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EFFECTS OF TROPICAL TUNA FISHERIES ON NON-TARGET SPECIES

Gary T. Sakagawa

NOAA-TM-NMFS-SWFC-69

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Center

NOAA Technical Memorandum NMFS

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CONTENTS

Page

BACKGROUND.. 1

CASE I - BLUE MARLIN.. 2

Biology and Distribution................................ 2

Fishery... 5

Effects... 11

CASE II - BAITFISHES.. 14

Biology and Distribution................................ 14

Fishery... 17

Effects... 21

Management Implications....................................... 22

ACKNOWLEDGMENTS... 22

LITERATURE CITED.. 24

LIST OF TABLES

Table		Page
1	Catch (mt) of blue marlin by the longline fisheries of the Indian and Pacific Oceans. (Source: FAO, 1984)	6
2	Baitfish and tuna catches of pole-and-line fisheries of the Pacific Ocean	15

LIST OF FIGURES

Figure		Page
1	Distributional range and areas of concentration of blue marlins in the Pacific and Indian Oceans. Concentration levels are determined from longline data	3
2	Spawning areas of blue marlin in the central and western tropical Pacific and south central Indian Oceans. Area inferred from data on larval catches. (Source: Suzuki and Honma, MS)	4
3	Location of the three major purse seine fisheries for tropical tunas in the Pacific and Indian Oceans. Catches for yellowfin tuna (YFT) and skipjack tuna (SKJ) are for 1984	8
4	Length-frequency distribution of blue marlin caught in the western tropical Pacific by longliners in 1967-75	10
5	Relation between catch of blue marlin and effective fishing effort. The curve represents equilibrium yield for the fisheries with maximum sustainable yield (MSY) and corresponding effort (fop) to obtain that yield. (Source: Yuen and Miyake 1980)	12
6	Average catch of blue marlin per angler day for recreational rod-and-reel fisheries in Guam, Hawaiian Islands and Tahiti. (Source: Squire 1986)	13
7	Distributional range of principal baitfishes for tropical tuna fisheries and location of baiting grounds(darkened) in the Pacific and Indian Oceans	16
8	Location of some pole-and-line fisheries for tropical tunas in the Pacific and Indian Oceans. Catches for yellowfin tuna (YFT) and skipjack tuna (SKJ) are for 1984	18

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BACKGROUND

In 1984 approximately 80% of the world catch of tunas, 2.1 million mt, was yellowfin tuna (Thunnus albacares) and skipjack tuna (Katsuwonus pelamis) of which about 45% was canned for the United States, French, Italian, Spanish and Japanese markets. Tuna supplied to these markets are caught mainly by pole-and-line and purse seine vessels. Volume of catch is a key factor for profitability in this industry, and high-volume vessels with long-range capability have been designed and built for this purpose. These vessels can move from one fishing area to another to follow shifts in availability of fish and to maintain high catch rates. They are capable of applying intense fishing pressure in localized areas. As a result, competition for fish among the large vessels, and with the less-mobile, artisanal fishermen has become a concern (IPTP 1985).

Another source of competition for artisanal fishermen is longline vessels. Longline vessels are large and mobile, and fish for a variety of large tunas. The amount of their catch, however, is substantially less than that of purse seiners and pole-and-line vessels and is sold primarily in the "sashimi" market of Japan. The sizes of tunas caught are also generally larger than than those caught by artisanal fishermen.

The effects of this competition are feared by some to be destructive to maintaining expected yields from the tuna resources and for survival of localized fisheries. Limited studies to date have not dispelled this fear but have reinforced it by showing the occurrence of competition among fisheries, although at low levels (e.g., Fink and Bayliff 1970; Kleiber, Argue, Sibert and Hammond 1984; Sibert 1984). Some governments have instituted measures to reduce the risk of competition by physically separating the fleets. In the tropical tuna fishery of the western Pacific, for example, Japan restricts her purse seine fleet to an area of approximately 4 million km^2, north of Papua New Guinea and outside the adjacent area where her pole-and-line fleet operates (Tanaka 1984). Papua New Guinea licenses foreign purse seiners to fish in her 200-mile zone but restricts their operations to areas outside the 12-mile territorial waters, where the artisanal fisheries occur (Doulman 1986).

There is wide recognition that adequate information on the effects of these measures is lacking. Focused studies have been called for to obtain information to predict the effects of changes in fishing intensity on the different fisheries and on the overall tuna resource (IPTP 1985). Not recognized, however, is the need for focused studies on non-target species as well.

