Migration Trends of Striped Marlin (*Tetrapturus audax*) in the Pacific Ocean

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Migration patterns of large pelagic fish such as tunas and billfishes are not well defined in the Pacific Ocean, in spite of extensive tagging programs conducted for some of the species. Information on the potential for trans-oceanic or long-distance migrations has been developed for some species, but how population segments actually move is poorly known.

Investigators can determine migration trends by analyzing tagging data, length frequencies, and other biological differences by geographical areas, as well as the locations and seasonal movements of areas of high catch-per-unit-effort (CPUE). This paper reviews the biological and fishery charcteristics of striped marlin (*Tetrapturus audax*) to develop a hypothesis on their movements throughout the Pacific Ocean.

Development of the Fishery

In the post-World War II era, the Japanese longline fishing fleet expanded its operations until tunas and billfishes were fished in all tropical and temperate oceans of the world. By the early 1950s, the Japanese longline fleet had already explored the western, southwestern, and central Pacific areas for tunas and billfishes. (Honma and Kamimura 1958). By 1956, the Japanese longline fleet had reached into the eastern Pacific (E. of 130°W) (Suda and Schaefer 1965). Expansion continued through 1962, with fishing targeted on yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) in the equatorial areas. At that time, tunas accounted for about 85% and billfishes for about 15% of the catch by weight. Billfish catches by number consisted of 9% blue marlin (*Makaira nigricans*); 4% striped marlin; and 1% of black marlin (*Makaira indica*), swordfish (*Xiphias gladius*), Pacific sailfish (*Istiophorus platypterus*), and shortbill spearfish (*Tetrapturus angustirostris*) combined.

A further expansion of the fishery occurred north of the equator in the early 1960s, with rapidly increased catches of striped marlin, sailfish, and swordfish. This increase occurred as the hooking rate of bigeye tuna declined in the eastern Pacific (Shiohama 1969). This final expansion completed the eastward exploration of the Pacific by the Japanese longline fleet.

Distribution of Striped Marlin

Fishing log records are maintained by longliners for the Japan Fishery Agency, and this organization has published catch and effort data annually on a worldwide basis for the years 1962 through 1980 (Anon 1962-1980). Biological data on striped marlin for many areas of the Pacific Ocean were also collected by Japanese fishery survey vessels and shore sampling, and these data have been published in various journals and reports.

Based on these Japanese data, various authors have attempted to describe the general distribution of striped marlin in the total Pacific or portions of it (Kume and Schaefer 1966, Kume and Joseph 1969, Howard and Ueyanagi 1965, Suda and Schaefer 1965, Nakamura 1974, Shiohama 1969, Honma and Kamimura 1958, Joseph et al 1974, Shingu et al 1974, Suzuki and Honma[1], Miyabe and Bayliff 1987). The general description of striped marlin distribution

[1]Suzuki, Ziro and M. Honma. 1977. Stock assessment of billfishes in the Pacific. Unpublished.

by Nakamura (1974), when modified to indicate low-catch-rate areas (Fig. 1), suggest that few striped marlin are found in the equatorial areas. Actually, data by Suzuki and Honma indicate low catch rates of <2.0 fish per 1,000 hooks in this area, possibly due to low catchability.

The relative size of the striped marlin population in various areas of the Pacific is of importance to this study. Results of the billfish stock assessment workshop (Shomura 1980) indicate that a considerable difference exists in population size between the north and south Pacific. For assessment purposes, the striped marlin population was divided at the equator. Areas of higher catch rates were observed in the northcentral, northeast, and southeast Pacific. The Pacific-wide stock was assessed as having a yield of 24,000 mt per year and the south Pacific estimate was 6,000 mt, about 1/3 that of the north Pacific yield. This significant difference in population size should be taken into account when comparing statistics for the various areas of the Pacific, particularly those for the southwest Pacific, an area of relatively low catch rate and population strength.

Movements of Striped Marlin

Evidence From Changes in CPUE

To determine how areas in the Pacific having high CPUE rates change, and to ascertain how these changes may relate to fish movements, the striped marlin CPUE data presented by Suzuki and Honma[1] were examined. For the period 1965-1975, the mean monthly CPUE values were ranked for each 5° long. by 5° lat. area. The 1965-75 period would cover years of full areal exploitation of striped marlin. Striped marlin occur as a by-catch in most areas of the

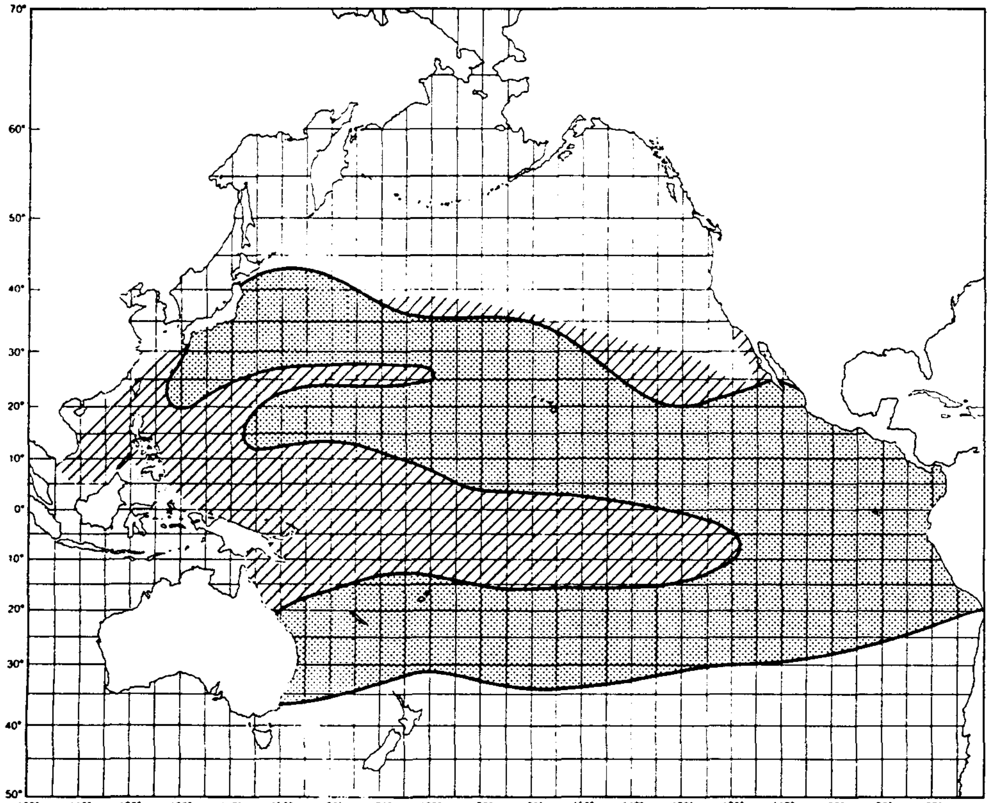

Figure 1. Distribution of good fishing grounds for striped marlin (*T. audax*) based on catch data from the Japanese longline fishery during 1964-1969 (adapted from Nakamura 1974). Light stippled areas indicate striped marlin occurrence, but at low catch levels.

