Striped Marlin in the Northeast Pacific — A Case for Local Depletion and Core Area Management

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Commercial and recreational fishermen have been fishing billfish along the west coast of the Americas from California to Chile for several decades. Game-fish fishermen using rod-and-reel have fished for sailfish *(Istiophorus platypterus)* in major catch areas off Mexico, Costa Rica, and Panama; for blue marlin *(Makaira nigricans)* and black marlin *(Makaira indica)* off Panama, Ecuador, and Peru; and for striped marlin *(Tetrapturus audax)* off southern California USA, Baja California Sur-Mexico, and Ecuador. There are also commercial harpoon fisheries for swordfish *(Xiphias gladius)* off southern California and Chile and hook-and-line fisheries for marlin and sailfish at localities along the east coasts of the Pacific Ocean. Since 1980, a commercial offshore drift-gill-net fishery has expanded off California, increasing the catches of swordfish and incidentally-caught striped marlin. These are localized fisheries that are dwarfed by Japanese longline operations in the eastern Pacific that began after 1960.

This paper reviews the development of the eastern Pacific longline fishery for striped marlin and its impacts upon recreational fishing. It presents some arguments for "core area" management of the striped marlin resource for providing a suitable level of catch necessary for both longline and recreational rod-and-reel fisheries.

Eastern Pacific Billfish Fisheries

Commercial Fishery

After World War II, the Japanese expanded their longline fishing operations from the western Pacific into the southwest and central Pacific. They began exploration into the eastern Pacific (east of 130°W) in 1956 and, by 1963, were fishing over most of the tropical and subtropical areas of that area (Fig. 1). During this same period, Japanese exploration and longline fishing for tunas and billfishes had also expanded into the Atlantic and Indian oceans.

In 1963, the Japanese shifted considerable longline effort into the northeast tropical Pacific (north to 27°N lat.), where they had already found concentrations of striped marlin, sailfish,

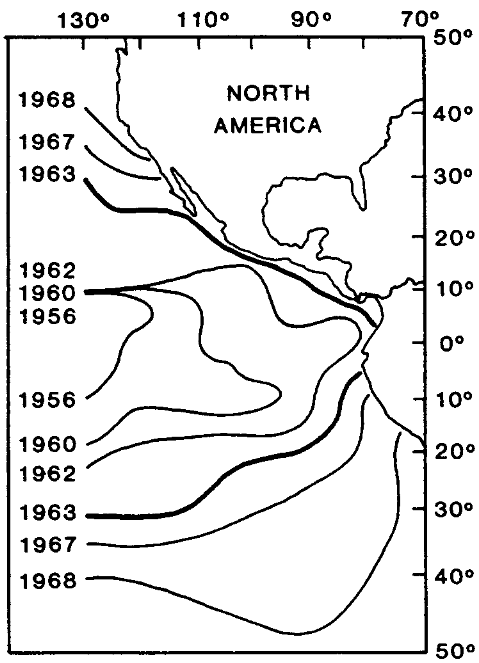

Figure 1. The 1956-1968 expansion of the Japanese longline operations into the eastern Pacific (E of 130°W), adapted from Joseph, Klawe, and Orange, 1974.

and swordfish as well as minor amounts of blue marlin and black marlin. Billfish catches increased in the eastern Pacific (Fig. 2), with the fleet concentrating on sailfish in areas from southern Mexico to Panama and on striped marlin and swordfish in an area from the Clarion and Socorro Islands to the southwestern coast of Baja California Sur, and the lower mouth of the Gulf of California. During 1962-1980, the catch of tunas and billfishes in the eastern Pacific amounted to 23.8 million fish, of which approximately 69% were tunas and 31% billfishes.

Fishery statistics of this expansion into the eastern Pacific have been collected by the Japan Fisheries Agency, which requires that all Japanese longliners prepare daily fishing logs. The results are published annually and give the total species catches and hook effort by 5° longitude and latitude intervals (Anon 1962-1980). Unfortunatly, the Japan Fishery Agency has not released these detailed catch-and-effort data for the years since 1980.

Striped marlin, swordfish, and sailfish catch trends in the Japanese longline fishery are shown in Figure 3 for the period 1956-1980. Striped marlin catches peaked in the eastern Pacific at 338,000 fish in 1968, but have declined since. Swordfish catches increased to 112,000 fish in the late 1960s, then declined by the early 1970s to 28,000 fish, due in part to findings of methylmercury in the fish (the "mercury problem"). Sailfish catches rose rapidly to 417,000 fish in 1965, but declined to 19,000 fish by 1980.

The catches noted preceding are less than the true totals by the amounts caught by Korean and Taiwanese longliners, tuna purse seiners (incidental catch), recreational anglers fishing from Peru to California, and by the commercial swordfish fleet. Some of these fisheries are expanding. The new drift-gill-net fishery off California landed over 25,000 swordfish in 1986, well above the 1978-1980 annual average of 4,500 fish taken by the traditional harpoon fishery.

Even so, the Japanese longline fleet and its associated joint-venture operations still comprise the major fishery for billfish in the eastern Pacific. Moreover, it is the only oceanic longline fishery there that has maintained acceptable fishing records over a long period of time.

Rereational Fishery

The billfish catch in the eastern Pacific taken otherwise than by longline is relatively minor. The recreational catch of striped marlin off California takes about 800 fish per year. [In contrast, an estimated 1,500 other striped marlin have been taken incidentally there in recent years

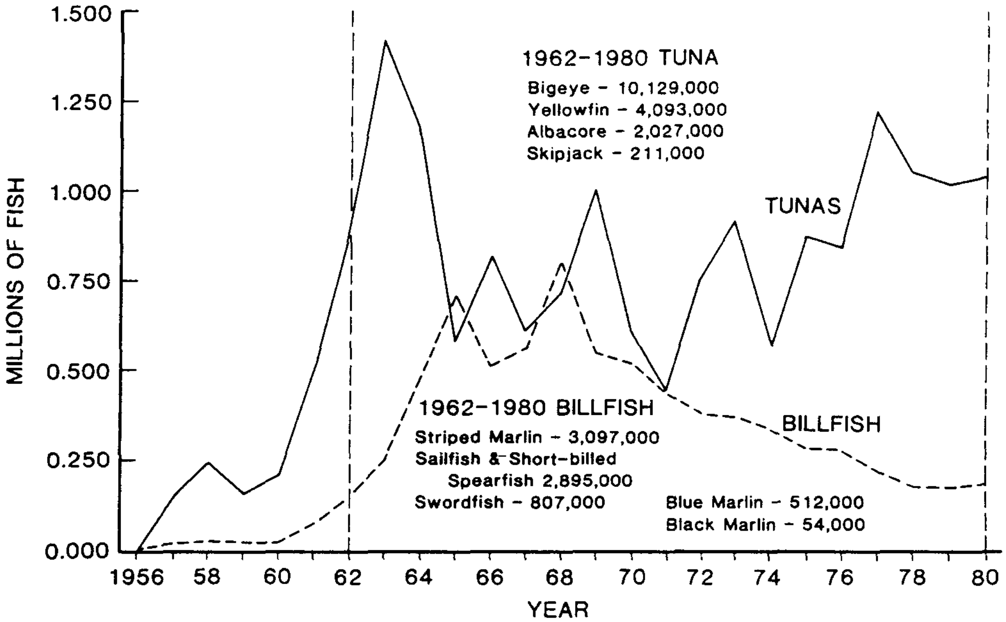

Figure 2. Catch by year for billfish and tuna, 1956-1980, by Japanese longline east of 130°W.