Non-target species are caught either incidentally or as an integral part of the tuna fishing activity. Their involvement in tuna fisheries is often unavoidable, or avoidable at high cost, and in some cases, is necessary. Consequently, information on how they are affected or how fisheries that specifically exploited them are affected by actions of tuna fisheries is necessary for informed management decisions. In this report, I describe two examples in which non-target species are affected by the activities of tropical tuna fisheries and review the principal effects of the fisheries on the non-target stocks.

CASE I - BLUE MARLIN

The first case concerns blue marlin (Makaira nigricans). Blue marlin are caught as a by-catch of tropical tuna purse seine, longline and rod-and-reel fisheries. The by-catches are often not reported or discarded at sea. In some locations the by-catches are a source of conflict between recreational and commercial fishermen (Joseph and Greenough, 1979).

Blue marlin belongs to the family Istiophoridae and is related to the tropical tunas through the taxonomic suborder, Scombroidei. One species inhabits the Pacific and Indian Oceans and perhaps the Atlantic Ocean as well (Nakamura 1985; Rivas 1975). It occurs across the oceans in a wide band (Figure 1). In the Pacific the band is narrower in the east than in the west -- approximately lat. 30° N to 35° S in the east and lat. 40° N to 45° S in the west. Blue marlin are usually not found close to land masses except where the shelf is narrow and drops off abruptly, such as around volcanic islands (Nakamura 1985), and atolls.

Biology and Distribution

Blue marlin is an oceanic species that prefers waters warmer than 25° C, thus limiting its distribution to tropical and subtropical regions. It attains a large size with females growing larger than males. Females reach a maximum size of about 450 cm fork-length (FL) (520 kg) and live to over 15 yr. Males grow to a maximum size of 300 cm FL (150 kg) and with perhaps a shorter life span (Skillman and Yong 1976; De Sylva 1974). Fish mature at about age 2-4 for males and age 5-6 for females. Two separate, major spawning areas - one in the central and western tropical Pacific and another in the south-central Indian Ocean (Figure 2) - have been located (Nishikawa, Kikawa, Honma and Ueyanagi 1978). Spawning appears to be year-round,