Pacific except the eastern Pacific, where the species is targeted. Changes in catchability that result from targeting or non-targeting the species should not mask main patterns. Areas having an average CPUE value of 2.1 to 5.0 striped marlin per 1,000 hooks fished were assigned a value of 1, and areas having an average CPUE value of 5.1 striped marlin or more were assigned a value of 2. The monthly ranks were summed for all 12 months in each 5° longitude by latitude area where striped marlin catch exceeded 2.1 fish per 1,000 hooks (Fig. 2). The highest CPUE value (24) is found near the southern tip of Baja California, Mexico. The highest value (24) means that an average CPUE level of 5.1 striped marlin or greater occurred for all months during 1965-1975. Smaller numbers represent lesser sums of the ranking of mean monthly CPUE values. The areas to the south and southeast, off Ecuador and near the Galapagos Islands, have high CPUE values, as do areas further southwest, from 10° to 30°S lat. along 100°W long.

The highest CPUE values in the northeast Pacific were observed from June to November, while highest values in the southeast Pacific were apparent from December to March. In the southwest Pacific, CPUE values were highest in the Coral Sea area from October through January. In the north and north-central Pacific, highest CPUE values were observed north and west of the Hawaiian Islands from April to July.

Based in part on information on the movements of striped marlin from Honma and Kamimura (1958) for the southwest Pacific, Shiohama (1969) for the eastern Pacific, and Suzuki and Honma[1] for the total Pacific, we now infer seasonal movements of striped marlin from areal changes of high CPUE (Figs. 3 to 6, wherein arrow length indicates the approximate

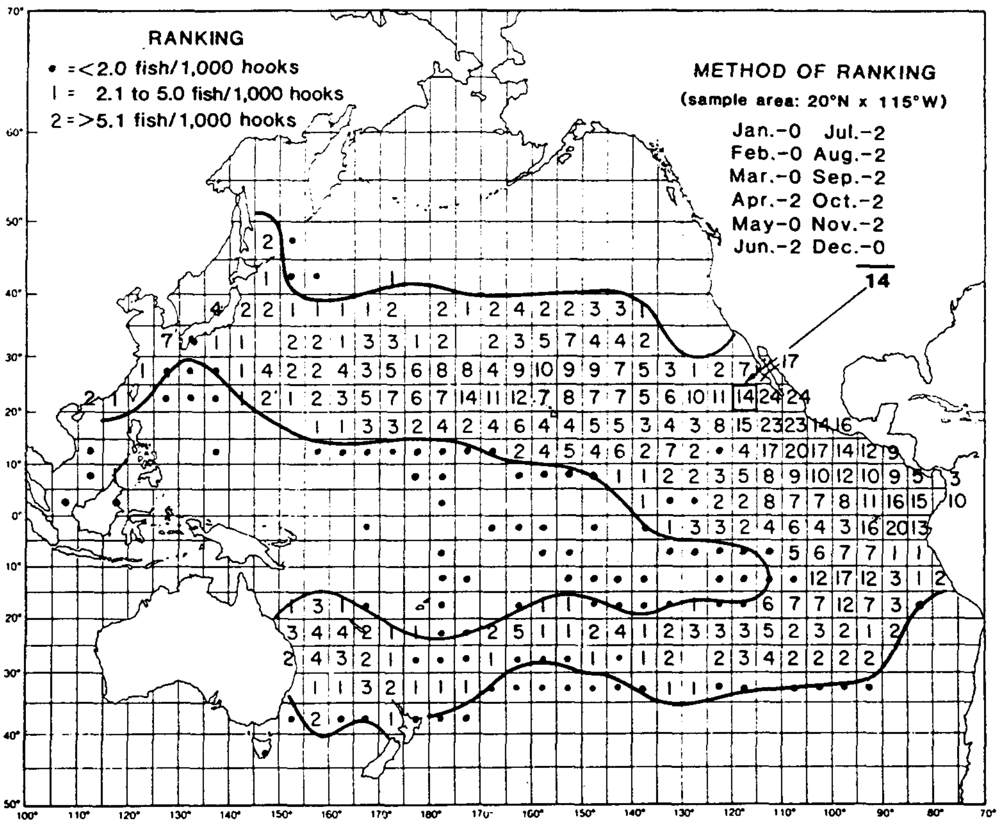

Figure 2. Rank values for hooking rates (CPUE) by Japanese longliners. Numbers represent the sum of mean monthly rank values for CPUE, 1965-1975.