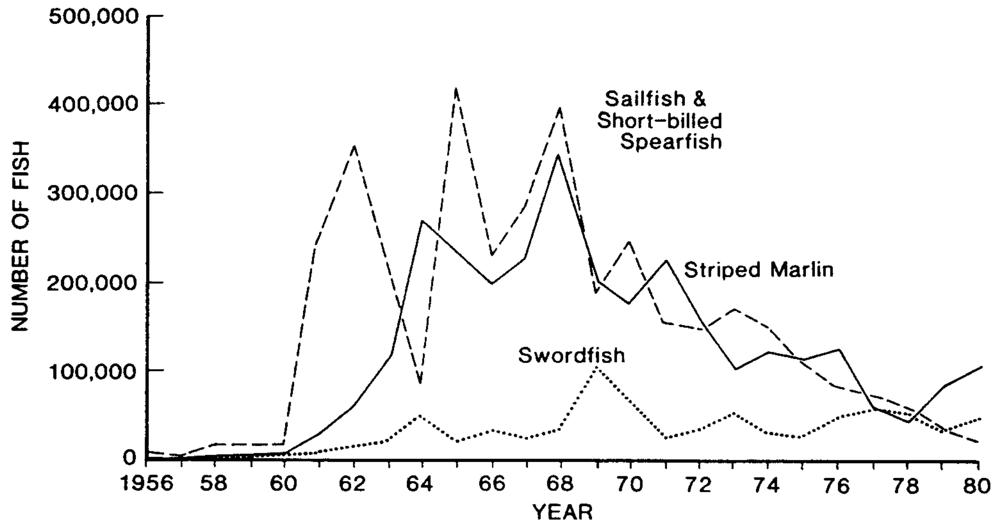

Figure 3. Eastern Pacific Japanese longline catch of sailfish and short-billed spearfish, swordfish, and striped marlin.

by the drift-gill-net fishery for swordfish and thresher shark *(Alopias* sp.).] A preliminary estimate of the recreational catch off Mexico (Joseph, unpubl. MS[1]) indicated 40,000 to 90,000 billfish taken per year. Most are Pacific sailfish, high production areas of which occur off Acapulco, Zihuatanejo, and northward to Mazatlán. The estimated annual Mexican recreational catch of striped marlin is 7,000 to 15,000 fish, the majority from around the southern tip of Baja California Sur. High angler catch rates for striped marlin (0.4 or more fish per angler day), plus occasional catches of blue marlin and black marlin, attract anglers to that area from the United States and many other countries.

Commercial companies that service recreational anglers are very important to the economy of the southern tip of Baja California, and catch rates must meet anglers' expectations. Recently, operators from the major sport fishing locations there have complained of declines in billfish catches, which they have blamed on newly developed, joint-venture longline fisheries.

The Striped Marlin Fishery

Management Approaches

Although Pacific-wide management of pelagic billfishes has long been considered, it is unrealistic to expect such management in the near future. The only international agency that has investigated management for billfish on an ocean-wide basis is the International Commission for the Conservation of Atlantic Tunas (ICCAT). That organization was formed before the widespread adoption of 200-mile economic or fishery zones in most areas of the world. The recent adoption of such by many Pacific countries complicates development of a single multilateral international agency for the Pacific.

Countries having substantial catches of billfishes and high catch-per-unit effort (CPUE) rates within their 200-mile zones readily foresee that localized restrictions upon foreign fishermen can have a measurable impact upon their own billfish fisheries. Economic conflicts among different billfish fisheries within these countries' extended boundaries also heighten the incentive for management. Interest in management of a pelagic resource at a localized level thus gains momentum.

The striped marlin resource around the southern tip of Baja California, Mexico, constitutes such a fishery. It supports a very productive localized commercial longline fishery having the highest reported CPUE in the Pacific. It also supports an economically important and productive recreational billfish fishery. Localized management that is restricted to this "core area" of striped marlin distribution (core-area management), and

[1]Joseph, J. 1981. Report on the development of a Mexican longline fishery, unpublished.

which provides for both fisheries, would thus appear feasible. Demonstrations of area depletion (or local depletion) of stock as grounds for this kind of management must, however, be viewed within the context of the entire exploited stock.

Management actually began in 1976 when the government of Mexico proclaimed a 200-mile exclusive economic zone (EEZ). In early 1977, Mexico made a concerted effort to enforce its conditions. Japanese and U.S. longliners, as well as other foreign nationals operating within the 200-mile limit, were not allowed to continue fishing. In 1980, however, a number of permits were issued, thereby allowing the operation of several foreign longliners in a joint-venture program within the EEZ. Commercial longlining under permit continued until mid-1984, when permits were again withheld. Permits were reissued in late 1985, and it is reported (M. Comparan, pers. comm.) that approximately 14 longliners were operating under permit in 1987, targeting on striped marlin and swordfish (plus 6 shark longliners which catch striped marlin incidentally). [*NB:* On many of our graphics, we show a dashed line separating the years 1977 to 1980 and 1984 to 1985, indicating the times during which there was enforcement of Mexico's 200-nautical-mile economic zone, when no longline permits were issued.] In August 1987, following strong complaints by sport fishing operators, new regulations were issued that restricted these longline operations to the offshore areas of Mexico's 200-mile zone, out of the high-catch-rate areas.

For slightly over 3 years — the first period when permits were withheld (early 1977 to late 1980) — commercial longlining was nearly nonexistent in that area having the highest striped marlin catch rate in the Pacific (see following) and also a high catch rate for swordfish. It is rare in the annals of high-seas pelagic fishing that a major catch area, or core area of abundance, becomes restricted, bringing catches nearly to zero. Although not designed as such, the government of Mexico had conducted an "experiment" that showed how a widespread offshore fishery affects local fishing.

Catch, Effort, and CPUE

The longline fishery. In the eastern Pacific (E of 130°W) the hook-effort generated by the longline fishery fluctuated but increased after 1961 in three stages: a sharp increase in the early 1960s, a moderate increase from 1964 to 1974, and a greater increase since then (Fig. 4) — from about 62.0 million hooks fished in 1964, to a 102.5 million hook-effort in 1980 (the latest data available).

The CPUE for catches of tunas and billfishes (all species) (Fig. 5) reflects a decline in tuna CPUE prior to the increased emphasis on billfish fishing in 1964.

The longline catch of striped marlin is incidental to the catch of tunas in most areas of the eastern Pacific. There are greater than average catches off Mexico, however, around and south of the Galapagos Islands, and in an area about 400 miles west of Peru during the southern summer (northern winter). Off Mexico, striped marlin and swordfish are notably targeted because of high CPUE rates. The best fishing areas are within the 200-mile economic zone. About 40% of the striped marlin catch (by weight) in the eastern Pacific is generated off Mexico (Joseph, unpubl. MS[1]).

The longline catch of striped marlin in the eastern tropical Pacific increased sharply to 270,000 fish in 1964 (Fig. 3), much of it from increased hook-effort off Mexico. The catch peaked again in 1968 at 338,000 fish, and then declined to 130,000 fish in 1976. As mentioned previously, these Japanese billfish catches are short of the total catch by the amounts of the recreational catch and incidental and directed catches by other fishing fleets. Unfortunately, neither these other catches nor the associated fishing effort are well documented.

Longline catch records show that the geographical area from off Magdalena Bay (on the southwest coast of Baja California) to the Clarion and Socorro Islands, and to the southern portion of the Gulf of California, has the highest catch rates in the Pacific (Suzuki and Honma 1977[2]). The Japanese records (Anon 1962-1980) of catch and hook-effort by 5° longitude and latitude areas show that two areas, 20°N by 110°W and 20° by 105°W (long. and lat. of lower right-hand corner of each 5° area), constitute the most important longline fishing locality for striped marlin in the Pacific (Fig. 7). These two 5° areas, or core areas of striped marlin abundance, accounted for about 23% of the total catch by number of striped marlin in the eastern Pacific (E of 130°W) prior to the establishment

[2]Suzuki, Z. and M. Honma. Stock assessment of billfishes in the Pacific. Working paper, Billfish Stock Assessment Workshop, Honolulu, HI, 5-16 Dec. 1977, unpublished.