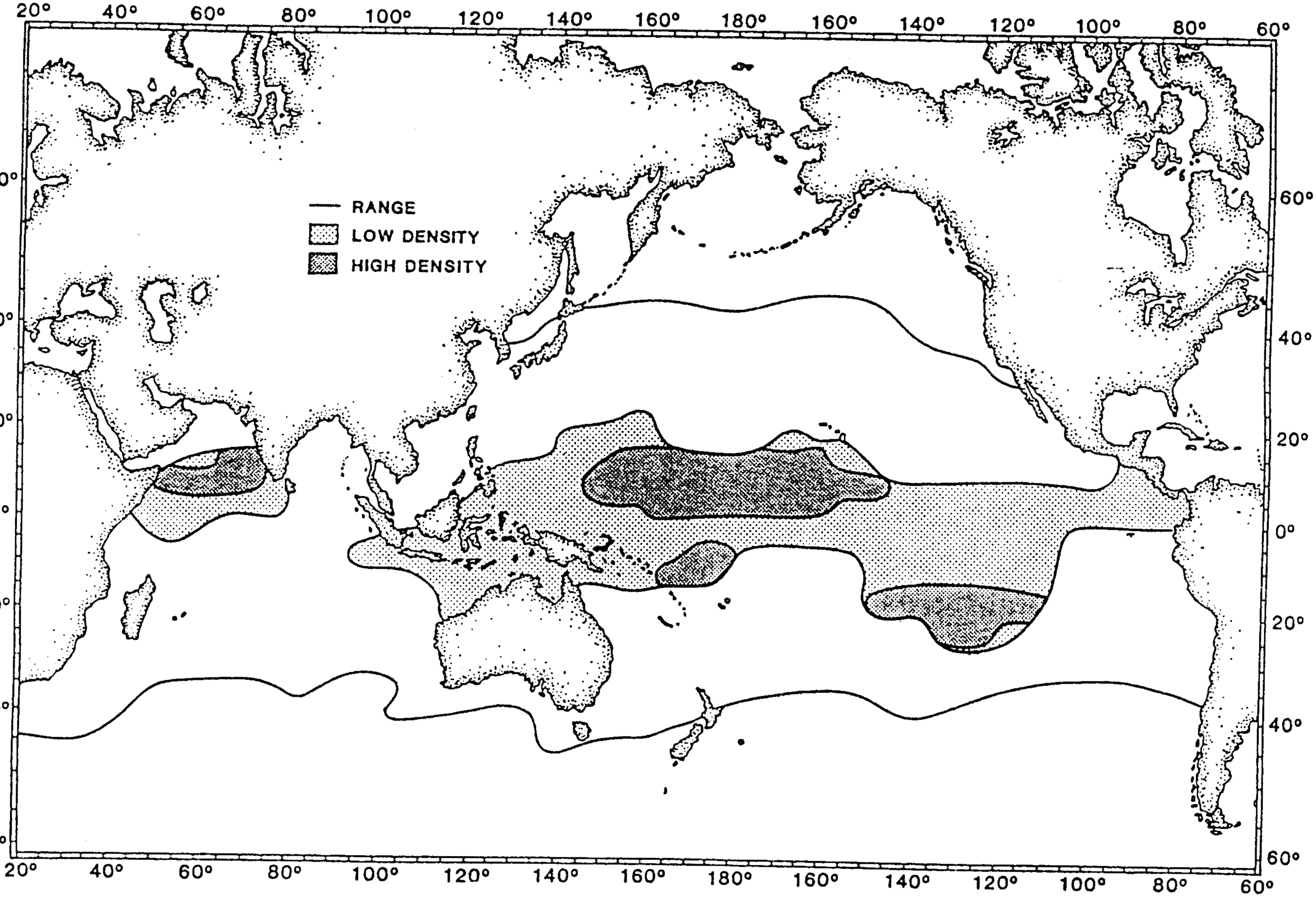

Figure 1. Distributional range and areas of concentration of blue marlins in the Pacific and Indian Oceans. Concentration levels are determined from longline data.

