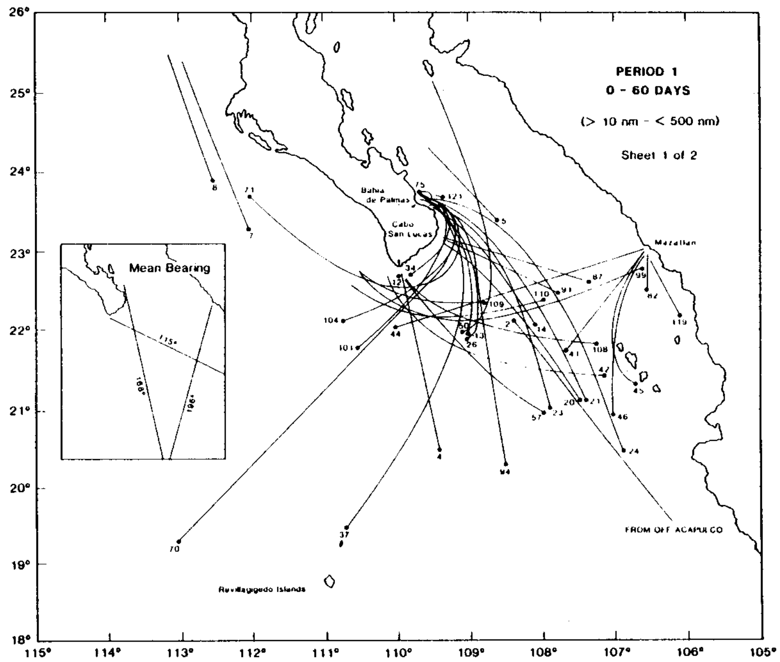
Figure 5.—Distribution of good fishing grounds for striped marlin, based on catch data from Japanese longline fishery during 1964-69 (from Nakamura, 1974).

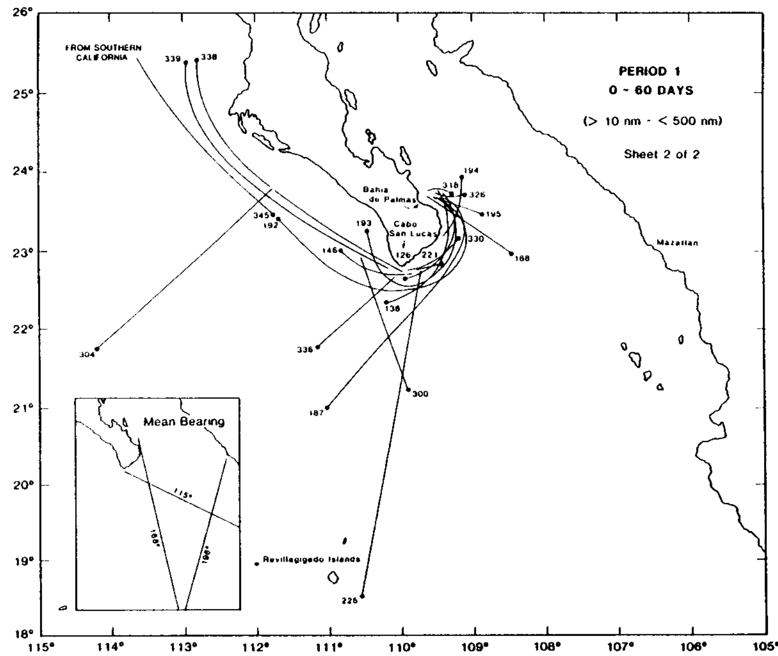
Few long-range recoveries were made. Only two marlin tagged off Mexico were recovered more than 1,000 n.mi. from the point of tagging (1.3 percent of the recoveries). One recovery was made 1,560 n.mi. south of the Baja California peninsula; the other recovery was made about 200 n.mi. southwest of the Hawaiian Islands. For southern California tagging, the majority of recoveries were off or south of the Magdalena Bay area with two of the eleven recoveries greater than 2,000 n.mi. from the tagging point. Of the three marlin recovered off southern California, two were tagged off southern California about 1 year before recovery, and the other had been tagged about the tip of Baja California Sur 130 days before recovery.

Direction of Migration

Locations of tagging, recovery, and mean bearing direction in degrees (True) of recovery from point of tagging are given in Figures 6-9 for time-at-large periods 0-60 days, 61-120 days, 121-240 days, and 241 days-1 year for striped marlin tagged off Baja California Sur, and Mazatlán. Figure 10 gives tagging and recovery locations for striped marlin tagged off southern California. From the tag and recovery geographical plots in Figures 6-10 it appears that all migration is radiating outward from a geographically localized point of tagging, and that the tagging location is the "center" of dis-

Figure 6.—Tag and recapture locations off Baja California Sur, Gulf of California, Mazatlán, and Acapulco for striped marlin released 0-60 days. Dot indicates tagging location. Line does not indicate migratory path. Mean bearing (°True) of recapture points to tagging location are shown.





tribution, which it is not. Striped marlin are tagged in an area as they migrate through it at various rates and directions. Numbers on the migration lines in Figures 6-10 indicate the NMFS Southwest Fisheries Center recovery number (Table 2).

For recoveries 0-60 days after tagging (Figure 6a, b) the mean bearing in degrees (True) from the location of tagging to area of recovery was for location of tagging off Cabo San Lucas, 115°, Mazatlán, 196°, and Bahia de Palmas, 168°. Although the mean bearing of tag recoveries is south to southeast from the southern tip of Baja California, several recoveries were made off and northwest of Magdalena Bay, indicating movement northwestward toward southern California, of striped marlin tagged about the southern tip of Baja California. Three recoveries from tagging off southern California, recovered within 60 days of release, were from recaptures of two striped marlin south of Magdalena Bay and one in the Bahia de Palmas area.

From 61 to 120 days after release (Fig. 7), most recoveries of striped marlin tagged near Cabo San Lucas and Bahia de Palmas were made to the south and southwest of Cabo San Lucas, generally in an area southwest of those recoveries observed with 60 days of release. Mean bearing for locations of tagging in relation to recovery points were for Cabo San Lucas, 182°, Mazatlán, 243°, and Bahia de Palmas, 201°. Some evidence of migration from the Bahia de Palmas/Cabo San Lucas area around the tip of Baja California was evidenced by four recoveries made south of Magdalena Bay. During the 61 to 120 day period after release two recoveries were made south of Magdalena Bay for striped marlin tagged off southern California.