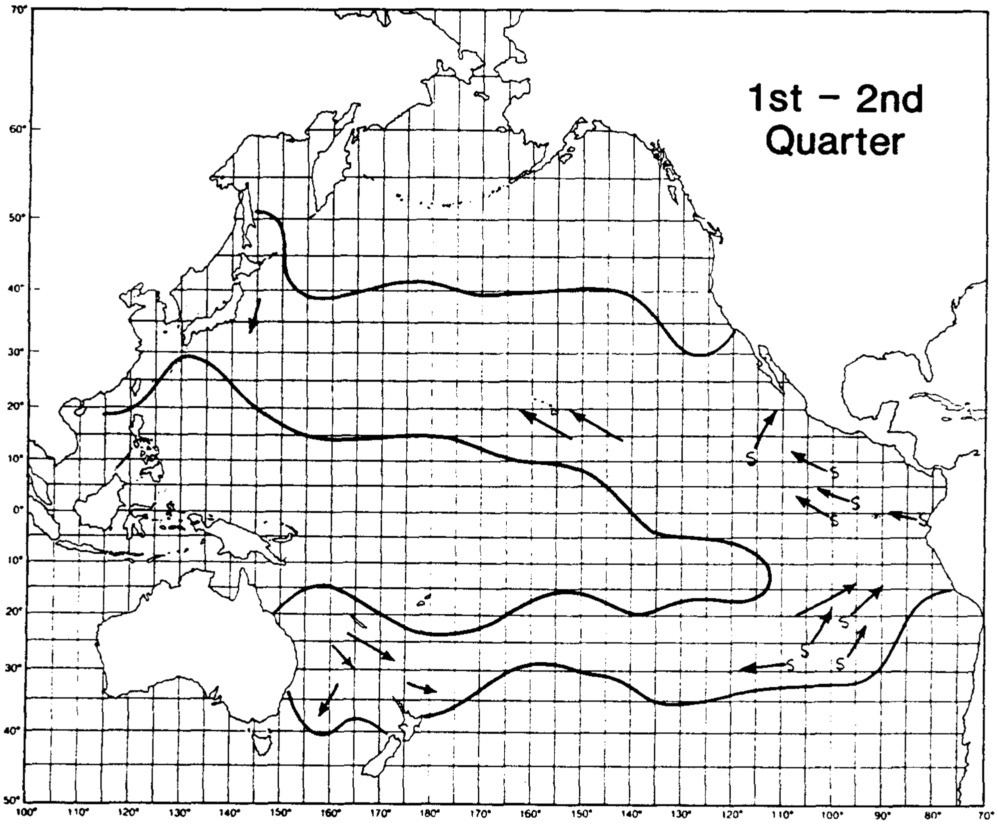

Figure 3. Trend of striped marlin CPUE movement from the first to second quarter. "S" indicates observations of Shiohama (1969).

geographical movement of higher CPUE areas).

In the southwest Pacific, striped marlin CPUE levels are low compared to those observed for the eastern and north Pacific, though seasonal changes are still evident. Fishing grounds north of New Zealand orient east to west at 16°-30°S latitude. The major fishing season is from August to January, with catches peaking in October and November. There is a west-northwest migration of high-CPUE areas to about 22°S lat. from August to November (Fig. 5) and migration is to the south to southeast after November (Fig. 6) and into the southern summer (Fig. 3). Honma and Kamimura (1958) reported a modal size group of 200 cm (eye-fork length) which was observed to be constant throughout the fishing season.

In the south-central Pacific high-CPUE areal movement to higher latitudes during the second and third quarters (Fig. 4) can be detected. There is some evidence of eastward movement from the third to fourth quarters (Fig. 5) and additional evidence of movement to the southeast Pacific area from the fourth to first quarters (Fig. 6).

In the northwest Pacific (W. of 165°E), there is evidence of a west to northwest movement of high-CPUE during the second to third quarters (Fig. 4) and evidence of a south to southeast migration during the third to fourth quarter (Fig. 5).

In the north-central Pacific (165°E to 130°W), high-CPUE movement to the east and northeast is noted from the second to third quarters (Fig. 4), shifting to a southwesterly movement in the early fall (September, Fig. 5). This movement continues through the fall and winter (Fig. 6) then shifts to a northwestward movement during the spring (March; Fig. 3).

In the eastern Pacific (E. of 130°), three areas have high CPUE levels (Fig. 2). Their areal

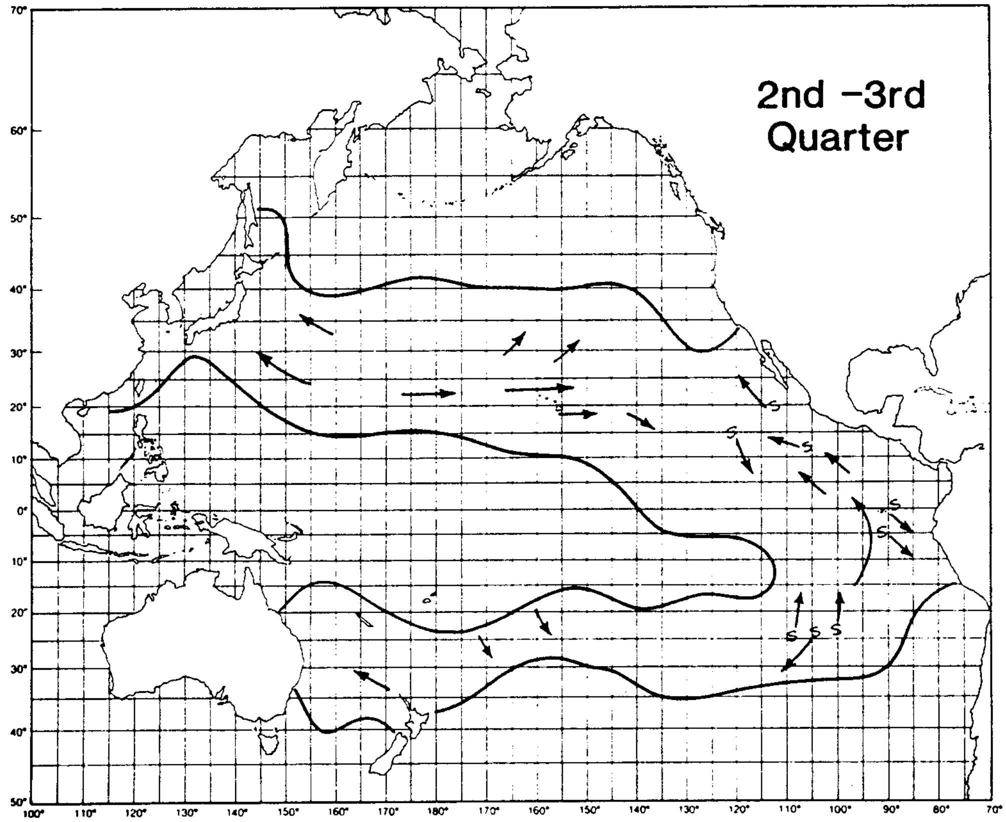

Figure 4. Trend of striped marlin CPUE movement from the second to third quarter.

changes during the first to second quarter (Fig. 3), shows a northwest movement toward Baja California from off Central America, a north to northeast movement towards the Galapagos Islands and Ecuador area, and a weaker movement toward the west at 110°W long, and 25° to 30°S lat. The change in CPUEs in the second to third quarters (Fig. 4) appears to be similar; areas of high CPUEs shift northwestward along the west coast of Mexico toward the high-CPUE areas off Baja California. A definite shift of high-CPUE areas occurs from the southeast to the northeast Pacific and there is a shift southeast of higher CPUE rates off Ecuador from the Galapagos Island area. Between the 3rd and 4th quarter, there is a shift in high-CPUE areas to the southwest off Baja California and a southeast shift toward the southern hemisphere in the offshore area off Mexico and Central America (90°-100°W long. by 5°-15°N lat.) (Fig. 5). The migration pattern southwest of the Galapagos Islands appears to be reflected in the shift toward the high-CPUE areas observed during the winter and spring months, centered about 10°-15°S lat. by 95°-100°W long.

The fourth to first quarter of the year in the northeast Pacific (Fig. 6) shows a reverse of the observations made during first to second and second to third quarter. The areas of high CPUEs shift to the southeast from the Baja California area and offshore central Mexico. A shift to the east with separate movements from the northwest and the southwest is evident in the southeast Pacific. This movement is again toward an area of high CPUE levels observed southwest of the Galapagos Islands (Fig. 2).