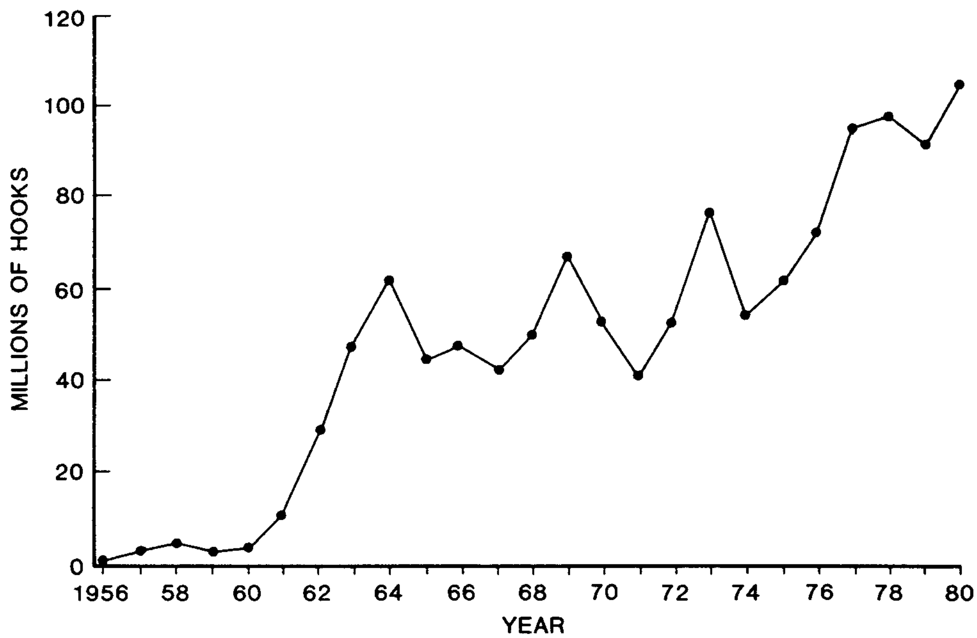

Figure 4. Longline hook effort (Japanese) east of 130°W.

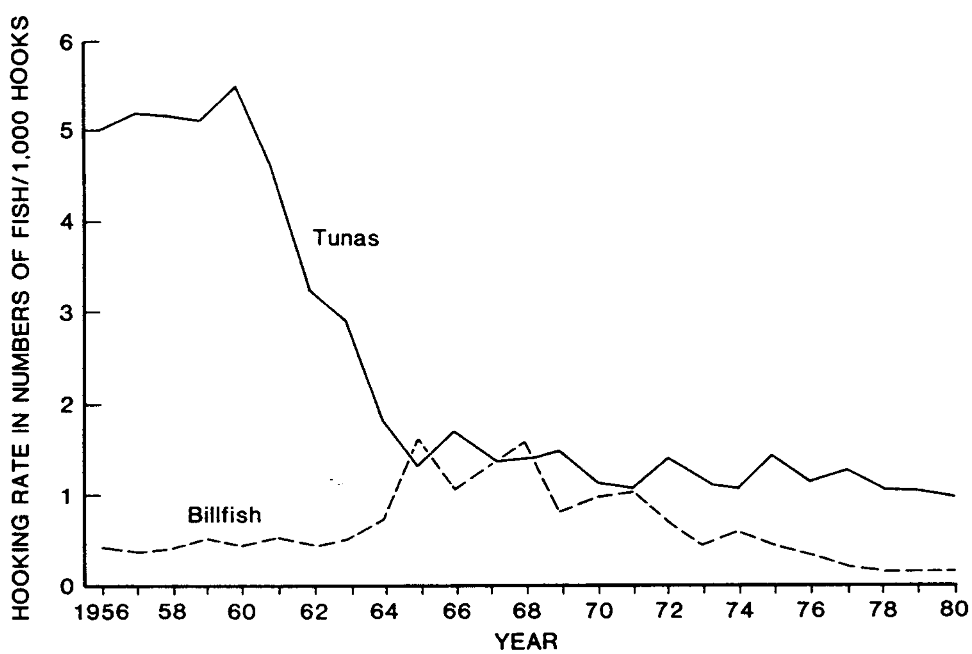

Figure 5. Catch rate for Japanese longline, tunas and billfish in the eastern Pacific in numbers of fish/1,000 hooks.

of the Mexican 200-mile limit.

The recreational fishery. In 1969, the National Marine Fisheries Service started the Pacific Billfish Angler Survey (Squire 1987a, 1987b). This annual survey collects catch-and-effort data from rod-and-reel billfish anglers. From these data, a CPUE (catch-per-unit-effort and/or number of fish per angler-day) is computed for the major recreational billfish fishing areas. Trends in the recreational striped marlin CPUE (1962-1980) for the above two 5° areas about the southern tip of Baja California, Mexico are southern tip of Baja California, Mexico, are shown in Figure 6. The trend of both the commercial longline and recreational fishery CPUE was downward prior to 1977. The commercial longline fishery declined at an average annual rate of about 0.90 fish per 1,000 hooks fished per year, or 5% per year. The recreational catch declined at a rate of about 0.04 fish per angler-day per year, or 6% per year.

Relationship Between the Fisheries

Re CPUE trends. The relationship between the inshore recreational fishery, the offshore joint-venture longline fishery (within Mexico's 200-mile limit), and the longline fishery in the remainder of the eastern Pacific, must be considered in any management plan. Figure 6 shows

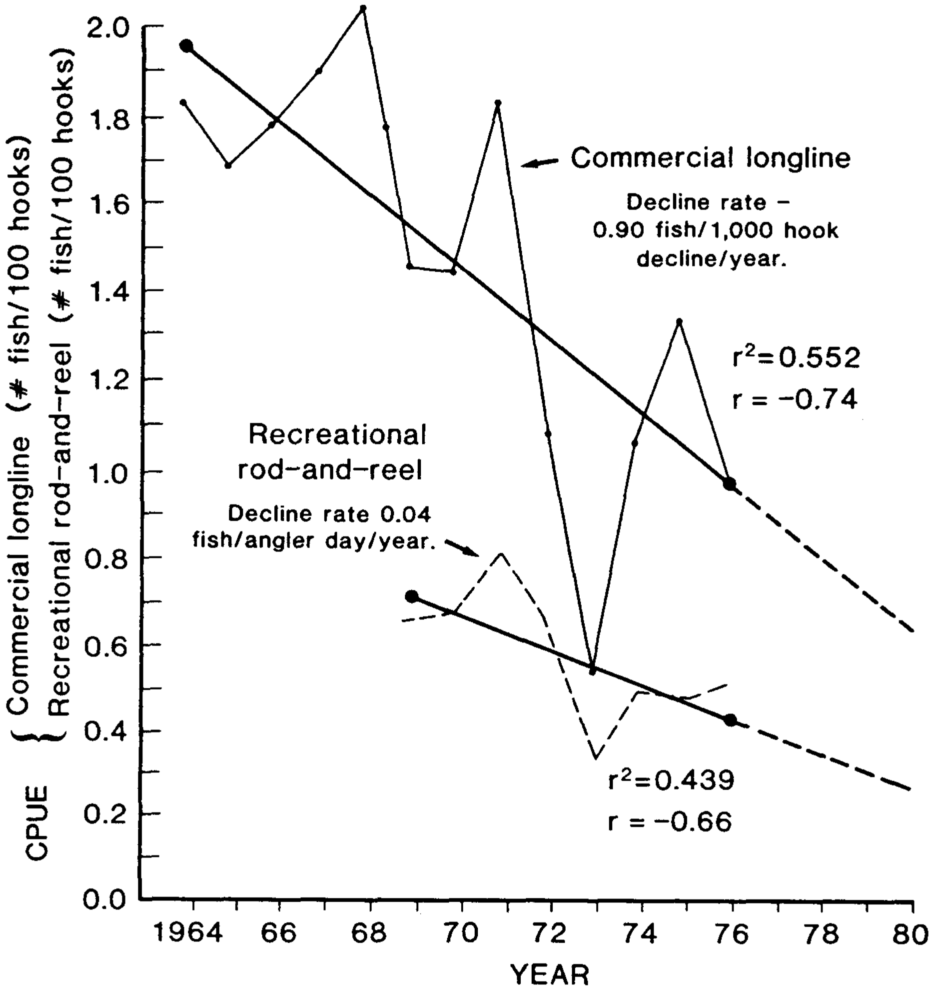

Figure 6. Catch rate and regressions for commercial longline in 5° long. by lat. area (20°N × 105°W) and for the recreational rod-and-reel fishery about the southern tip of Baja California, Mexico.