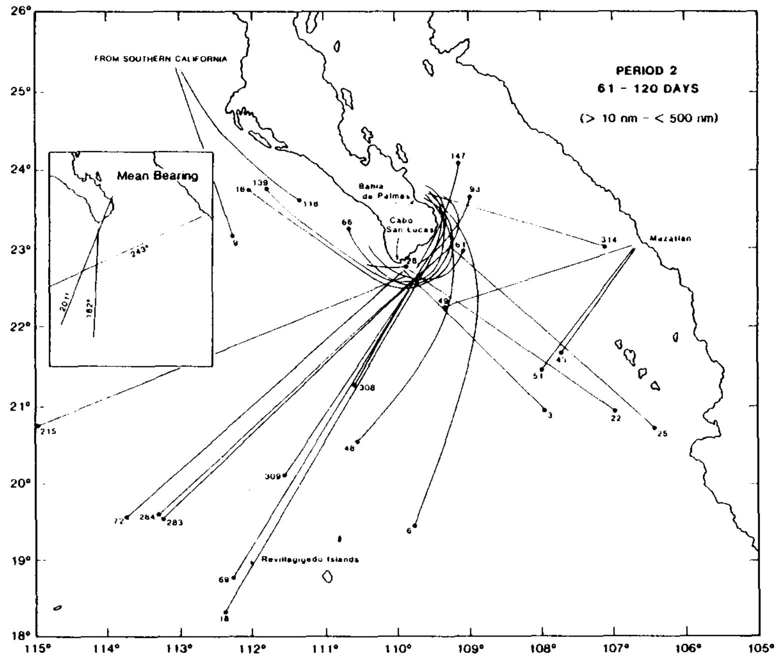


Figure 7.—Tag and recapture location for striped marlin having a release time of 61-120 days. Dot indicates tagging location. Mean bearing (°True) of recapture points to tagging location are shown.

The third time period (121-240 days after release) (Fig. 8) includes the mid-year (180 days) time of release. In considering an annual migration pattern, the 180-day time period could be important as it marks the time the fish might reach its most distant point from the tagging location. The mean bearing direction of recovery points in relation to tagging locations about the tip of Baja California again was shifted to the southwest. Mean bearing directions from tagging off Cabo San Lucas was 212° and Bahia de Palmas 196°. Five striped marlin were recovered northwest of Cabo San Lucas, between Cabo San Lucas and Magdalena Bay. The majority of recoveries were further southwest than those observed for the 61-120 day period.

Recoveries for release times of 241 days-1 year and for 1-2 years (Fig. 9a, b) were in the same area as those observed for the first two time periods. Recoveries of striped marlin tagged off southern California are given in Figure 10 and show a southern migration from the summer and early fall fishery. For recoveries of striped marlin tagged off southern California the mean bearing of recoveries 0-60 days was 153°. For the 61-120 days release time the recovery locations were 161°.

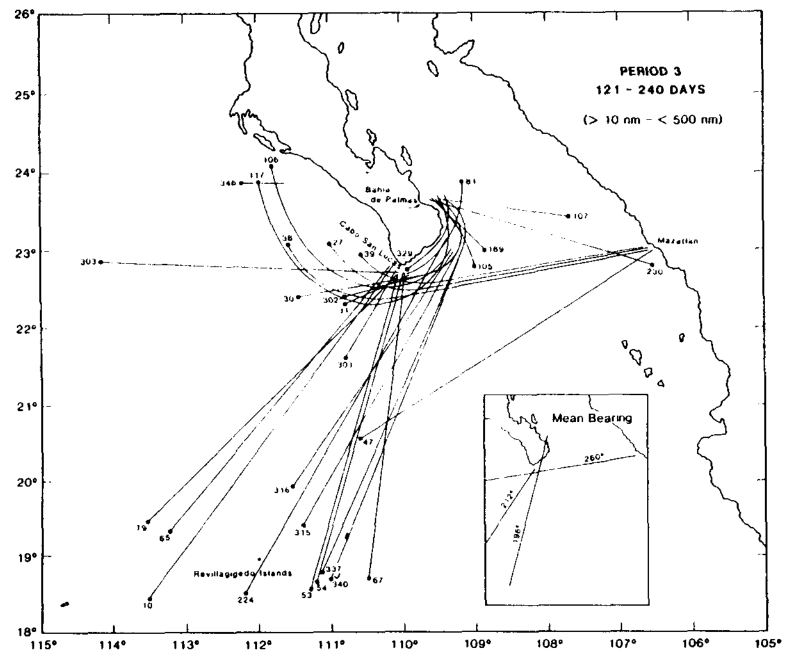
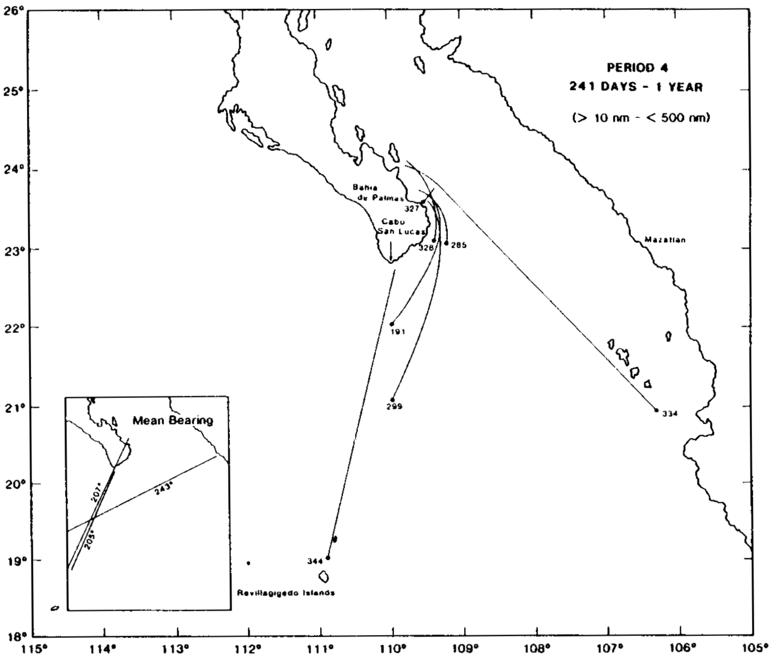


Figure 8.—Tag and recapture locations for striped marlin having a release time of 121-240 days. Dot indicates tagging location. Mean bearing (°True) of recapture points to tagging location are shown.

Rates of Migration

The average migration rate in nautical miles per day (n.mi./day) away from the location of tagging was calculated for the same time-at-large periods 0-60 days,



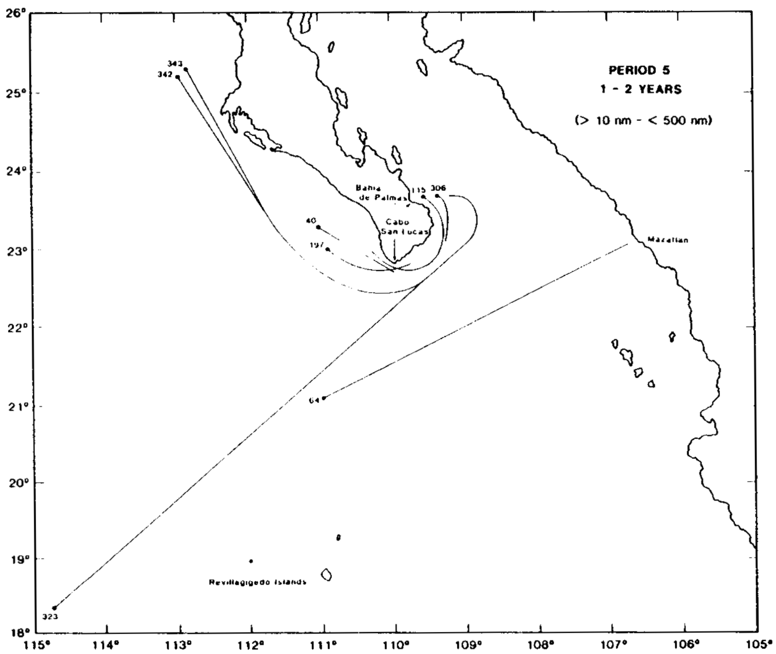


Figure 9.—Tag and recapture locations for striped marlin having a release time of 241-365 days and 1-2 years. Dot indicates tagging location. Mean bearing (°True) of recapture points to tagging location for both charts is shown on the Period 5 chart.