The foregoing longline CPUE data, from logbook summaries of catch and effort produced by the Japan Fishery Agency, must be used with caution. These data lack details needed for accurate interpretation of CPUE. Longline gear may be fished in many ways to target on specific species. Target species are not indicated on the fishing log. From sampling reported by Suzuki and Honma[1], longline gear appears to capture mostly large, older fish. Only a small percentage of striped marlin is reported at 90 cm (eye-fork) or less. The minimum and maximum sizes reported were 30 cm and 290 cm, respectively. Longline gear has the capability of capturing striped marlin over a considerable range of sizes (and ages), but data from this gear may be more applicable to the older fish. Finally, areal changes in CPUE could reflect changes in catchability or availability rather than movement.

Longline summary data (Suzuki and Honma[1]) can, nevertheless, give consistent results, and have previously been used in an analysis of tagging results for black marlin tagged in the Coral Sea off the Great Barrier Reef, Queensland, Australia (Squire and Nielsen 1983). Initial movement of tagged black marlin was generally in a southeast direction, parallelling the change of the longline CPUE rate. In the northeast Pacific, the seasonal change of high longline CPUE values for striped marlin also paralleled the movement of tagged striped marlin (Squire 1987).

Evidence From Tagging

Tagging programs for billfishes have resulted in over 12,000 striped marlin being tagged and released, with most of the fish tagged and released by anglers in the northeast Pacific off Baja California. Information from the tagging program is generally limited to migration rates and direction and distance of striped marlin routes in the northeast Pacific (Squire 1987).

The percentage of striped marlin recovered is low (about 1%). This low return rate is a common feature of billfish tagging programs in both the Pacific and Atlantic (Mather et al 1974, Squire and Nielsen 1983, Squire 1987). This may be due to tag loss, either from increased

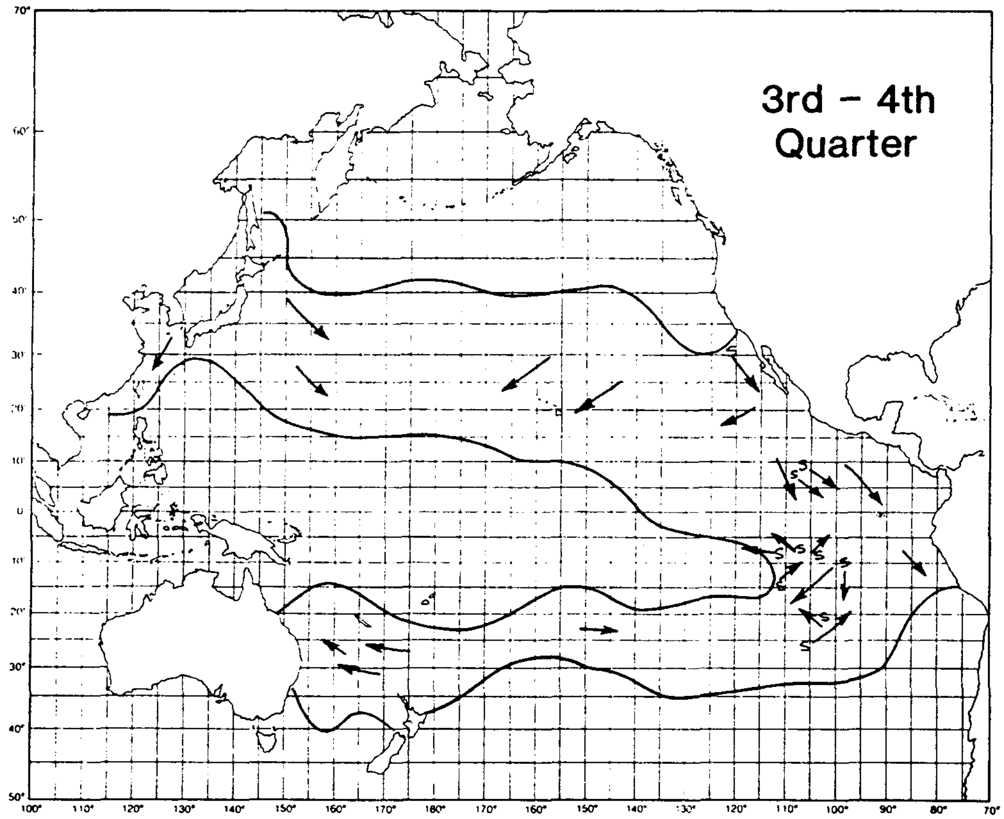

Figure 5. Trend of striped marlin CPUE movement third to fourth quarter.

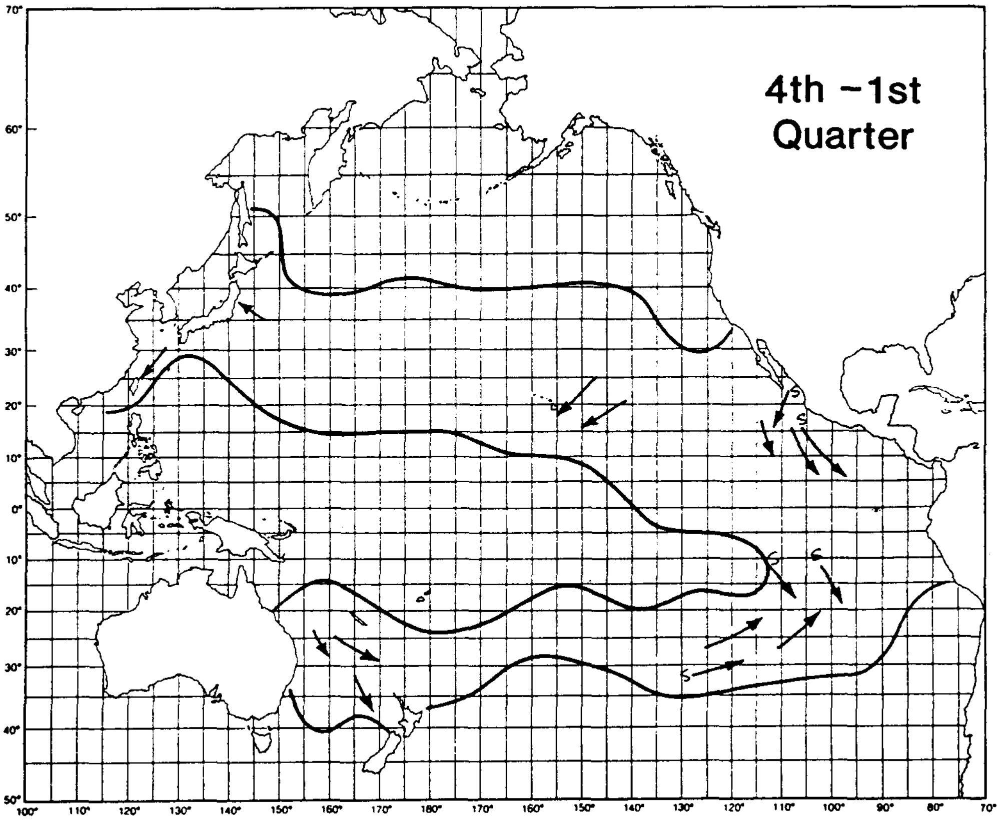

Figure 6. Trend of striped marlin CPUE movement fourth to first quarter.