an apparent correlation between the CPUE trend of the recreational fishery and that of the commercial longline fleet operating near the southern tip of Baja California. This is better shown in Figure 10 which also shows the correlation during the years 1980 through 1986. These correlations, between commercial and recreational CPUEs (data normalized), are statistically significant ($r = 0.89$, 0.96; $Ps < 0.01$). There is a further close relationship between the population in the two 5° longitude by latitude, high CPUE areas off Baja California (20°N × 110°W), and that of the remainder of the eastern Pacific, as indicated by similarity in the respective CPUE fluctuations (Fig. 7). It is therefore reasonable to assume that the CPUEs generated by the longline fleet off Baja California are generally representative of the total eastern population.

Re movements. Examination of data representing over 12,000 striped marlin tagged by anglers in the northeast Pacific (mostly tagged near the tip of Baja California) suggests an interchange of fish between waters off southern Baja California and surrounding areas. There appears to be movement from the southern tip of Baja California to the south and southwest in early summer, and also some movement to the northwest (Squire 1987b). There were few long-distance and few long-term (>2 years) recoveries. Most recoveries were at distances relatively near the area of tagging. Figure 8 shows the average recapture distance from the major locations of tagging off Baja California and Mazatlán for various release-recapture periods. These data suggest that fish move outward from the high-catch areas to the surrounding low-catch-rate oceanic areas. The reasons for this movement are not well known but may be related to movements to major spawning areas (Squire and Suzuki 1989), or to seasonal changes in desirability of the area.

Similarly, an analysis of the movements by striped marlin from important longline fishing areas in the eastern Pacific (Squire and Suzuki 1989), from CPUE data provided by Suzuki and Honma (1977)[2], indicated a south and southeast seasonal movement of the resource. This movement resulted in increased catch rates in the central-eastern and southeastern Pacific during the northern winter (southern summer). A northwestward movement to areas of higher longline CPUE was also evident in the northern spring and early summer.

Re morphometrics. Measurements of striped marlin lengths (eye orbit to fork of tail) in the eastern Pacific (Suzuki and Honma 1977[2]) suggest a pattern which may reflect long-term

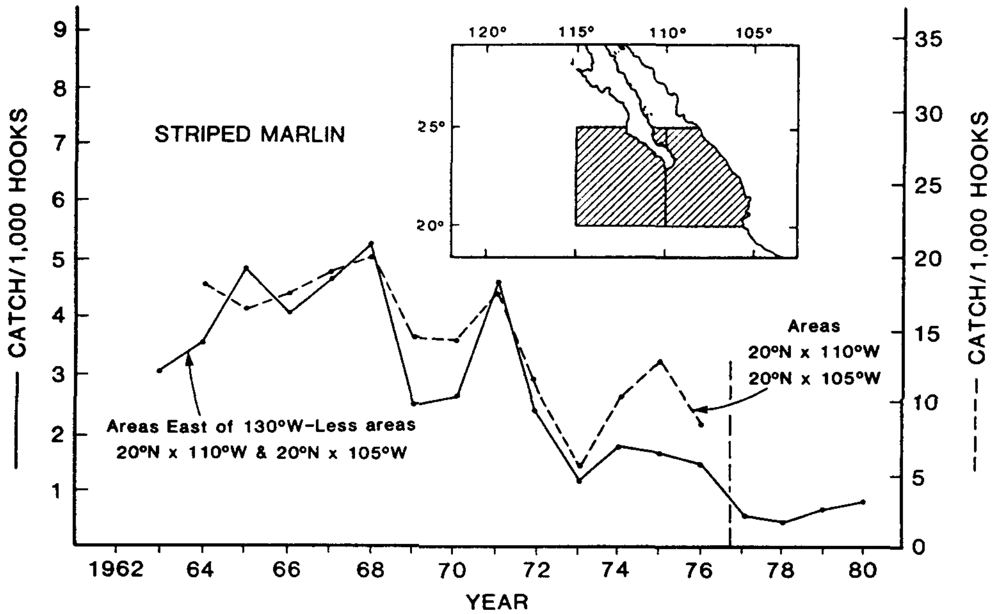

Figure 7. Comparison of CPUE's for the total eastern Pacific (E of 130°W) less 2-5° long. by lat. areas about Baja California and the CPUE for the 2-5° areas combined.

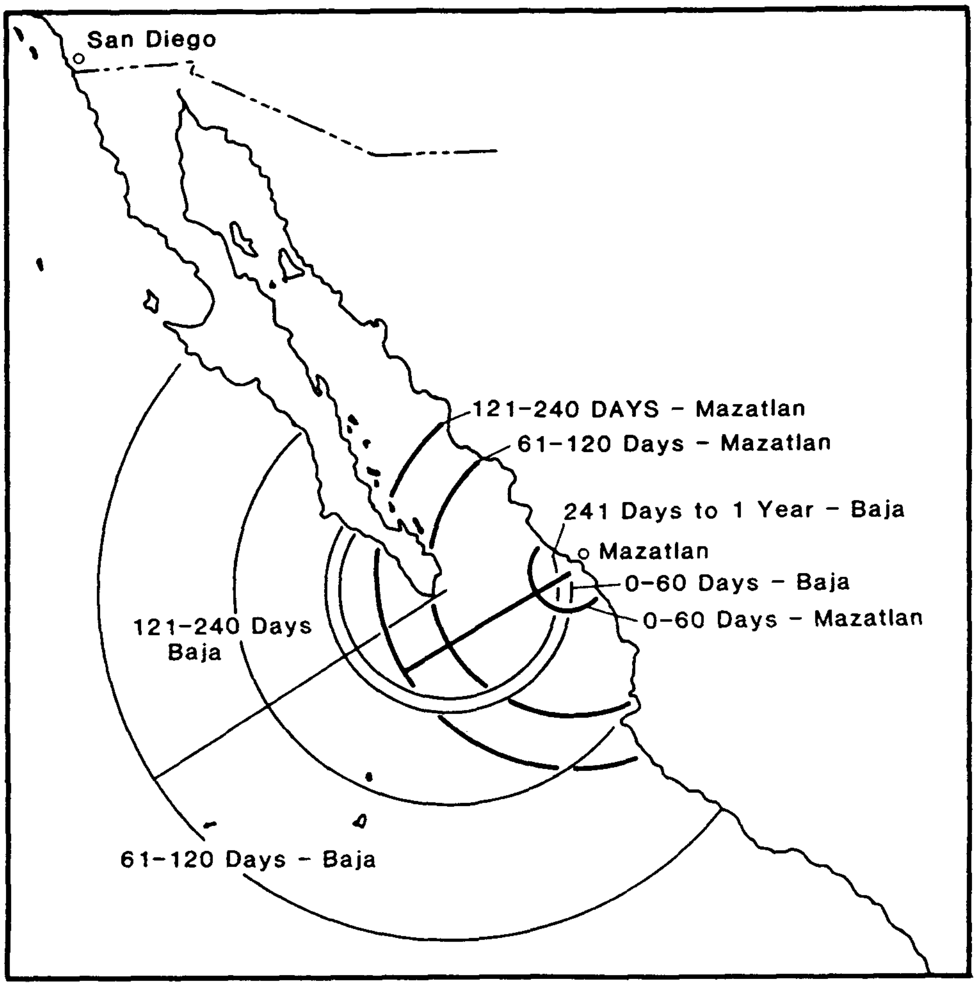

Figure 8. Migration distances by time periods from tagging to recovery, 0-60, 61-120, 121-240, 241 days to 1 year for tagging off Baja California and Mazatlán, Mexico.