61-120 days, 121-240 days, 241 days-1 year, 1-2 years, and 2-3 years using data derived from time and distance from the tagging point to the recovery point. Table 6 gives the high and low migration rates observed in n.mi./day by tagging area and time period. The greatest observed migration rate for any striped marlin recovered was 31.5 n.mi./day; the fish was recovered after 80 days. The mean migration rate for all recoveries with time/distance data available was 1.6 n.mi./day.

For the first 120 days of release time, the average rate of migration about the southern tip of Baja California is much lower than the average rate of migration observed for fish tagged off southern California. Recoveries from southern California tagging recovered to the southeast or south averaged 13.3 n.mi./day. Recoveries from tagging in other areas distant from Baja California indicate that one recovery from Acapulco migrated northwest at a rate of 8.6 n.mi./day and one from Guaymas moved south at a rate of 8.3 n.mi./day.

I was most interested in the data obtained from recoveries within the first three time-at-large periods (0-60, 61-120, and 121-240 days) because these data may better define the average migration rate of striped marlin away from the major areas of tagging during the first half year of release. The average move-

Table 6.—High and low migration rates (n.mi./day) by tagging area and time period.

	High/low in n.mi./day		
Period	S. Calif.	Baja Calif. Sur	Mazatlán
0-60 days	25.7/9.5	31.2/0.42	8.3/2.5
61-120 days	31.5/5.6	26.0/0.59	2.3/1.4
121-240 days	None	6.2/0.28	1.7/1.1
241-365 days	None	0.8/0.03	None
1-2 years	10.09	1.0/0.5	10/0.1
2-3 years	None	10.0/0.1	None

ment in n.mi./day for the first three time periods was determined; then each rate was multiplied by the mean number of days within each time period in relation to zero day or date of tagging, to obtain the estimated average distance of migration per period of time-at-large. Average movement (n.mi./day) away from the tagging location for the three major areas of tagging and by time periods is given in Table 7.

A migration rate (n.mi./day) difference is evident between tagging periods in the two areas about the tip of Baja California Sur (Cabo San Lucas tip area and offshore Bahia de Palmas). I examined time and distance data for recovered marlin for differences in migration rates (n.mi./day) between these areas during the first 60 days of release time. For the Cabo San Lucas area during the winter months of November through March, the average migration rate for 13 recaptures was 4.45 n.mi./day. During the spring and early summer months of April through June, the average migration rate for 5 recaptures was 5.18 n.mi./day. For the Bahia de Palmas area, only one sample was available during the winter months of November through March. Twenty-seven recoveries were available from April through June. The average migration rate was 2.53 n.mi./day.

The average migration rate for the first 60 days for the eastern tip area (Bahia de Palmas) for both time periods combined (November-March, April-June) was 2.54 n.mi./day; off the southern tip area (Cabo San Lucas) for both time periods the rate was 4.6 n.mi./day. Therefore, striped marlin appear to be moving at about twice the rate in the southern tip area (Cabo San Lucas).

The average rate of migration from the southern tip of Baja California Sur peninsula decreases in the third time period from the date of tagging. The average migration rate for the first 60 days of release time was 4.2 n.mi./day, for 61-120 days release time the rate was 4.3 n.mi./day, and for 121-240 days the rate was 1.4 n.mi./day. For the nearby area of Mazatlán some decrease in average nautical miles per day was also evident; however, the average migration rate was about half that observed off the Baja peninsula. For 0-60 days of release time the rate was 1.9 n.mi./day, for 61-120 days the rate was 1.4 n.mi./day, and for 121-240 days the rate was also 1.4 n.mi./day.

A scatter diagram (Fig. 11) compares recovery points in nautical miles from point of tagging and release to elapsed time in days from release for recoveries made within the first 240 days of release time from tagging off Baja California Sur. For marlin recovered more than 240 days after release about the Baja California Sur peninsula, the average distance from the tagging point to the recovery

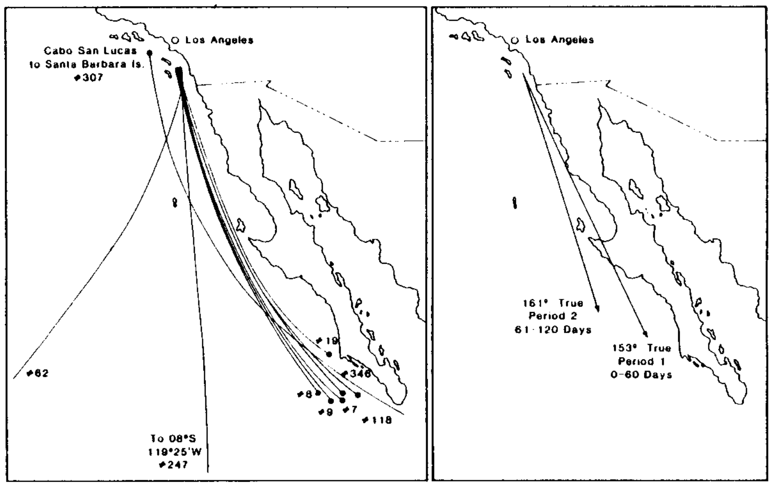


Figure 10.—Tag and recapture locations for marlin tagged off southern California. Numbers indicate month of tagging and number of days between tagging and recapture. Dot indicates recapture location and origin of line indicated tagging location. Line does not indicate migratory path. Mean bearings (°True) of recapture points to tagging locations are shown for recaptures for 0-60 days and 61-120 days.

Table 7.—Average movement away from the tagging location in nautical miles per day for each area, by time periods[1].