mortality due to hooking, or from tag shedding, or to a combination of factors. Another unknown in evaluating the frequency of long-term recoveries is behavioral changes in migration patterns related to age. As striped marlin become older, they may move away from the highly productive "target fishing areas" into less frequently fished areas. This would tend to reduce the chance of recapture. In the northeast Pacific, length-frequency data (1965-1976 and 1980-1983) from the longline fishery (Suzuki and Honma[1]; M. Comparan, pers. comm.) would indicate that the larger size fish (older year classes) are not represented in the catch as they are in other areas of the Pacific. These factors may limit the ability of billfish tagging results to describe accurately the interactions between populations observed in various geographical areas of the Pacific.

A hypothesis describing the seasonal trend of striped marlin migration in the northeast Pacific was given by Squire (1987). Using plots of tag and recovery points, migration direction and rate analyses, movements of high-CPUE areas in the commercial longline fishery over time, and the spawning behavior exhibited in the northeast Pacific, he developed a schematic of seasonal migration. The movements can be shown in the form of time periods and distance of recovery points from the tagging site (Fig. 7) for time periods 0-60, 61-120, 121-240, and 241-360 days after tagging and release to recapture. Some of the tagged fish return to the tagging area; however, most returns were short-term (<1 year).

Long-range and non-seasonal movements from one area of the Pacific to another has been shown for some striped marlin tagged off Baja California, but a greater percentage of distant-water recoveries to the west and southwest has resulted from the limited tagging off southern California. Most recoveries from southern

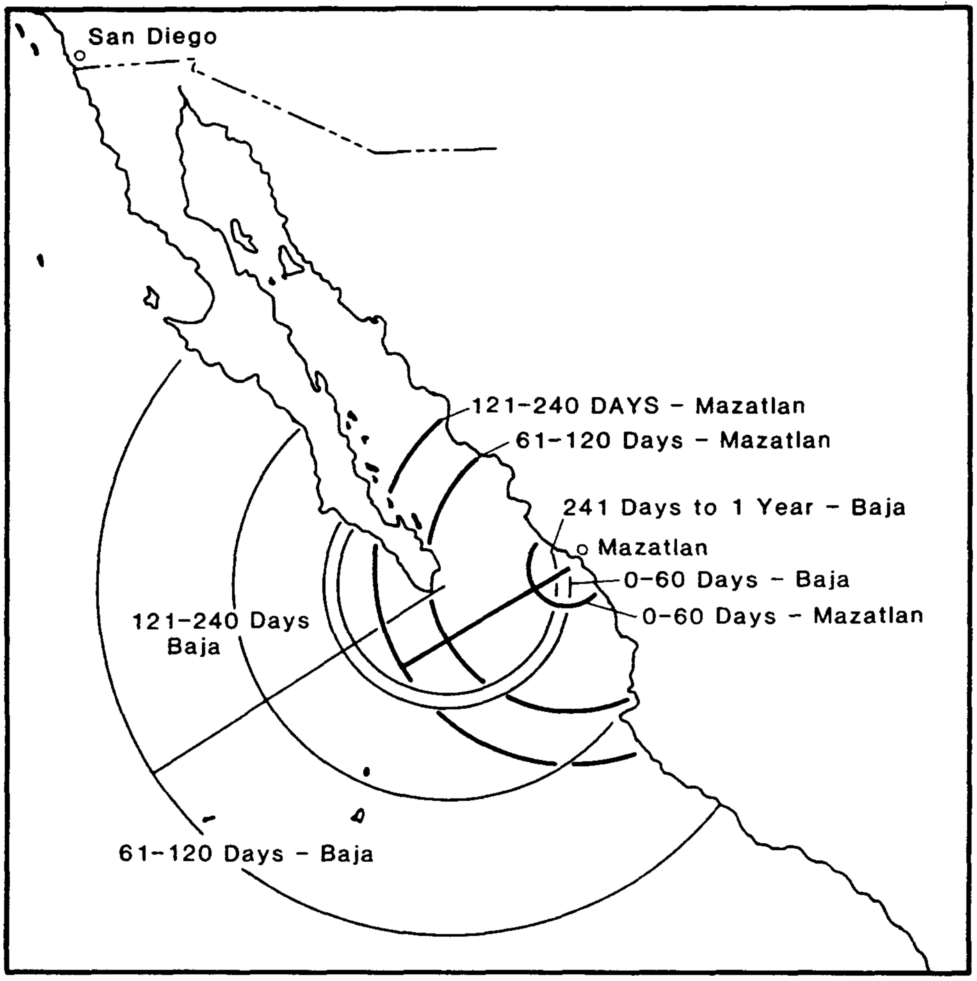

Figure 7. Average midpoint migration distances from tagging areas off Baja California Sur and Mazatlán to recapture points for time periods, tagging to recapture, 0-60, 61-120, 121-240, and 241 days to 1 year.

California tagging have been made to the southeast off Baja California, the most distant at 113°W long. by 20°S lat. Several recoveries have been made near the Hawaiian Islands, indicating that some movement is to both the north-central and southeastern Pacific from off southern California.

In January 1983, a striped marlin was reported tagged off Cabo San Lucas, Mexico, and was recovered near Norfolk Island, north of New Zealand, in September 1984. This fish was identified by the angler and charter boat captain at the time of tagging as a striped marlin; upon recapture, it was reported by the vessel's agent in New Zealand as a black marlin. The body and dorsal fin differences between a striped marlin and a blue marlin or black marlin are sufficient for identification at the time of tagging; therefore, this recovery was assumed to have been a striped marlin.