fish movements. The marlin in the northeast Pacific are slightly smaller (in mode) than those in the southeast Pacific. There appears to be a cline in the length-frequency pattern from the north-central Pacific to the northwest, northeast, southeast, and southwest Pacific (Squire and Suzuki 1989). Samples from the recreational striped marlin catch off Baja California, Mexico, indicate that the average eye-fork length is about 160 cm (Wares and Sakagawa 1974). This length compares favorably with the historical length-frequency data for the longline fishery off Mexico (Suzuki and Honma 1977[2]) and with length measurements collected recently by the Mexican-Japanese joint-venture fishery from the port of Ensenada, Mexico (Squire; pers. comm., M. Comparan). These areal changes in length frequency suggest that the fish move toward the eastern Pacific and southern Baja California as they grow. These findings suggest that the high-catch-rate areas off Mexico are areas of at least temporary accumulation or aggregation for fish of about 160-170 cm in eye-fork length. Individuals longer than 210 cm do not appear to remain in this area in any number. Movements of the larger fish may be related to maturity and, thus, to spawning seasons and spawning areas.

Local CPUE Changes off Mexico

Billfish angler survey trends. Striped marlin catch rates, determined from the Pacific Billfish Angler Survey (catch per angler-day), are shown in Figure 9. Additionally, and prior to the start of the Angler Survey in 1969, logbook data had been made available by Rancho Buena Vista, an important fishing resort on the East Cape area of Baja California. These records indicated a catch rate (fish per angler-day) of 0.60 for 1965, 0.73 for 1967, and 0.90 for 1968. The Angler Survey then showed a declining CPUE trend for Baja California, 1969 through 1976 (Fig. 9). This trend then reversed, and CPUEs increased in 1978, 1979, and 1980. Since 1980, CPUEs in the Baja California sport fishery have fluctuated at about 0.5 fish per angler-day. The nearby southern California rod-and-reel fishery, which has consistently shown a low CPUE (about 0.1 fish/day), showed little trend. The catch rate increased slightly after 1981, and the highest catch rate recorded was in 1985, slightly over 0.3 fish per day. It returned to the 0.1 CPUE rate in 1986.

The cited changes in angler CPUE reflect similar changes in longline CPUE in adjacent oceanic areas, as previously noted. This situation (Fig. 10) is a composite of, (a) longline CPUE in the eastern Pacific excluding the two 5° longitude by 5° latitude areas about the tip of Baja California (20°N × 105°W and 20°N × 110°W); (b) longline CPUE in the two excluded 5° longitude by latitude areas only; and (c) CPUE from the recreational striped marlin fishery about the tip of Baja California. Examination of the figure indicates the following trends of longline CPUE change as affected by fishery closures.

In the Japanese longline fishery. Total eastern Pacific catch-and-effort data — less data for the two 5° areas off Baja California — show a decline in CPUE from 1964 to 1978, from about 5 to 0.4 fish per 1,000 hooks (nominal effort) fished, with a decline rate of 0.38 fish per 1,000 hooks fished per year. Since the early 1970s, considerable deep-longlining has been conducted in the equatorial area for bigeye tuna *(Thunnus obesus)*. This method of longlining reduces the chances of catching billfish. For the two 5° longitude by latitude areas off Baja California — where bigeye tuna fishing is relatively unimportant — the CPUEs declined during the period 1964 to 1976 from about 18 to 9 fish per 1,000 hooks fished, with a decline rate of 1.10 fish per 1,000 hooks fished per year. Then, during the period of restricted fishing, 1979 and 1980, the CPUE rose to near 23 fish per 1,000 hooks fished for both years. [Japanese longline catches within the two 5° areas that are within Mexico's 200-mile economic zone may have been from joint-venture longliners.] After 1980, Japanese longline data were no longer accessible.

In the Mexican joint-venture longline fishery. Sampling of Japanese longliners, operating on a joint-venture arrangement within the 200-mile limit and out of the port of Ensenada, Mexico (courtesy of Comapro SA. de CV.), showed that the CPUE in 1980 had risen to 22.0 fish per 1,000 hooks fished (Table 1). From the spring of 1984 to the fall of 1985, permits to operate

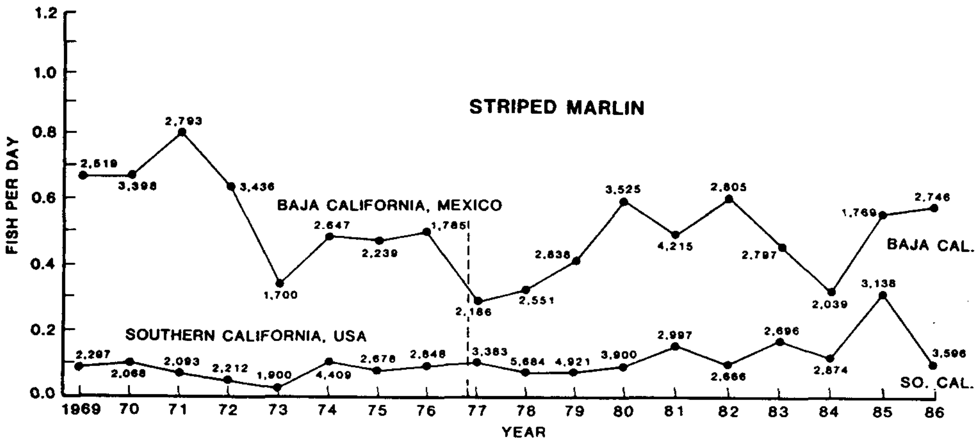

Figure 9. CPUE trend (fish per angler-day) for striped marlin about the southern tip of Baja California, 1969-1985, from the Pacific billfish angler survey. Numbers by the points indicate angler-days.

within Mexico's 200-mile limit were again withheld. During that period, the CPUE rose by about 1.5 fish per 1,000 hooks fished per year.

Table 1. CPUE data obtained from a portion of the joint-venture Japanese fleet operating from Ensenada, Mexico (courtesy Comapro SA. de CV.).

Year	# hooks fished	# fish/1,000 hooks
1980	547.000	22.0
1981	1,899.900	12.0
1982	1,235.000	23.0
1983	1[illegible]8.600	12.0
1985	143.000	16.0
1986	301.300	13.0

The Fishing Areas

Intensive and productive fishing actually occurs in only portions of the approximately 165,000 sq.-n.mi. core area, probably due to environmental conditions (Hanamoto 1974). Figure 11 shows fishing effort distribution for a portion of the joint-venture longline fleet operating in 1982 and 1983. The most productive fishing areas were along the edge of the continental shelf off Magdalena Bay, at the mouth of the Gulf of California, and around the Revillagigedo Islands. Catches were primarily of striped marlin during the summer from off Magdalena Bay to the Revillagigedo Islands, and of both swordfish and striped marlin during the winter months off Magdalena Bay and about the mouth of the Gulf of California.

Summary

Changes in angler-CPUE appear to reflect offshore changes in the exploited population. From 1969 to 1977 (the year after the last full year of unrestricted commercial longline fishing), the angler-CPUE had declined from 0.69 to 0.30 fish per angler day, about 0.04 fish per angler day per year (Fig. 10). During the restricted commercial longlining period from 1977 to 1980, when longline-CPUE increased by about 3.6 fish per thousand hooks per year, the angler-CPUE increased from about 0.3 to 0.6 fish per angler-day. This increase is about 0.15 fish per angler-day per year. Since 1980, when joint-venture longline fishing began, the billfish-angler-CPUE showed a decline, again, from about 0.58 to 0.46 in 1985, a decline rate of 0.02 billfish per angler-day per year. The changing trends in angler-CPUE therefore appear to follow the major changes in the offshore commercial fishery (Fig. 12).