Area	Period	(Midpoint time in days)	No. in samples	Average n.mi./day	Period midpoint (n.mi.)
Baja,	0-60 days	(30)	49	4.2	126
California	61-120 days	(91)	23	4.3	391
Sur, Mex.	121-240 days	(181)	28	1.4	253
	241-365 days	(303)	7	0.4	121
	1-2 years	(547)	7	0.3	52
	2-3 years	(912)	1	0.01	9.1
Southern	0-60 days	(30)	6	11.3	339
California,	61-120 days	(91)	2	16.0	1,456
U.S.A.	121-240 days	(181)	1	11.7	2,117
	241-365 days	(303)	1	0.2	61
	1-2 years	(547)	1	0.1	55
	2-3 years	(912)	0		
Mazatlán,	0-60 days	(30)	9	1.8	54
Mexico	61-120 days	(91)	3	1.9	173
	121-240 days	(181)	1	1.3	235
	241-365 days	(303)	0		
	1-2 years	(547)	1	0.6	328
	2-3 years	(912)	0		

[1]Recaptures from Acapulco (1) and Guaymas (1) averaged 8.64 and 8.26 n.mi. per day.

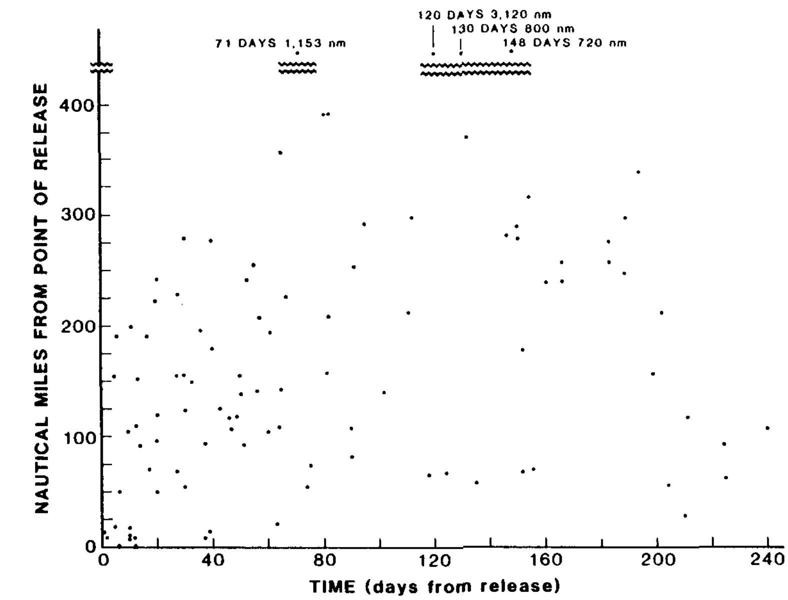


Figure 11.—Scatter diagram for first 240 days of release time for striped marlin tagged about Baja California Sur.

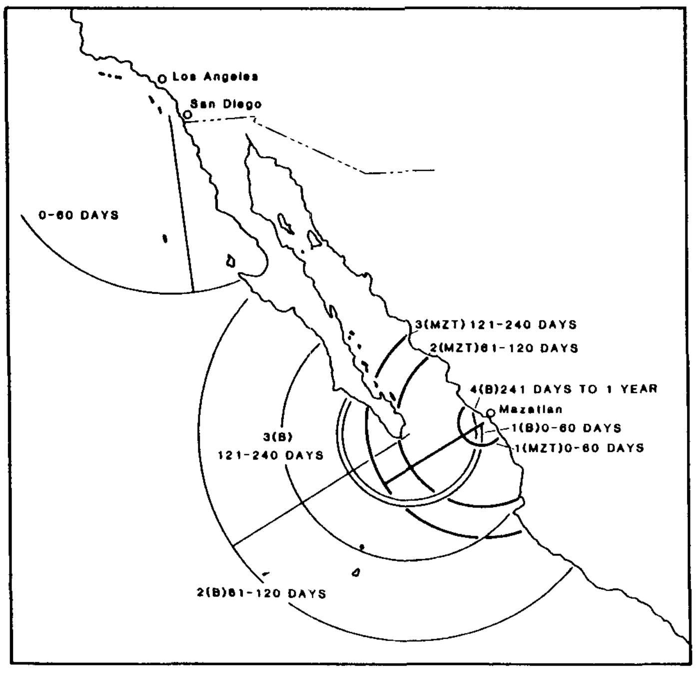


Figure 12.—Midpoint migration distances for time periods, tagging to recapture, 0-60 days, 61-120 days, and 121-240 days.

point was, for 241 days-1 year, 119 n.mi. (high, 207 n.mi., low, 12 n.mi.); for the 1-2 year period, 172 n.mi. (high, 410 n.mi., low, 20 n.mi.); and 5 n.mi. for the single recovery made 2-3 years after tagging.

Arcs showing average mileage limits for four time periods (0-60, 61-120, 121-240 and 241-360 days) for Baja California Sur recoveries were plotted (Fig. 12), using the average distance traveled from tagging to recovery per day by time period (average n.mi. per day times the midpoint for each time period).

Results would indicate a more rapid movement away from the southern tip of Baja California for marlin tagged during the late spring and early summer and during the 0-120 day period than for the following 121-240 day period. Long-term recoveries of one or more years were made in the area from Cabo San Lucas to the Revillagigedo Islands indicating that the striped marlin either remained in the area, or returned to it.

Discussion

Factors Related to and Affecting Tagging and Recovery

Tagging of large pelagics such as billfish cannot be done in large numbers, unlike with the smaller pelagics such as tuna. Also, it is difficult to obtain sufficient numbers of billfish to tag and release other than in areas having a productive rod-and-reel recreational fishery. In attempting to determine the general migrating pattern of billfish, data collected in other biological, physical oceanography, and catch analysis studies may be useful in developing a hypothesis to describe a migration pattern.

For a more ideal program to better define seasonal migration patterns, as an aid in determining stock boundaries, tagging effort should be distributed throughout the range of the species. For the migration patterns of striped marlin, tagging should be conducted in the northeast and southwest Pacific, central north Pacific, off Ecuador and around Galapagos Island, and in an area about 400 n.mi. west of Peru. The tagging effort reported here is from one portion of the striped marlin's distributional range—the northeast Pacific.

Tag Recoveries in the Eastern Pacific in Relation to the Geographical Distribution of the Longline Fishing Effort

The amount of fishing effort varies in the geographical areas fished by commercial longline, and these changes may affect the number of recoveries and recovery location. Data describing the catch and effort patterns for black marlin by the Japanese longline fishery operating off Queensland, Australia, have been useful in estimating migration patterns for black marlin in the southwest Pacific (Squire and Nielsen, 1983). Longline catch and effort data covering all the major oceans are published annually by the Research Department of the Japan Fisheries Agency, and these data are grouped by 5° longitude by 5° latitude areas and include results for striped marlin fishing.

From 1965 to 1975, striped marlin catch rates for the Japanese longline fishery in many areas of the northeast Pacific averaged 2.1 to 5.1 or more striped marlin per 1,000 hooks effective hooking effort (Suzuki and Honma[1]); maximum catch rates in the Pacific Ocean were recorded near the tagging area off the Baja California peninsula. Figure 13 outlines for 1956-70 (from Joseph et al., 1974) the average level of Japanese longline striped marlin catch per thousand hooks fished in the eastern Pacific. The effectiveness index (E) of the effort on striped marlin (effective hooks/nominal hooks) has exceeded 1.0 in the eastern Pacific since 1964 indicating "targeting" on striped marlin resources (Suzuki and Honma[1]).