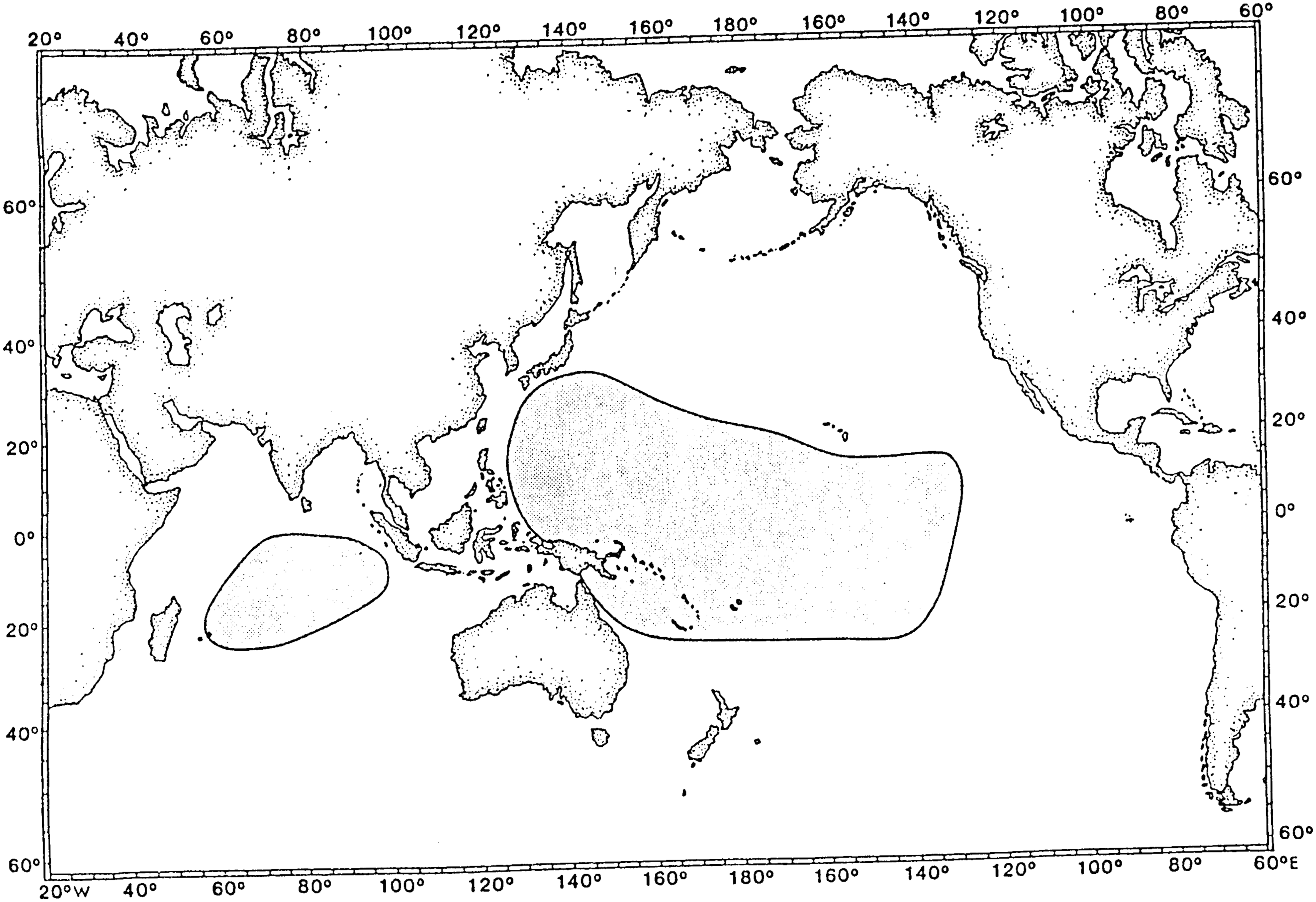

Figure 2. Spawning areas of blue marlin in the central and western tropical Pacific and south central Indian Oceans. Area inferred from data on larval catches. (Source: Suzuki and Honma, MS).

although seasonal (summer) in some parts of the distributional range.

Like other members of Istiophoridae, blue marlin roam widely and are capable of traveling great distances (thousands of km) in a lifetime. Interchange of fish between the Pacific and Indian Oceans has not been demonstrated but is possible through the East Indies region or around Australia. However, population studies to date have generally treated fish in the Indian Ocean as a separate stock from fish in the Pacific.

Blue marlin are solitary animals and dispersed in distribution, although found more concentrated in regions where food is abundant. As a top predator , they feed on a variety of fishes and cephalopods, with tuna and tuna-like species making up a significant portion of their diet (Rivas 1975; Zavala-Camin 1986).

Fishery

Because blue marlin are widely dispersed and in low densities, fisheries specifically for this species have not been developed. Catches are by fisheries principally for other species, such as the commercial longline fisheries for tunas and the recreational rod-and-reel fisheries for a mixture of large pelagic fishes.

Published statistics on the total catches of blue marlin vary among sources. In 1977, experts reviewed available statistics for the Pacific Ocean and agreed on a set of reported total catches for the period 1952-75 (Yuen and Miyake 1980). The statistics show a downward trend from a peak of 31,300 mt in 1966 to 12,500 mt in 1975. Similarly, in 1979 experts reviewed statistics for the Indian Ocean and estimated the total catches of blue marlin for 1952-76 (FAO 1980). The results of this 1979 review were less than satisfactory since statistics for only the major fleets were available. The statistics indicate a peak catch of 5,200 mt in 1956, followed by a period of fluctuating catches above 3,500 mt, and a declining trend after 1970, reaching 1,700 mt in 1976.

Comparable statistics for more recent years are not available, although statistics from major sources are published annually by FAO and are widely quoted. The FAO statistics are incomplete and provide only a crude indication of recent trends. Most recent statistics (Table 1) indicate an upward trend during the 1974-84 period for both the Pacific and Indian Oceans. Current catches exceed 18,000 mt for the Pacific Ocean and 3,000 mt for the Indian Ocean.