Core-Area Assessment and Management

Concept

Regardless of the status of an oceanic stock, or of any overall management regime implemented, local reductions in CPUE usually precipitate calls for restrictions on fishing. The restrictions are usually aimed at extra-local fisheries, and may be justified if those fisheries control the abundance or availability of fish in the local area. Extra-local management may

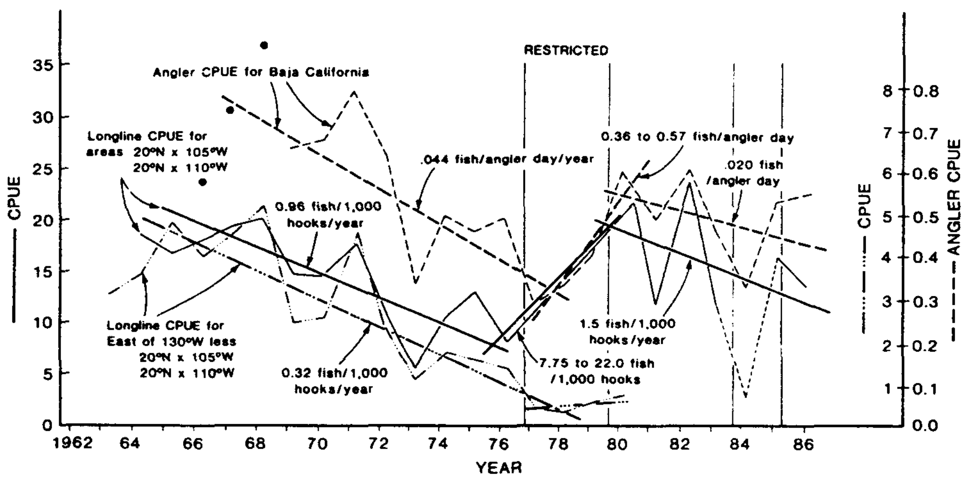

Figure 10. Comparison of CPUE trends for longline in the total eastern Pacific and for rod-and-reel and longline about Baja California.

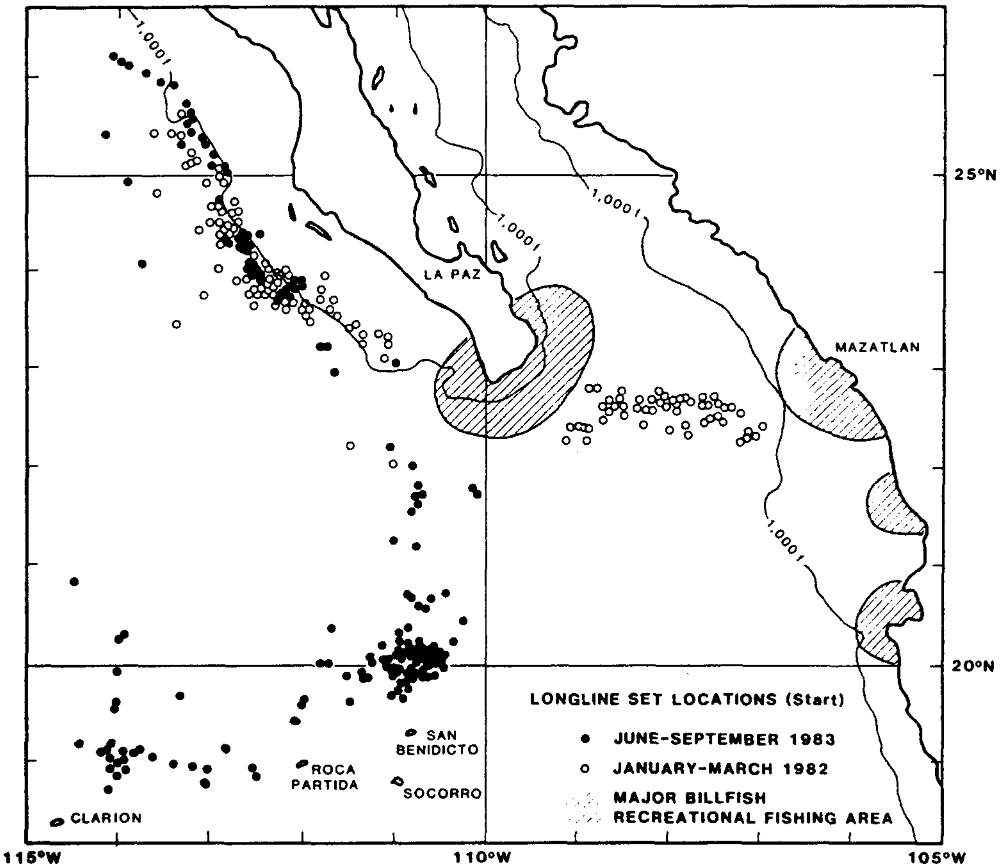

Figure 11. Locations of the start of longline sets (portion of joint-venture fleet) during the winter and spring of 1982 and summer of 1983.

itself be restricted in scope, designed only to alleviate the local fishery problem. When the stock concerned is part of an international oceanic fishery, such management requires international agreement or else political control in the relevant areas.

It is preferable, of course, for extra-local management to address the status of the entire stock, but it need not encompass all external fisheries. It may be restricted to certain localized core distribution areas if the stock aggregates toward such areas, or if for any other reason the population there has a controlling relationship to the abundance of the entire stock.

The two 5° latitude × longitude blocks off southern Baja California, Mexico (Fig. 7) can be considered a core area for eastern Pacific striped marlin. Approximately 23% of all striped marlin caught in the eastern Pacific (E of 130°W) comes from that localized area. The evidence presented suggests here that the fish are attracted to, or regularly linger while passing through, that area during their growth and development (see, also, Squire and Suzuki 1989). This core area produces the highest catch rates for striped marlin, and is the focal area for its fishery in the Pacific. Furthermore, the CPUEs in the core area correlate with both the species' CPUEs in the entire eastern Pacific (exclusive of the core area) and with the sport-fishery CPUEs along the Mexico coast (Figs. 6, 7, and 10). The former relationship is due to the attractiveness of the core and surrounding areas to the species — probably for feeding (Hanamoto 1974); the latter relationship is due to the proximity of the core area to the localized shore-based sport fisheries. While these CPUE trends may be correlated, however, the time rates of these CPUE

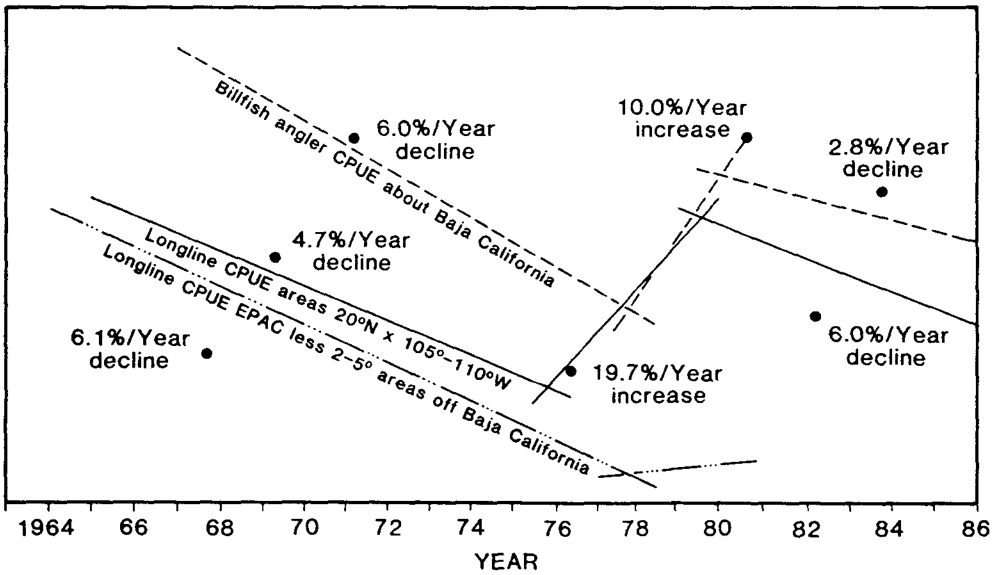

Figure 12. Percentage catch rate change per year for commercial longline and recreational rod-and-reel fisheries.

changes should not necessarily be the same. Each local fishing area is characterized by its own catchability and availability factors and, therefore, by the nature of its response to fishing. The more localized an area, the more likely its CPUE changes will differ from those of other areas.