Figure 14 illustrates the distribution of Japanese longline effort in the eastern Pacific at intervals of 5 years during which the tagging was conducted. Hook effort is distributed at levels of 1-2 million or more hooks per year per 5° longitude by 5° latitude area south and west of the tagging area in the equatorial area from about lat. 10°N to lat. 15°S. High

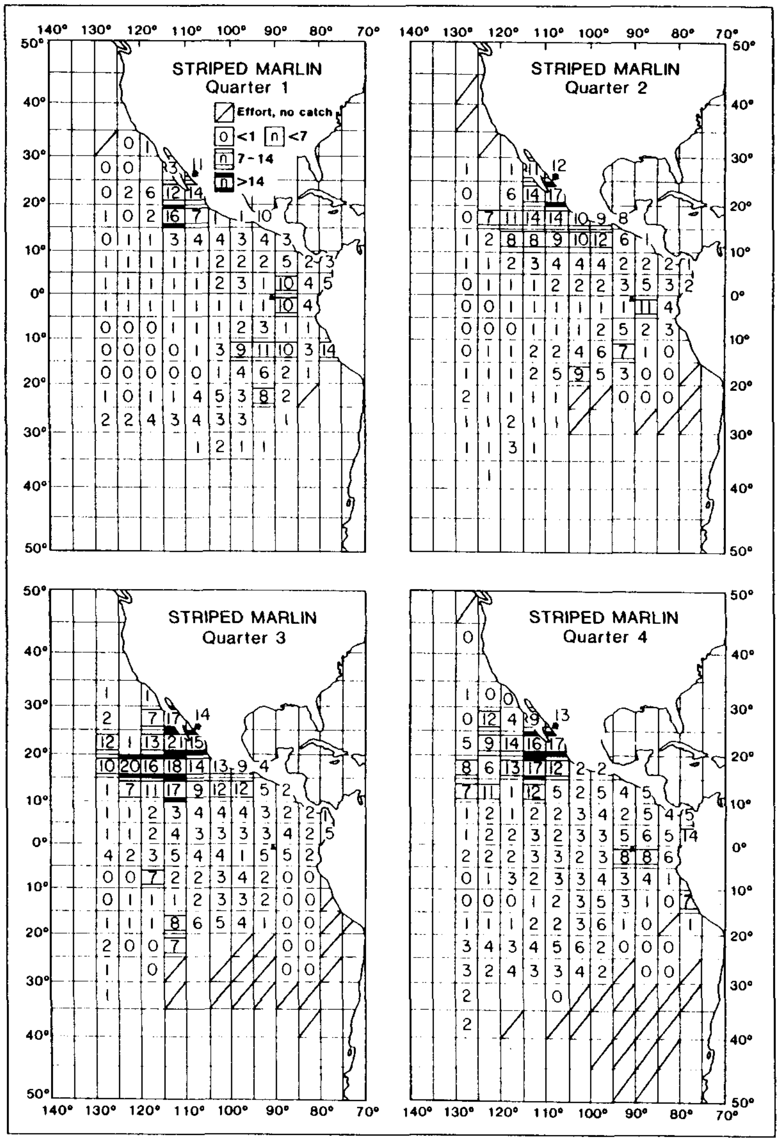


Figure 13.—Average number of striped marlin caught per 1,000 hooks by Japanese longline vessels in the eastern Pacific by quarters, 1956-70 and by 5° areas (from Joseph et al., 1974).

(1-2 million hooks) effort levels have been recorded 1,200 n.mi. southwest to 1,500 n.mi. west of the tagging area. In addition to the high hook effort near the area of tagging, these other areas of high effort provide possible recovery points for striped marlin that migrate toward more distant waters.

Relationship of Tagging Results to Spawning

Presumably striped marlin spawn be-

[1]Suzuki, Z., and Misao Honma. 1977. Stock assessment of billfishes in the Pacific. Billfish stock assessment workshop, Honolulu, HI, 5-16 December 1977. Unpubl. working pap., 129 p.