Not accounted for in most published statistics are catches by recreational fisheries, the tropical tuna purse seine fisheries and artisanal fisheries. Incidental catches by these

Table 1. Catch (mt) of blue marlin by the longline fisheries of the Indian and Pacific Oceans. (Source: FAO, 1984)

Year	Pacific Ocean	Indian Ocean	Total
1974	11,500	1,400	12,900
1975	11,500	2,300	13,800
1976	12,700	1,600	14,300
1977	13,400	1,400	14,800
1978	14,900	2,600	17,500
1979	16,200	2,500	18,700
1980	18,700	2,400	21,100
1981	17,900	2,700	20,600
1982	17,900	2,400	20,300
1983	18,500	3,100	21,600
1984	18,200[1]	3,400	21,600

[1] Estimated.

fisheries for the most part are discarded at sea and are not reported, so they must be estimated from fragmented information. Because the purse seine fisheries are large, they are believed to have a significant by-catch of blue marlin that is unreported.

The major purse seine fisheries for tropical tunas in the Pacific and Indian Oceans (Figure 3), are: eastern tropical Pacific (ETP), western tropical Indian Ocean (WTI) and western tropical Pacific (WTP). The ETP purse seine fishery, off central and South America, produced 199,000 mt of yellowfin and skipjack tunas in 1984 with yellowfin tuna the dominant species (71%). This fishery relies primarily on dolphin (Stenella spp.)-associated schools and "schoolfish" (non-associated schools) for its production (Perrin 1969; Punsly 1983). It operates outside the areas of high concentration of blue marlin and rarely catches any.

The WTI purse seine fishery is centered in the Seychelles Islands area, and is dependent on yellowfin tuna for a majority of its production (Marsac and Stequent 1984). In 1984, the total yellowfin-skipjack catch was 97,000 mt with yellowfin tuna making up 54% of this total. This fishery until recently was largely dependent on log-associated schools for its production; currently both schoolfish and log-associated schools are important. The fishery operates outside of the area of highest concentration of blue marlin and the incidental catches of blue marlin are rare (J.P. Hallier, ORSTOM, Victoria, Seychelles, pers. comm.)