Further to examine the relationship of striped marlin tagged in the northeast Pacific to the remainder of the eastern Pacific population, the CPUE trend was compared over time between the major "target areas" for commercial and recreational fishing (and tagging) of striped marlin off Baja California (20°N lat. by 105° and 110°W long.) and the longline CPUE trend observed for the total eastern Pacific (east of 130°W long.). There is a good association between fluctuations in CPUE for the target area off Baja California (which accounts for about 23% of the striped marlin caught by the longline fleet in the eastern Pacific) and fluctuations in CPUE for the total eastern Pacific (Fig. 8). This indicates mixing between populations in the eastern Pacific at rates greater than suggested by tagging results for the Baja California area (Squire 1987). In studies of the Japanese longline fishery around Baja California, Squire and Au (1990) observed a rapid rebuilding of the striped marlin population following cessation of longline operations within Mexico's EEZ. This population increase was attributed to immigration from other areas of the Pacific into the major feeding and growth area in the northeast Pacific.

Evidence From Spawning Areas

Although spawning has been identified in the eastern Pacific by studies of gonad indices (Joseph et al 1974, Squire 1987), biological surveys to date have failed to identify this area as a major spawning location in the Pacific. The surveys include those by EASTROPAC, IATTC, and the billfish spawning surveys conducted south of Baja California, Mexico, in 1968 by the U.S. Fish and Wildlife Service.

Spawning in the western Pacific on the other hand has been well established through extensive collection of striped marlin larvae in the central and western Pacific (Ueyanagi 1959, 1974; Nishikawa et al 1985). Honma and Kamimura (1958) reviewed the southwest Pacific fishery for striped marlin and it was evident that the seasonal movement of the fishery is in positive relationship to the spawning season and area. In the eastern Pacific, tagging has indicated that striped marlin likewise tend to migrate rapidly southward of the southern tip of Baja California in the summer into an area of reported but unverified spawning (Squire 1987).

During the summer, larval and juvenile fish in the proposed spawning areas of the northeast Pacific should be carried to the west in the North Equatorial Current. Little is known of spawning in the southeast Pacific, although concentrations of striped marlin are evident there during the southern summer (5°-10°S × 100°-110°W). If this concentration is a spawning population, then the larvae and juveniles would drift westward in the South Equatorial Current.

Ueyanagi's (1974) and Nishikawa's (1985) larval distribution charts indicate that many larvae occur in the north-central to northwestern Pacific between the equator and 30°N latitude, and in the south Pacific between 10°S and 25°S

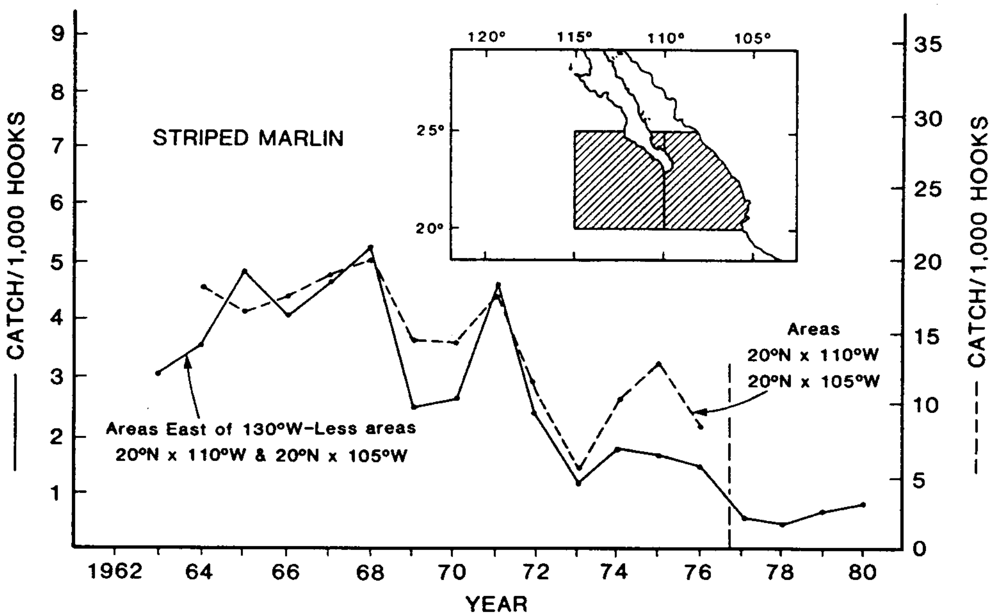

Figure 8. Comparison of CPUE trends for areas around Baja California (20°N × 105° and 110°W) and for the total eastern Pacific, less these areas.

latitude. No collections of larvae are reported east of 135°W longitude. During the summer, the current and larval drift there is westward in the North Equatorial Current, although some larvae and juveniles may drift to the east in the lower latitudes in the North Equatorial Countercurrent. In the southern hemisphere, spawning during the southern summer should result in larval and juvenile drift to the northwest.

Data from the fishery indicate that younger fish (<110 cm eye-fork) are concentrated in the north-central Pacific area, with lesser concentrations in the northwest and south central Pacific. These data, plus the dearth of larvae in the eastern Pacific — even when considering westward transport of larvae by the currents — suggest that mature fish are less likely to reside in the eastern Pacific.

Evidence From Biometrics

In 1956, Kamimura and Honma (1958) made a biometric comparison of the external characteristics of striped marlin from the north Pacific (30°-35°N) and the south Pacific (18°-25°S). Among five morphometric characters measured, a noticeable difference was observed only in pectoral fin length relative to the eye-fork length. Biological sampling (morphometrics) of striped marlin in the eastern Pacific, about the southern tip of Baja California and Mazatlan, Mexico, and southern California in the late 1960s, was reported by Wares and Sakagawa (1974). They found no differences between samples taken from off southern California and those off Mexico in the relationship of pectoral fin length and eye-fork length. Data from Wares and Sakagawa (1974) and Royce (1957) were replotted on the graphic from Kamimura and Honma (1958) for pectoral length vs. body (eye-fork) length (Fig. 9). In Honma and Kamimura's (1958) study, the difference between pectoral fin-body length relationships in the northwest and southwest Pacific appears to be size related. In the northeast Pacific, pectoral fin length (compared to eye-fork length) overlapped that of both the northwest and southwest Pacific.

Fin length and other minor differences in morphology are not supported as species-differentiating characters in other studies of pelagic species such as yellowfin tuna (Schaefer et al 1963, Mimura 1963). Royce (1957) examined fish from the central and eastern equatorial Pacific (Fig. 9). Wares and Sakagawa (1974), in reporting the findings of Kamimura and Honma (1958) and Royce (1957), concluded that there appears to be "mixing in the central Pacific of the presumed south and north stocks, of striped marlin, or Kamimura and Honma's samples did not adequately reflect the degree of variability in length of pectoral fin of fish from the north and south Pacific." It is possible that striped marlin exhibit allometric growth, and that the larger sizes have longer pectorals relative to eye-fork length. Data on pectoral fin lengths presented to date would indicate the possibility of a cline in the Pacific between the northwest and southwestern Pacific, with broad overlap into the eastern Pacific.