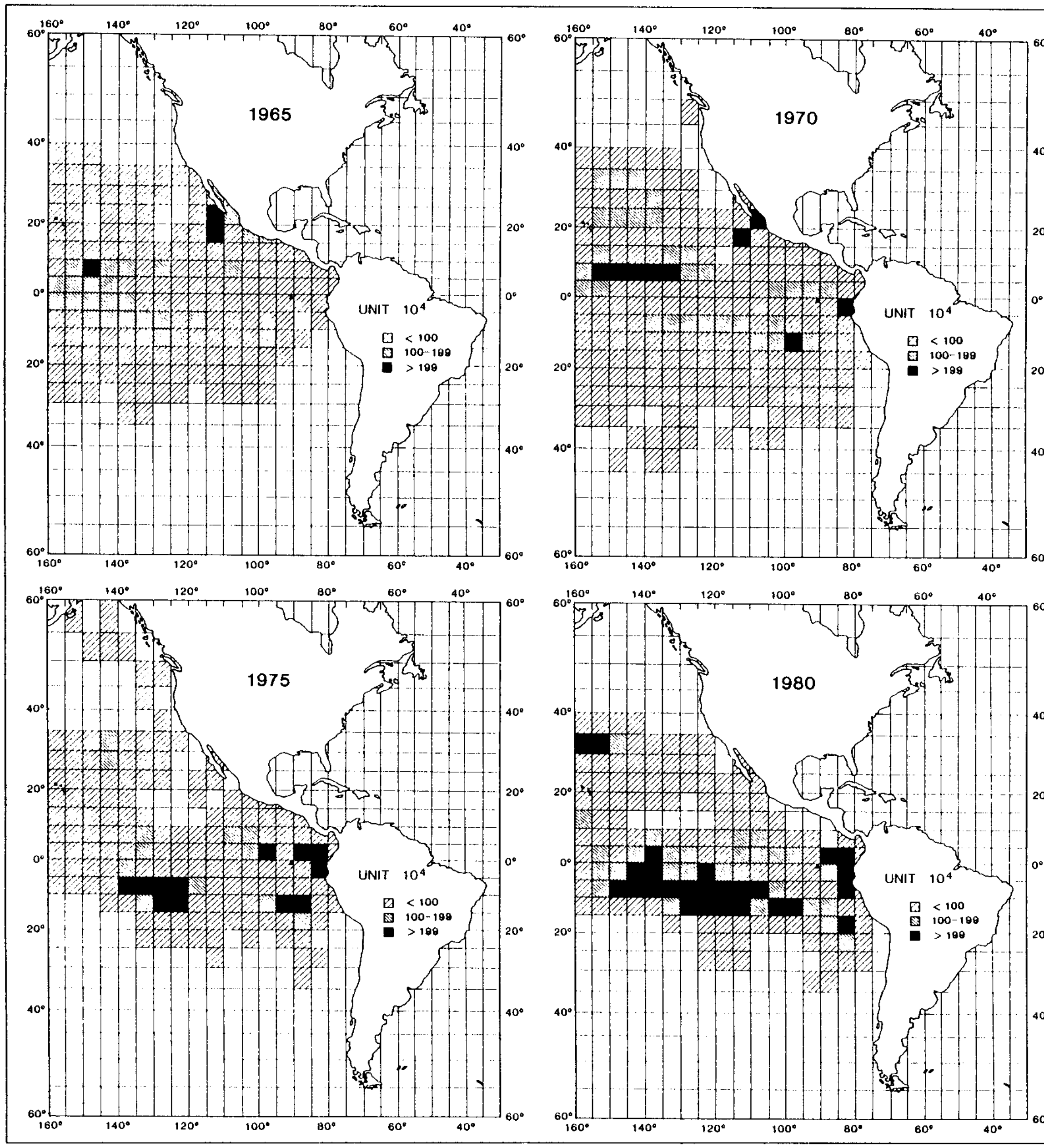


Figure 14.—Distribution of estimated total fishing effort in hook number for Japanese longline operations in the eastern Pacific.

tween June and October in the offshore areas of the northeast Pacific, south and southwest of Cabo San Lucas in the area of the Revillagigedo Islands (Joseph et al., 1974; Shoki[2]). Maturity is reached at about 160 cm (eye-fork length) based on gonad indices (Kume and Joseph, 1969). Japanese longline data for 1967 through 1975 (Suzuki and Honma[1]) indicates that in the northeast Pacific (10° × 130°W) the greatest numbers of fish were caught in the 160-170 cm eye-fork length range.

[2]Shoki, G. A., Manzanillo, Mex., 1965. Personal commun.

Longline records taken in 1983-84 for striped marlin caught by joint-venture operations in the area about Baja California indicate the maximum number of fish in the 165-170 cm eye-fork length range. Both sets of data show a large catch under the 160-165 cm length range; therefore, the population of striped marlin in the reported spawning area southwest of Baja California would appear to be composed of a mixture of immature and mature fish.

Off Mazatlán, tagging was conducted primarily during late winter and spring months, before the predicted spawning in the northeast Pacific. Also, maximum tagging effort was conducted around the tip of Baja California Sur, in late spring and early summer before and at the beginning of the predicted spawning in the northeast Pacific. Developing gonads have been noted about the tip of Baja California Sur in June and July (J. Squire, personal observ.). However, they were not approaching the high gonad index levels of near-spawning as observed several hundred miles to the south or southwest from samples provided by Japanese longline vessels.

Tagging off southern California was done in the late summer and early fall during the predicted spawning period in the area southwest of the tip of the Baja California peninsula. Sampling of striped marlin off southern California in summer and early fall showed little gonad development (gonad indices <1.0) (Eldridge and Wares, 1974). Observations of gonad development, suggest that possibly half of the tagging of striped marlin about the southern tip of Baja California may be on the immature or prespawning segment of the population. The prespawners move offshore south and southwest of Cabo San Lucas toward a spawning or feeding area.

Physical Environment Relative to Migration

Hanamoto (1974), describing longline fishing conditions in the "target" areas off Mexico, noted the movement of the fishery for striped marlin in relation to a shift in thermocline depth. He reported that the pattern of expansion and contraction of the shallow-water thermocline area of about 30.5 m (100 feet) in depth along Mexico's mainland and Baja California coast coincided with the pattern of seasonal expansion and contraction of good fishing grounds. Figure 15 is a composite of illustrations by Hanamoto (1974) which give the monthly distribution of mean relative abundance of striped marlin for 1966-70 and the monthly thermocline topography of the northeastern tropical Pacific.

Effects of Tagging and Hooking Mortality

Mortality of striped marlin as a result of the tagging process is not known. All marlin tagged were subjected to varying amounts of sublethal stress from hooking before they were tagged. Stress from hooking may not result in immediate mortality in most cases but may, in some cases, reduce the ability of the animal to cope with routine stress of the environment, and may ultimately result in an increased mortality rate (Wydoski, 1977). Hooking mortality studies on anadromous and freshwater species indicate a wide range of mortality levels, ranging from 10 percent to about 25 percent. The levels were related to the type of hooks and bait used in fishing. Hooking mortality plus natural mortality may result in a lower survival rate for tagged striped marlin.

No tag returns have been obtained for fish >3 years at large. This may be due to increased mortality due to hooking, tag loss, and the fact that a relatively small number of tags (average number tagged, 668/year) is being diluted by a large population of striped marlin (Bartoo and Ueyanagi, 1980). In comparison, Mather et al. (1974) reports that for the tagging in the western north Atlantic (with tags similar to those used in the Pacific) of 2,039 white marlin, *Tetrapturus albidus*, a species similar to striped marlin, and 216 tagged blue marlin, *Makaira nigricans*, 70 white marlin and one blue marlin were recovered. The recovery rates were 3.4 percent for white marlin and 0.4 percent for blue marlin. The population estimate for white marlin in the northwest Atlantic is considerably smaller than the population estimate for striped marlin in the Pacific (Shomura, 1980; Zuboy[3]). Higher recovery rates than those for striped marlin in the northeast Pacific, such as those observed for black marlin in the southwest Pacific (2.3 percent) and for white marlin in the Atlantic (3.4 percent) may be related to lower tag dilution rate, relative to population size.

Estimates of the Central Tendency of Migration

A tentative hypothesis can be developed describing the central tendency of migration direction and rate for striped marlin in the northeast Pacific. Using information derived from the graphic plots of tag and recovery points, the migration direction and rate analysis, movements of high CPUE areas in the commercial longline fishery over time, the geographical distribution of longline fishery effort in the total eastern Pacific, and the spawning behavior exhibited in the northeast Pacific, I suggest the following:

1) In the northeast Pacific areas of high CPUE, striped marlin move south or southwest from the tagging area in the summer and early fall and then move northward toward the Baja California peninsula in the winter and spring seasons. Tagging results parallel the seasonal catch distribution of the longline fleet.

2) The seasonal shift of thermocline depth in relation to catch distribution changes are similar to the seasonal geographical changes observed in longline CPUE rates.

3) Movement of striped marlin from an area of low gonad indices or a nonspawning area about the tip of Baja California to an area of high gonad indices and reported spawning south and southwest gives support to the results of tagging which show similar movements.

4) Recovery data indicate a predominate movement south from tagging off southern California, and the data indicate that some marlin from about the tip of Baja California Sur migrate northwest to off southern California.

5) Because few (5 or 3.2 percent) of the total recovered marlin were caught at

[3]Zuboy, J. R. 1977. Atlantic billfish stock assessment. Billfish Technical Workshop, Honolulu, HI, 5-19 December 1977. Working pap. QP-2, 36 p., unpubl.