By contrast, the WTP purse seine fishery, centered north of Papua New Guinea, is the largest of the three purse seine fisheries (Figure 3). Total yellowfin-skipjack production in 1984 was approximately 359,000 mt with skipjack tuna making up 80% of this catch (IPTP 1986). Most of the catch is from log-associated schools, or schools associated with flotsam (Tsukagoe 1981). The area of operation of this fishery overlaps the area of high concentration of blue marlin in the Pacific (Figure 1), and preliminary data indicate incidence of blue marlin caught in purse seine sets (Gillett 1986a; 1986b).

To determine the magnitude of the incidental blue marlin catch in this WTP purse seine fishery, I compiled various statistics, and made several assumptions to estimate the by-catch for 1984. The total purse seine catch of yellowfin and skipjack, 359,500 mt was stratified into U.S. and non-U.S. (principally Japanese) catches -- 155,700 mt for U.S.[1] and 203,800 mt for non-U.S. (IPTP 1986). Mode of fishing of these two categories are

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[1]Tuna catch statistics used throughout this report is from a single source, IPTP (1986) although other sources probably are more accurate. For example, Herrick and Koplin (1985) give a more accurate estimate of the U.S. catch from the WTP in 1984 of 170,500 mt.

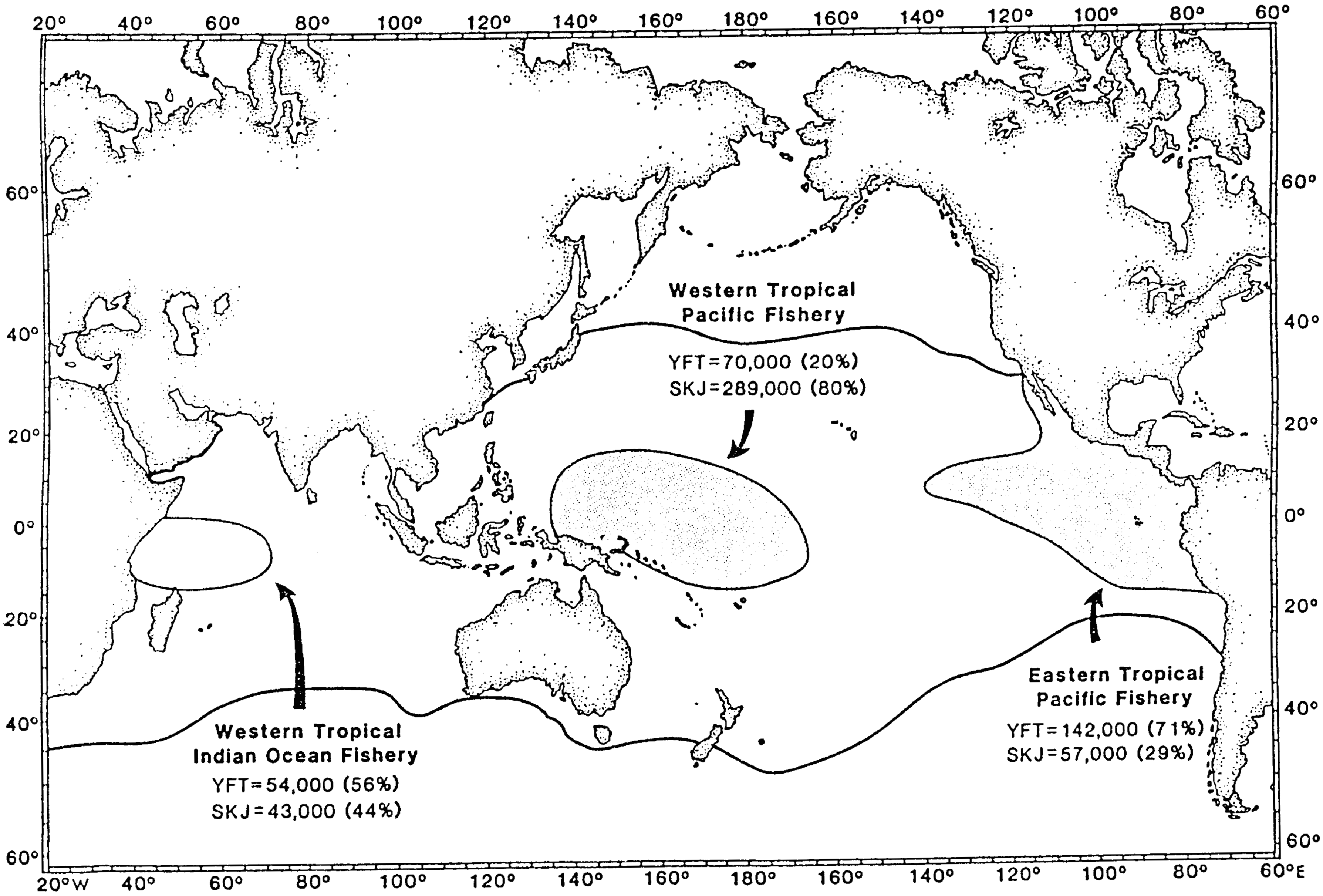

Figure 3. Location of the three major purse seine fisheries for tropical tunas in the Pacific and Indian Oceans. Catches for yellowfin tuna (YFT) and skipjack tuna (SKJ) are for 1984.

different in that U.S. vessels are larger and tend to fish more schoolfish whereas the non-U.S. vessels are generally smaller and tend to fish more log-associated schools.

Statistics for 1981 (Tanaka 1982) indicate that the Japanese fleet had an average catch per set of 21.3 mt of tuna with 82% of the sets being on log-associated schools. Assuming these statistics are applicable to the 1984 season for the non-U.S. fleet, the fleet made an estimated 9,570 sets in 1984 of which 7,850 were on log-associated schools. Assuming an incidental catch rate of blue marlin for the fishery of approximately 0.8 marlin per log-associated set (Gillett 1986a, 1986b), the estimated incidental catch of blue marlin by the non-U.S. fleet in 1984 is approximately 6,300 fish.

Recent fishing performance statistics for the U.S. purse seine fleet in the WTP fishery are not readily available. Published statistics on a small number of vessels (Gillett 1986a; Bailey and Souter 1982) indicate that the catch rate is about 11 mt per set[2] and about 30% of the sets are on log-associated schools, the remainder on schoolfish. Applying these rates to the 1984 U.S. catch of 155,700 mt yields a total of 14,200 sets of which 4,300 were log-associated sets. If each log-associated set results in capture of 0.8 blue marlin, an estimated 3,400 blue marlin were caught by the U.S. fleet in 1984.

The total incidental blue marlin catch for the WTP purse seine fishery is thus approximately 6,300 + 3,400 = 9,700 fish. Since most marlins caught in a tuna purse seine net either die or escape with injuries that probably result in death (Gillett, 1986a, 1986b), virtually the entire catch can be assumed to be removals from the population.

The tonnage of this blue marlin catch is estimated by assuming that the average size of blue marlins caught by the purse seine fleets is the same as fish landed by the Japanese longline fleet. Suzuki and Honma (ms) provided eye-fork length measurements for 610,505 blue marlin caught by longliners in 1967-75 within the same area of operations as the WTP purse seine fishery (Figure 4). The measurements were converted to fork length with an equation given by Royce (1957) and then to weight (W) with the equation, $\ln W = \ln (5.0048 \times 10^{-6}) + 3.0214 \ln FL$, of Skillman and Yong (1974). The average is 65 kg. Applying this average to the incidental catch in numbers, gives 630 mt as the estimated incidental catch in weight.

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[2]Sources familiar with operations of the U.S. fleet indicate that recent catch rates have been higher, and total number of log-associated sets is about 4,200.