Mexico's fishing "experiment", which temporarily curtailed the fishery within its 200-mile EEZ, encompassed the core area and showed an effect of fishery interactions. When commercial fishing was stopped, during 1977-1980, the CPUEs rose from a long period of decline to near pre-exploitation levels, both in the core area longline fishery and in the sport fishery (Figs. 10 and 12). These increases all occurred within a 3-year period. Considering the large areal extent of the striped marlin resource, and its overall fishery in the eastern Pacific, together with the limited areal extent of the core and shore-based sport fisheries, this rapid increase in CPUE would appear to reflect effects from the fishing down and rebuilding of localized fishing "hot spots," whose populations are continuously augmented by immigration, rather than overall stock recovery from a decline.

From the foregoing, and evidence previously presented, it is argued that management in the core area off Mexico is feasible (relative to ocean-wide, international management) and can even effect control of the eastern Pacific stock. Moreover, as that stock declines from increased fishing, core-area management could exert even greater control because the percentage of the entire stock attracted to the core area should increase. Since all of the two 5° square areas constituting the core area lie within Mexico's 200-mile EEZ, Mexico has a controlling position to implement core-area management. Such management could endeavor to maintain CPUE levels consistent both with the principles of stock management for the commercial fishery and with needs for an economically viable CPUE level in the adjacent sport fisheries.

Weighted CPUE vs. Fishing Effort

The relationship between striped marlin CPUE and fishing effort was examined using the same Japanese catch-effort data and Mexican-Japanese joint-venture records already described, but here the CPUE was calculated as an area-weighted index (see Beverton and Holt 1957, p. 148). This CPUE was calculated for both an "index" area and for an enlarged core area that consisted of four adjacent 5° square areas (Fig. 13). The index area consisted of 17 whole or partial 5° squares where striped marlin appeared to be the target species in the Japanese fishery. These areas exhibited consistent high catches and catch rates for striped marlin, and

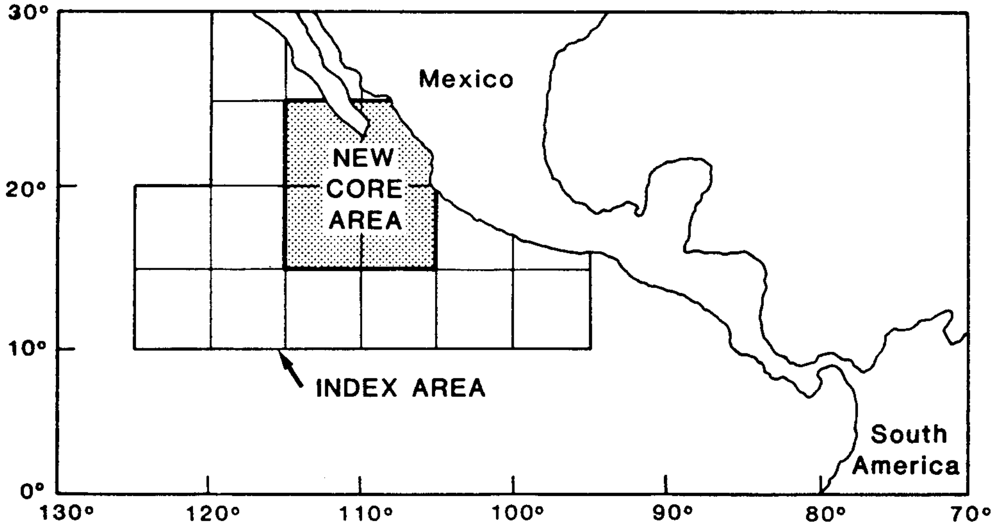

Figure 13. Core and index areas for which CPUEs were calculated as area-weighted averages of CPUEs from each 5° area.

relatively low yellowfin tuna *(Thunnus albacares)* catches. Furthermore, yellowfin tuna catches were greater than bigeye tuna catches, i.e., deep-longlining was not likely to have been important there. The new expanded core area included two adjacent 5° squares directly south of the two squares of the previously described core area. These two new squares are often intensely fished and are significant producers of striped marlin; their inclusion therefore increased the sample size for core-area calculations. In both the index and new core areas, CPUE was calculated only from those 5° squares for which fishing effort, during any time period of interest, was at least 10,000 hooks. This condition was applied to reduce the computing of extreme CPUE ratios.

Results

The time trend in the area-weighted CPUEs (Table 2) was closely similar to that of the simple (effort-weighted) CPUEs previously calculated (Fig. 10). This similarity is an indication of a fishery that is highly focused onto prime fishing areas, i.e., the average catch rate is little altered by inclusion of fishing rates from other areas. In both CPUE series, there was a general decline with time through 1976 or 1977, a rapid rise to near pre-exploitation CPUE levels during the 1977-1980 years of fishery closure, and a decline afterwards in the joint-venture fishery. The area-weighted core- and index-area CPUEs were clearly correlated (since the index-CPUE pertains to a large area that incorporates the new core area). After 1968, the CPUEs declined in a way that indicated the eastern Pacific striped marlin resource had become fully exploited (as seen, also, in Figure 10 for the effort-weighted index).

CPUEs (and also total catches) for the years 1969 to 1984 were therefore plotted against fishing effort to determine their relationship (Fig. 14) in terms of annual index-area CPUE vs. annual effective hooks, the latter calculated by dividing annual catch by annual CPUE. There appears to be a negative regression in the 1969 to 1976 data, although this relationship is obscured if core, not index, area CPUEs are plotted against core hook effort, in turn calculated either from annual or 2nd semestral CPUEs (most striped marlin are taken during the 3rd and 4th quarters of the year).

Reexamining Figure 14, it can be seen that the apparent regression depends strongly upon the 1971 and 1973 data points, which represent good and poor fishing years, respectively (Fig. 10 and Table 2). The more recent data shown cannot be considered very reliable with respect to the stock size-fishing effort relationship. The 1979 and 1980 catch-effort data were sampled from a largely closed near-shore fishery, and the post-1980 data points were based on a tenuous assumption that joint-venture catches were the only catches in the index area. The

Table 2. Catch, catch/effort (CPUE), and effort in the eastern Pacific striped marlin fishery (Japanese and Mexican data only), 1962-1984.