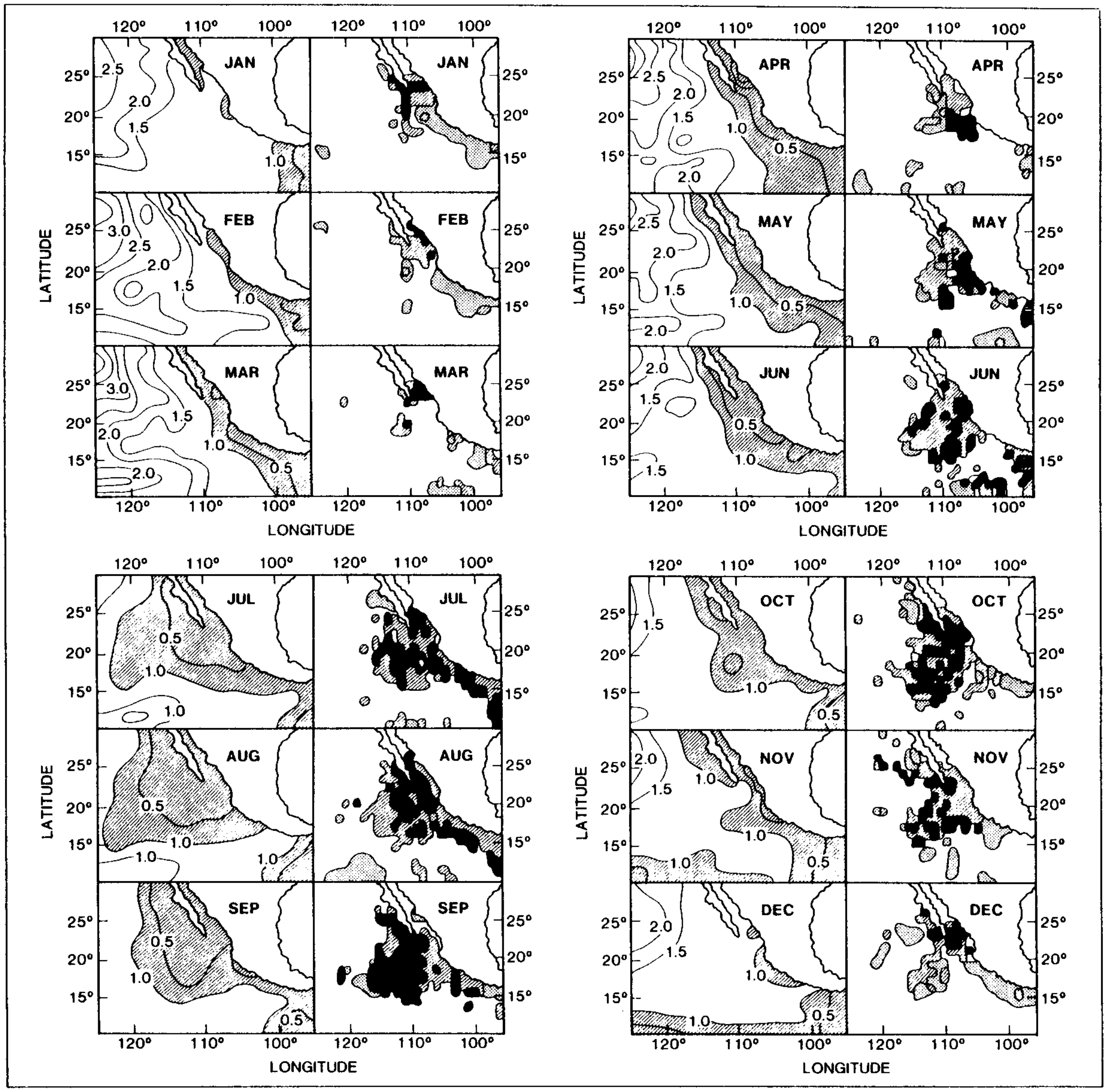


Figure 15.—Monthly distribution of mean relative abundance of striped marlin and monthly thermocline topography for fishing areas off Mexico, 1966-70. Numbers on the contour line represent the depth to the top of the thermocline in hundreds of feet. Areas of relative abundance are: high abundance (>1.5 percent), dark areas; medium abundance (1.4 to 0.5 percent), hatched areas; low abundance (>0.5 percent), strippled areas (from Hanamoto, 1974).

a distance greater than 800 n.mi. from the point of tagging, striped marlin cannot be considered short-term distant-water migrators in the Pacific, like bluefin tuna, *Thunnus thynnus*, and albacore, *Thunnus alalunga*.

The migration of striped marlin in the northeastern Pacific area of tagging and of the commercial longline fishery can be hypothesized from the results of tagging (Fig. 16). The tagging results indicate that the migratory rates and patterns of striped marlin are highly variable. There is, however, a central tendency of movement of tagged striped marlin which is similar to the shifts in CPUE; the movement of tagged fish is also patterned by biological and environmental factors that occur in the tagging and fishing area.

The recreational rod-and-reel fishery that has tagged and released striped marlin off Baja California is fishing on the same population as the commercial longline fleet operating about the tip of Baja California, as the recreational fishery and the commercial longline fishery and the recreational fishery catch-per-unit-effort (CPUE) exhibited a coefficient of correlation of $r_2 = 0.82$ (Squire, 1982). The relation of migratory patterns of striped marlin tagged in the northeast Pacific to striped marlin resources common to other geographical areas is unclear. However, the fluctuations and the downward trend of the commercial longline catch rate for areas about the southern tip of Baja California (lat. 20°N × long. 109°W and 105°W) appears to be similar to other areas in the eastern Pacific (Fig. 17). Throughout most of the remaining eastern Pacific striped marlin is not a target species for the longline fishery, and catches are incidental to catches of tuna and other species of billfish. The similarity of catch rate trends (Fig. 17) indicate that there is a relationship between the population of striped marlin that is being subjected to targeting off Mexico (25-28 percent of the eastern Pacific catch) and to striped marlin common to other areas of the eastern Pacific.

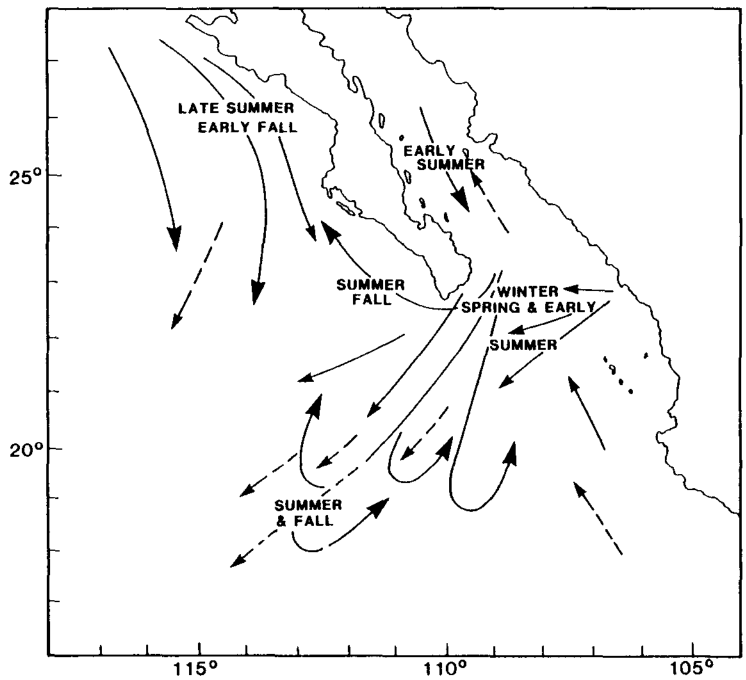


Figure 16.—Hypothetical striped marlin migration patterns for the northeast Pacific.