The concept of a stock cline seems appropriate for two reasons: the distributon of striped marlin in the Pacific is of a continuous "horseshoe shape" (north Pacific, eastern Pacific, and south Pacific); and the population in the northeast Pacific has characteristics that are representative of both the northwest and southwest Pacific (Wares and Sakagawa 1974). It appears unlikely, for reasons of proximity alone, that the southwestern population is distinct or separated from the remainder of the Pacific. However, it is possible that the population in the southwest Pacific is associated with the populations in the Indian Ocean, even though striped marlin are not caught in any substantial quantity from the Coral Sea to the Indian Ocean, and the size frequency is different from the two areas (Suzuki, pers. comm.). The southwest Pacific appears, instead, to be an area preferred by large, but not smaller, striped marlin.

Evidence From Changes In Modal Length

Examination of Japanese commercial longline length-frequency data (eye-fork lengths in cm) taken for six areas of the Pacific (Suzuki and Honma[1]) reveals a progression of modal changes among the six areas. Data for modal lengths (and the maturity point of about 160 cm; Ueyanagi and Wares 1975), spawning areas, and higher catch-rate areas (Fig. 10) can be used to infer trans-Pacific (long-range) movements of (Pacific) striped marlin over an extended time period (several years).

The north-central Pacific (Area I — east of 130°W long. and north of the equator to 20°N lat.) has within its boundaries the major areas of spawning as indicated by larval fish abundance. The catch sample for the north-central area represents 212,600 striped marlin. Only this area shows a bimodal frequency distribution with

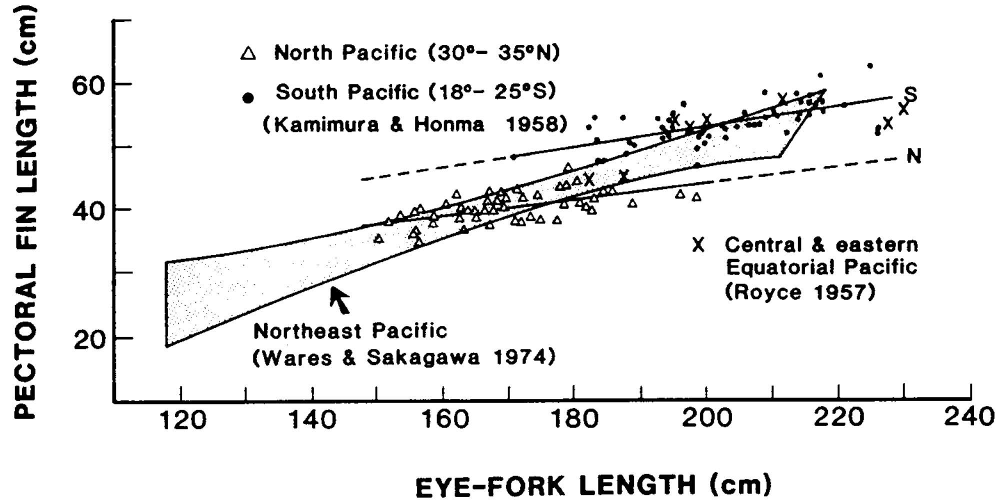

Figure 9. Relations between striped marlin pectoral fin length and body length in the north and south Pacific (Kamimura and Honma 1958), in the northeast Pacific (Wares and Sakagawa 1974), and in the central and eastern Equatorial Pacific (Royce 1957).

young fish (mode 110 cm) nearly equaling the abundance of older fish (mode 160 cm). The first mode at 110 cm (= 10-18 kg fish) was composed of fish ranging in size from 80 to 130 cm, representing immature fish seldom observed in the other areas, except Area II and Area Ia to a lesser degree. Approximately 25% of the fish sampled were within the range of 80 to 130 cm, and an estimated 55% of the sample was of immature sizes (<160 cm). The second mode was at 160 cm, with the maximum size recorded at 270 cm.

The northwest Pacific (Area II — north of 20°N lat. and east of 130°W long.) sample represents a catch of 757,400 fish; the modal length is 160 cm, which also represents about a 50% point, immature to mature fish. The numbers of fish of the smaller modal size of 80 to 130 cm observed in Area I were greatly reduced. A small mode of 230 cm fish is recorded.

The south-central Pacific (Area Ia — 0° to 10°S lat. and west of 130°W long.) is an area of lower catch, with the sample representing a total catch of 22,900 fish. The modal length in this area is 10 cm larger than in Area I, with an estimated 60% of the fish catch being above the maturity point of 160 cm. The 80 to 130 cm group, the range so substantially represented in Area I is observed, but even less so than in Area II.

For the northeast Pacific (Area III — north of 10°N lat. and east of 130°W long.), the sample represents a catch of 611,900 fish and the modal size was 170 cm, 10 cm larger than that observed for the northwest Pacific (Area II). About 65% of the fish catch is within the mature range ≥160 cm), but fish under 95 cm and fish over 210 cm were not observed, making this area the most constricted in length-frequency range. Only a small portion of the sample was of the 80 to 130 cm size group observed in the north-central or northwest Pacific (Areas I and II).

The southeast Pacific (Area IV — east of 130°W long. and south of 10°N) sample represents a catch of 498,000 fish and the modal length was 180 cm, 10 cm larger than that observed for the northeast Pacific. The size frequency range was greater than observed in the northeast Pacific (80 to 265 cm). The 80 to 130 cm group observed in the west-central Pacific represents only a small percentage of the catch. About 75% of the catch is estimated to be in the mature range. As observed for the northeast Pacific, few adults larger than 210 cm were sampled. In contrast to these eastern Pacific areas, the other areas had evidence of larger fish with small modes at 210 cm (Area I), 230 cm (Area II) and 260 cm (Areas Ia and V).