	Annual catch (number of fish)			CPUE (fish per 1,000 hooks)						Annual effective effort (10^6 hooks) in							
										Japan longline						Mex. JV	
	Jap. LL		Mex JV	Jap. LL				Mex. JV				From index area		From core area		From core area	
				Annual[1]		Semester[2]		Ann.[1]	Sem.[2]								
Year	Index	Core	Core	Index	Core	Index	Core	Core	Core	Ann.[3] CPUE	Sem.[4] CPUE	Ann.[5] CPUE	Sem.[6] CPUE	Ann.[5] CPUE	Sem.[6] CPUE	Ann.[5] CPUE	Sem.[6] CPUE
1962	742	—		4.35	—	2.40	—			0.17	0.31	—	—	—	—		
1963	8,796	6,799		17.93	41.80	17.12	39.02			0.49	0.51	0.21	0.22	0.16	0.17		
1964	145,120	125,346		9.44	16.43	10.76	14.94			15.37	13.49	8.83	9.71	7.63	8.39		
1965	103,300	75,781		9.54	14.17	10.72	14.53			10.83	9.64	7.29	7.11	5.35	5.22		
1966	71,268	53,894		10.03	16.16	10.54	17.05			7.10	6.76	4.41	4.18	3.34	3.16		
1967	100,224	78,082		11.12	18.20	12.19	16.98			9.01	8.22	5.51	5.90	4.29	4.60		
1968	220,552	179,623		14.12	19.03	16.25	19.57			15.62	13.35	11.59	11.27	9.44	9.18		
1969	93,713	82,350		11.61	14.28	12.73	13.95			8.07	7.36	6.56	6.72	5.77	5.90		
1970	89,345	82,312		11.23	13.00	11.68	14.31			7.96	7.65	6.87	6.24	6.33	5.75		
1971	114,877	99,730		15.65	16.53	16.09	17.41			7.34	7.14	6.95	6.60	6.03	5.73		
1972	79,176	74,885		9.65	12.49	10.53	12.32			8.20	7.52	6.36	6.43	6.00	6.08		
1973	57,764	53,689		4.63	7.02	5.30	6.61			12.48	10.09	8.23	8.74	7.65	8.12		
1974	76,964	74,151		7.92	10.79	8.18	10.89			9.72	9.41	7.13	7.07	6.87	6.81		
1981			19,024					5.07	14.36							3.75	1.32
1982			11,117					9.22	14.31							1.20	0.78
1983			23,916					6.71	8.34							3.56	2.87
1984			1,992					4.59	1.92							0.43	1.04

[1]Annual values.
[2]2nd semestral values.
[3]Calculated from index area annual CPUE.
[4]Calculated from index area 2nd semestral CPUE.
[5]Calculated from core area annual CPUE.
[6]Calculated from core area 2nd semestral CPUE.

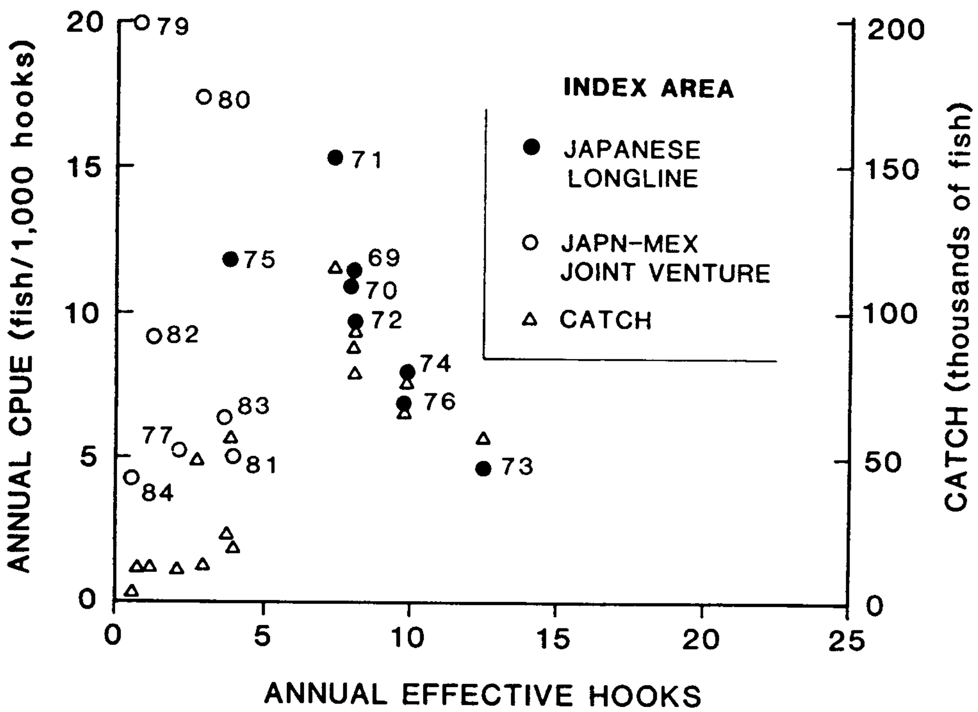

Figure 14. Relationship of index-area annual CPUE and annual catch to annual effective fishing effort. Catch is represented by triangles, annual CPUE by circles.

data appear insufficient to describe the expected negative relationship between CPUE and fishing effort in the eastern Pacific, in spite of the clear time trend of decreasing CPUE off Mexico.

Discussion

The amount of decrease in CPUE that occurred in the core area and elsewhere in the eastern Pacific during the years of active longline fishing was probably due less to declining overall stock than to changes in catchability or availability experienced by the expanding fishery in the localized area. The catch-effort relationship (Fig. 14) suggests little if any slowing of catches with increasing effective effort. Furthermore, a clear increasing trend in effective effort from 1969 to 1976 was lacking in either index or core areas (Table 2).

Catchability/availability changes are likely a function of evolving fishing tactics and of fish behavior. In particular, the rapid rise of CPUE in the small sport and starting-up joint-venture fisheries, after the cessation of longlining in Mexico's EEZ, was likely due to fish populations building up first and quickly in favored localities, which then become the natural focus of any renewed fishing. As these "hot spots" are again fished down, the fishery spreads out to include surrounding larger but lower catchability/availability areas. Overall CPUE thus at first decreases rapidly, then more slowly [such events are predictable from the tenets of optimal foraging theory (see Pyke et al 1977)]. The resulting CPUEs can therefore change rather strikingly with changes in the fishery, but not necessarily as a reflection of changes in overall stock size. Thus, adjacent coastal sport fisheries, located on the inner side of the aggregation area for striped marlin and whose fish are therefore first subjected to an external fishery, are affected (Fig. 15).

The eastern Pacific striped marlin is probably not overexploited. Nevertheless, its catch rates and fishery behavior warrant continual monitoring. This may be accomplished in relatively localized key or core areas where it may also be feasible to implement management measures such as closed seasons or areas, catch limits, etc. Such measures would best be implemented within the context of an international management regime. Lacking that, a coastal state may opt to act unilaterally if, by so doing, it can mitigate declines in the local catch rate. Core-area management off Mexico would recognize the importance of areas toward which fish aggregate and that, in such areas, differences in catchability/availability affect fishing tactics and CPUE trends. Quite possibly, and in general, changes in catchability/availability from the fishing down of localized "hot spots" may explain more of the proverbial "good old days" of fishing than the usual "fishing up" explanation (see Ricker 1975, p. 260).

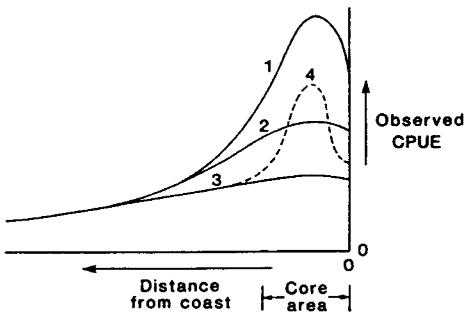

Figure 15. Hypothetical CPUE — distance profile showing effects of increased fishing (curves 1-3), followed by a rebuilding of the stock (curve 4). Catchability/availability is considered to decrease as the stock (CPUE) becomes less concentrated around the peak (peak broadens), which is where rebuilding occurs first.

A previous assessment by Bartoo and Ueyanagi (in Shomura 1980), using 1952-1975 data for north, south, and Pacific-wide "stocks," also concluded that there was no evidence for overexploitation. That study treated the entire data series as though it were applicable to a fully exploited stock although, in reality, the fishery had been expanding from west to east in the Pacific, at least up through the mid-1960s.

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