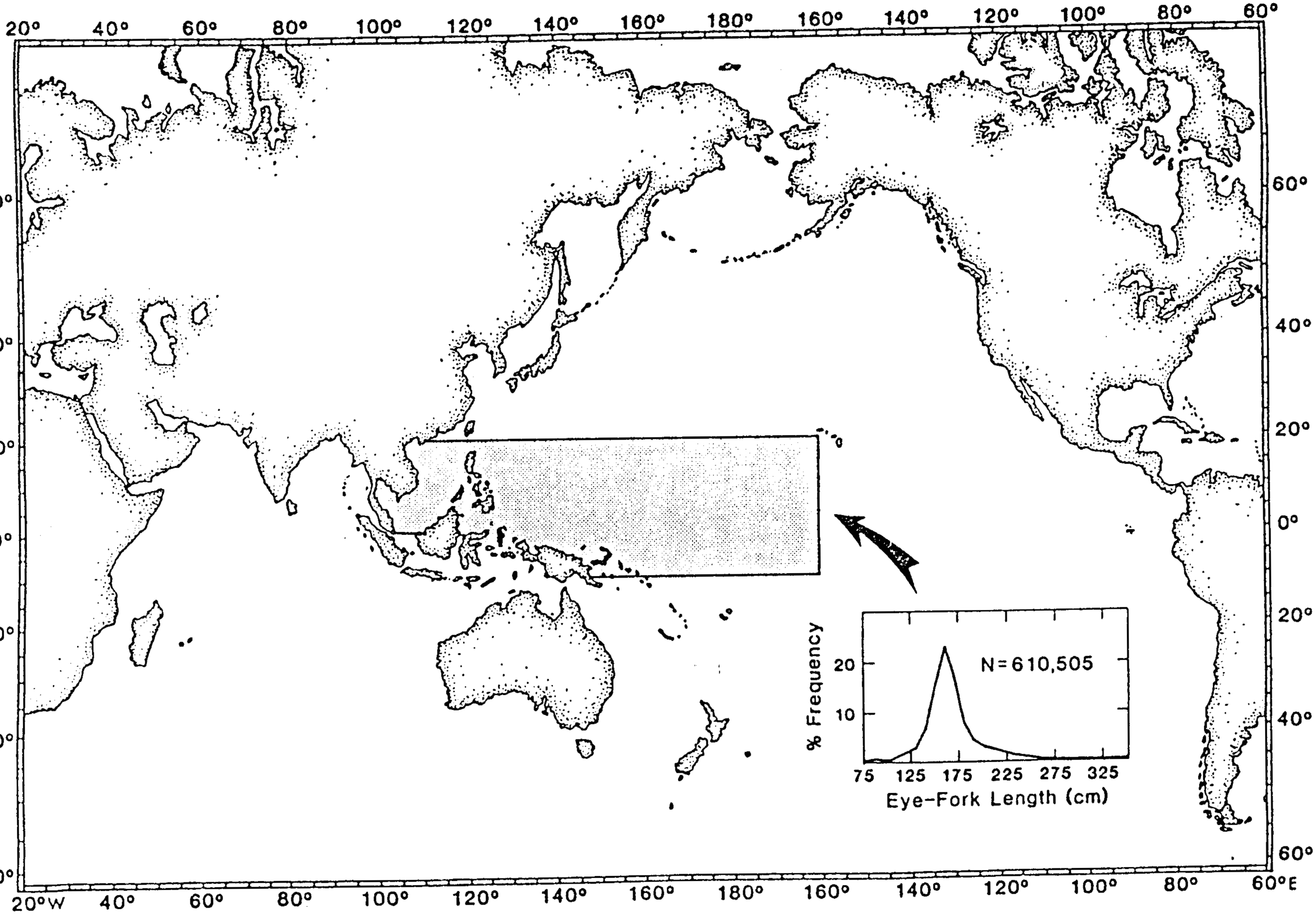

Figure 4. Length-frequency distribution of blue marlin caught in the western tropical Pacific by longliners in 1967-75.

Effects

The WTP purse seine fishery appears to be a minor source (about 3%) of fishing mortality for the blue marlin population of the Pacific Ocean. Catches of the longline fleets (Table 1) are substantially greater than that for the WTP purse seine fishery. Because some of my assumptions are probably not warranted, e.g., the blue marlin catch rate is not representative because of small sample sizes or not only log-associated sets results in blue marlin catches, my conclusion might be suspect. However, if I relax some assumptions such as all purse seine sets and not only log-associated sets result in a by-catch of blue marlin, as preliminary observations by Gillett (1988b) suggest, then my estimate is an underestimate by a factor of about two. This would double my estimate but still be a small portion of the total Pacific catch of blue marlin.

The overall level of catch from all sources, however, may be high with respect to total impact on the blue marlin population. In 1977 an analysis of available data resulted in the conclusion that the Pacific blue marlin stock was overfished (Yuen and Miyake 1980) -- fishing effort was excessive, catch was below the maximum sustainable (MSY) level of 22,000 mt, and the catch rate was at record low levels (Figure 5).

Data for updating this 1977 analysis are not available. By using fragmented data on catches and some assumptions, I estimated where recent points would probably lie on the production curve. Yuen and Miyake (1980) reported a catch rate of about 0.05 fish/1,000 hooks fished for 1975. This was the lowest rate in a declining series recorded for 1952-75. I used two different scenarios: one is I assumed that in 1976-1984 the rate is the same as in 1975, and the other, I assumed that the rate doubled as longline catches increased (Table 1). The points (Figure 5) fall within a cluster to the right of the MSY, indicating that either the fisheries continue to be operating on the overfishing side of the curve, or that substantial changes in the pattern of longline operations necessitates a new analysis of the equilibrium yield curve and the MSY value.