The southwest Pacific (Area V — east of 130°W long. and south of 10°S) sample represented a catch of 498,400 fish and showed an increase in modal size to 190 cm, again a 10 cm increase over the southeast Pacific and a 20 cm increase over the south-central Pacific. Only

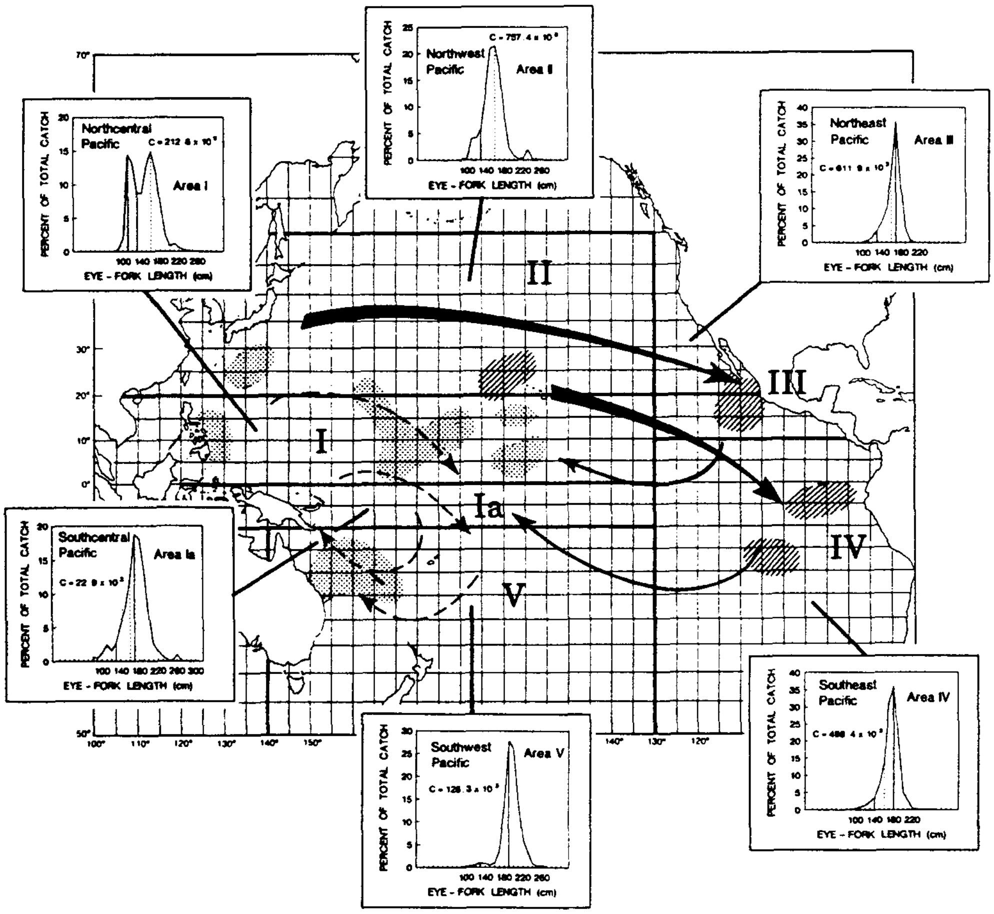

Figure 10. Distribution of length frequencies (eye-fork lengths) observed 1967-1973 in 6 areas of the Pacific Ocean, and a general scheme of movement. Heavy arrows indicate, for younger fish, the eastward clockwise movements for feeding and growth and the westward return to the spawning areas. Dashed arrows indicate similar movements of large, older fish. Movements of intermediate-aged fish would be intermediate between the patterns shown.

a small percentage of fish were observed in the 80 to 130 cm size and an estimated 85% of the fish were above the maturity breakpoint of 160 cm.

The increase in modal lengths from the north-central to northwestern and south-central, and from the northwestern to northeastern and south-eastern and to the southwest Pacific, would appear to be a reflection of the effects of long term defusive migration between the various geographical areas (Fig. 10.

Summary

From examination of the geographical locations of the major known spawning areas, the distribution of length-frequency modes, differences in morphometrics, and changes of high-CPUE areas in the commercial longline fishery, a generalized migration pattern can be hypothesized:

- The major spawning area is in the western Pacific (north-central to western). Some spawning may occur in the eastern Pacific but few larvae have been caught there. There is also spawning in the southwest Pacific. Only a small percentage of young fish is caught in the northeast, southeast, and southwest Pacific, whereas a large percentage of small fish are observed in the catch in the north-central Pacific; the percentage declines in the northwest and south-central Pacific. Small fish are more common westward from the central Pacific. Young fish (larvae or juveniles) may migrate or drift westward from the major spawning area in the North Equatorial Current and, as they grow, some may move into the northwest and south-central Pacific. Sizable numbers of juvenile striped marlin must, however, migrate to the northeast and southeast Pacific areas, which are the most productive for fish of 170 and 180 cm (eye-fork length).

- Changes in areas with high CPUE values indicate local migrations that parallel the seasonal changes of the total environment (physical and biological); i.e., poleward during the northern and southern summers in the respective hemispheres. Changes in migration patterns with growth in size is likely.
- Modal shifts in eye-fork length can be observed from length-frequency data (Fig. 10), which indicate a shifting of individuals over time from the north-central to the northwest and south-central Pacific, and to the north and southeast Pacific, and then to the southwest Pacific. Modal data indicate that the north-central, northwestern, and south-central areas have populations of both old and young fish, while the northeastern and southeastern areas have intermediate-sized individuals.

In their publication on tunas and billfishes, Joseph et al (1979) describe tunas as "wandering fish," and this description could also be applied to striped marlin. From tagging evidence, however, striped marlin cannot be described as "highly migratory" in the sense that rapid trans-ocean migrations are as common as for such species as bluefin tuna *(Thunnus thynnus)* and albacore tuna *(Thunnus alalunga)*.

Evidence suggests that a net long-term movement occurs from areas having high percentages of smaller fish to areas with larger fish. The indicated long-term movement between the north-central Pacific, an area with small fish, to the southeast and northeast Pacific, and the movement of fish back to the west as they grow, appears to be slow. The larger sizes (>200 cm) are not present in the northeast and southeast Pacific, indicating that these areas are more important as feeding than as spawning areas for intermediate size fish. After a period of time in the eastern Pacific, the maturing fish probably wander back westward to the major spawning areas, and the larger sizes thereafter tend to remain closer to the spawning areas in the western Pacific. A possibility exists of an identifiable population in the southwest Pacific, based on pectoral fin length; however, data from other areas tend to refute this possibility even though indicating a gradation or cline of pectoral fin lengths — which may be due to allometric growth.

The migration patterns of striped marlin appear as a general movement that would indicate a stock relationship among all areas in the Pacific. This relationship may be similar to that of yellowfin tuna in the Pacific (Suzuki et al 1978) as "semi-independent subpopulations" in the high-abundance areas. The actual interchanges among areas will be difficult to determine because, throughout the Pacific, these fish seasonally move poleward and back and between feeding and spawning areas, their availability alternately increasing and decreasing in the geographical areas that are centers for feeding or spawning. Depending upon maturity and feeding conditions, some fish will range farther than others, and it is possible that most may move, in time, to most other areas of the Pacific. Overall movements, however, are diffusive over years rather than highly migratory, and this circumstance should permit management by "stocks."

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