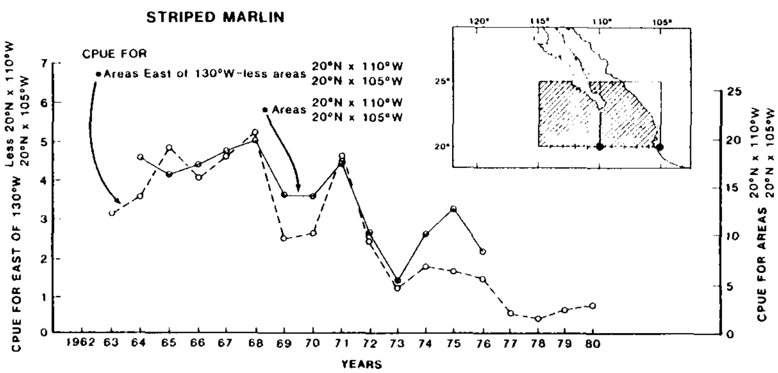


Figure 17.—Fluctuations in the Japanese longline CPUE for two 5° areas off Baja California, and the CPUE for the eastern Pacific (E of long. 130°W) less the two 5° areas.

Relation of the Findings to Management

One of the primary purposes of this tagging program is to provide data for management decisions relative to the resource stock structure of striped marlin. The stock structure of striped marlin is not fully understood; also, if any striped marlin substocks exist they have not yet been identified.

Three possible stock structure hypotheses have been proposed for striped marlin in the Pacific. At the 1977 Billfish Stock Assessment Workshop in Honolulu, Hawaii, Suzuki and Honma[1] suggested a northwest, southwest, and eastern Pacific stock division, based on biological and catch distribution evidence. The two other stock structure hypotheses which were believed most tenable at that time (Shomura, 1980) were: 1) A single-unit stock in the Pacific. This hypothesis is supported by the continuous distribution of striped marlin in a horseshoe-shaped pattern. 2) A two-stock structure, with the stocks separated roughly at the equator into North Pacific and South Pacific stocks and with some intermixing in the eastern Pacific. The two-stock hypothesis is supported by morphometric differences between adults from the north and south regions of the western Pacific (Kamimura and Honma, 1958) and perhaps also in the eastern Pacific (Howard an Ueyanagi, 1965). Kamimura and Honma (1958) also noted that there is a zone of low longline catch rates along the equator in the central and western Pacific. Larval distribution suggests two centers of spawning, one in the northwest and one in the southwest Pacific. Gonad index data (Kume and Joseph, 1969) suggest that spawning occurs throughout the eastern tropical Pacific, the supposed region of stock mixing.

The relationship of striped marlin migration observed patterns from tagging in the northeast Pacific to striped marlin inhabiting other areas of the Pacific is unclear. Relatively short migrations were common in the northeast Pacific; few recaptures in distant areas would indicate a minimum of mixing. Long-range movements over time are possible; however, only 3.2 percent of the recoveries were at a distance of greater than 800 n.mi. from tagging. Nonetheless, if a high percentage of striped marlin migrated considerable distances away from the tagging area, they would still be subject to incidental recapture since the commercial longline fishery operates over a large area at considerable distances from the tagging area.

The long-term interchange rate of the population found in the northeast Pacific with the population of the northwest and southwest Pacific area is unclear. No recaptures have been made in these areas, although a small percentage of the recaptured fish was headed in those directions, which indicates that some population interchange could be expected over time. Therefore, defining the various populations of these areas as "unit stocks" as required for stock assessment methods (Cushing, 1970) may be academic in the case of striped marlin.

The results of this migration study, when combined with other information developed from studies of striped marlin biology, fishery dynamics, and catch distribution, would indicate that the northeastern Pacific resource of striped marlin, though not meeting the unit stock criteria for management purposes as defined by Cushing (1970), could be considered a manageable resource unit of a greater Pacific resource to the extent that this area off Mexico contributes about 25-28 percent of the total eastern Pacific catch of striped marlin and 14 percent of the total Pacific catch (1962-80). If management regulations were adopted for the northeast Pacific unit if would have an impact on the status of the striped marlin resource and the associated recreational and commercial fisheries (Squire, 1982). However, management of the striped marlin resource in the Pacific on a resource unit basis would be required to include all high catch rate and target fishing areas, and would likely be part of a comprehensive international management plan for billfish and tuna.

Acknowledgments

The cooperation of the marine anglers who caught, tagged, and released striped marlin made this study possible. Their support and willingness to participate and the support of such organizations as the International Game Fish Association, National Coalition of Marine Conservation, and the major billfish clubs of southern California, enable us to carry out this work. In particular, our appreciation goes to Horace Witherspoon, Herb Kameon, and Ed Martin, for without their assistance tagging in both southern California and Baja California would have been much less successful. In Baja California Sur, where most of the striped marlin were tagged, special thanks go to Eugene Walters (now deceased), operators of Rancho Buena Vista[4], S.A., longtime supporters of the tagging program and other scientific studies in the Baja area, and to the current staff of Rancho Buena Vista, Ted Bonney, Mark Walters, and the fishing captains, and to the captain tagging and releasing the most striped marlin in the eastern Pacific, Jesus Ariza Ruiz. Others in the Baja California Sur area have given outstanding support: These include Jorge Excudero, Bob Van Wormer, Bud Parr, and most of the charter boat operators about the tip of Baja. Without the cooperation of these individuals, and the U.S. sportfishing boats that frequently fish and tag in the Baja area, in addition to tagging off southern California, increased knowledge of the oceanic migration patterns of billfish would not be possible.

Recaptures of tagged fish are just as important as tagging, and we wish to convey our appreciation to the Japanese and Korean commercial longline fleet captains and crews and to the marine anglers who recaptured tagged marlin and returned the tags. Guillermo Adachi of Manzanillo and Mario Comparan of Ensenada, Mex., have been of assistance through contacts with the Japanese longline operations off Mexico. The Japan Fisheries Agency, Far Seas Fishery Research Laboratory, Shimizu, Japan, has also been instrumental in returning tags from striped marlin recaptures by the Japanese fleet, and these important efforts are appreciated.

[4]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

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