This latter conclusion appears most plausible given that the longline catch increased 61% between 1975 and 1983 (Table 1) despite increased purse seining activity in the WTP and with apparently less effective effort as the longline fleets targeted on the deep swimming bigeye tuna. During the late 1970's, the longline fleets switched to "deep longlining" which places the hooks below the mixed layer depth, where blue marlin generally occur (Suzuki, Warashima and Kishida, 1977). Before this switch, regular longline gear, which fishes the mixed layer depths, was used.

Also, catch rates for recreational rod-and reel fisheries show recent improvement in blue marlin apparent abundance (Figure 6). In the Hawaiian Islands and Guam the rates show an

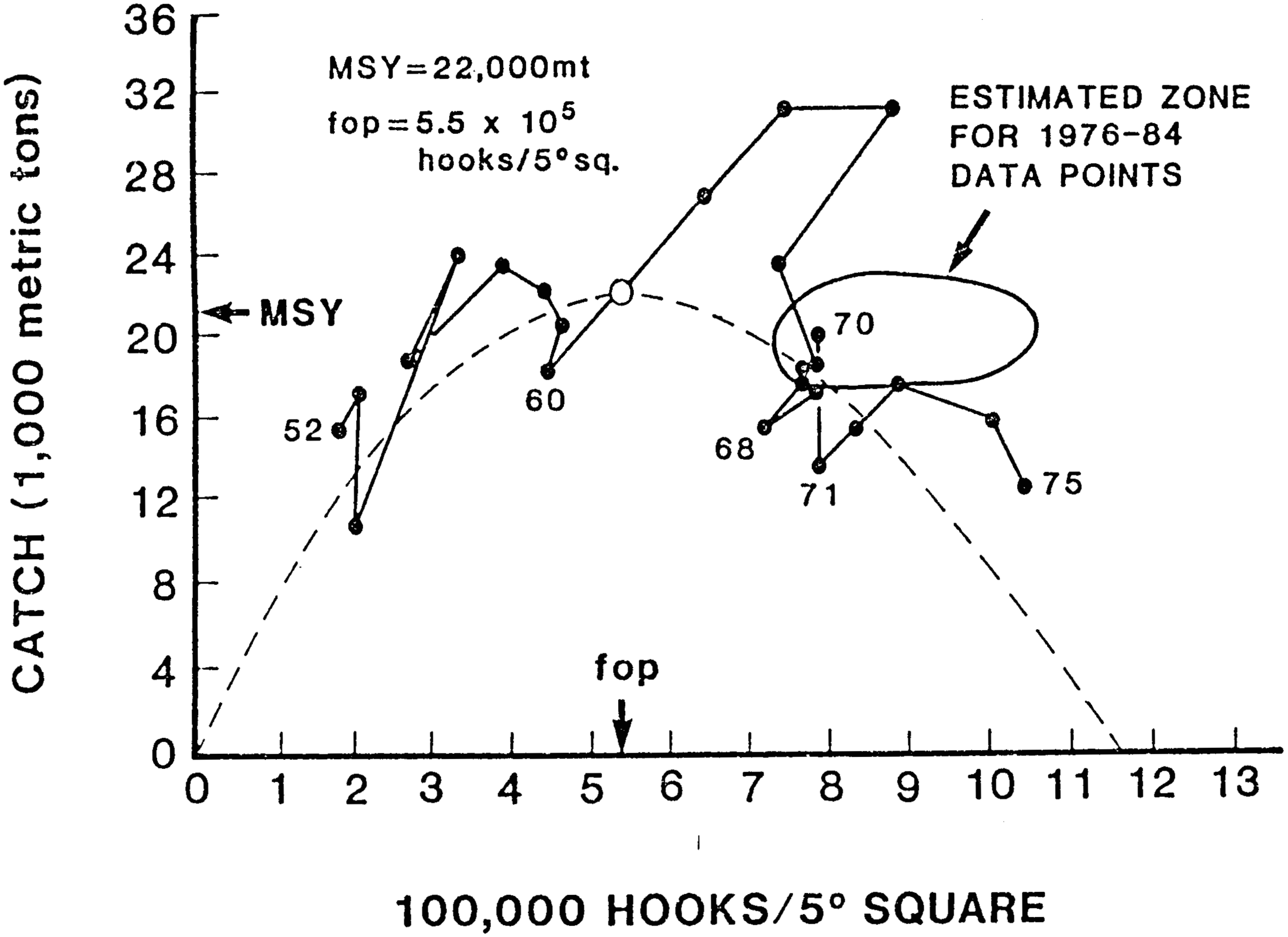

Figure 5. Relation between catch of blue marlin and effective fishing effort. The curve represents equilibrium yield for the fisheries with maximum sustainable yield (MSY) and corresponding effort (fop) to obtain that yield. (Source: Yuen and Miyake 1980.)

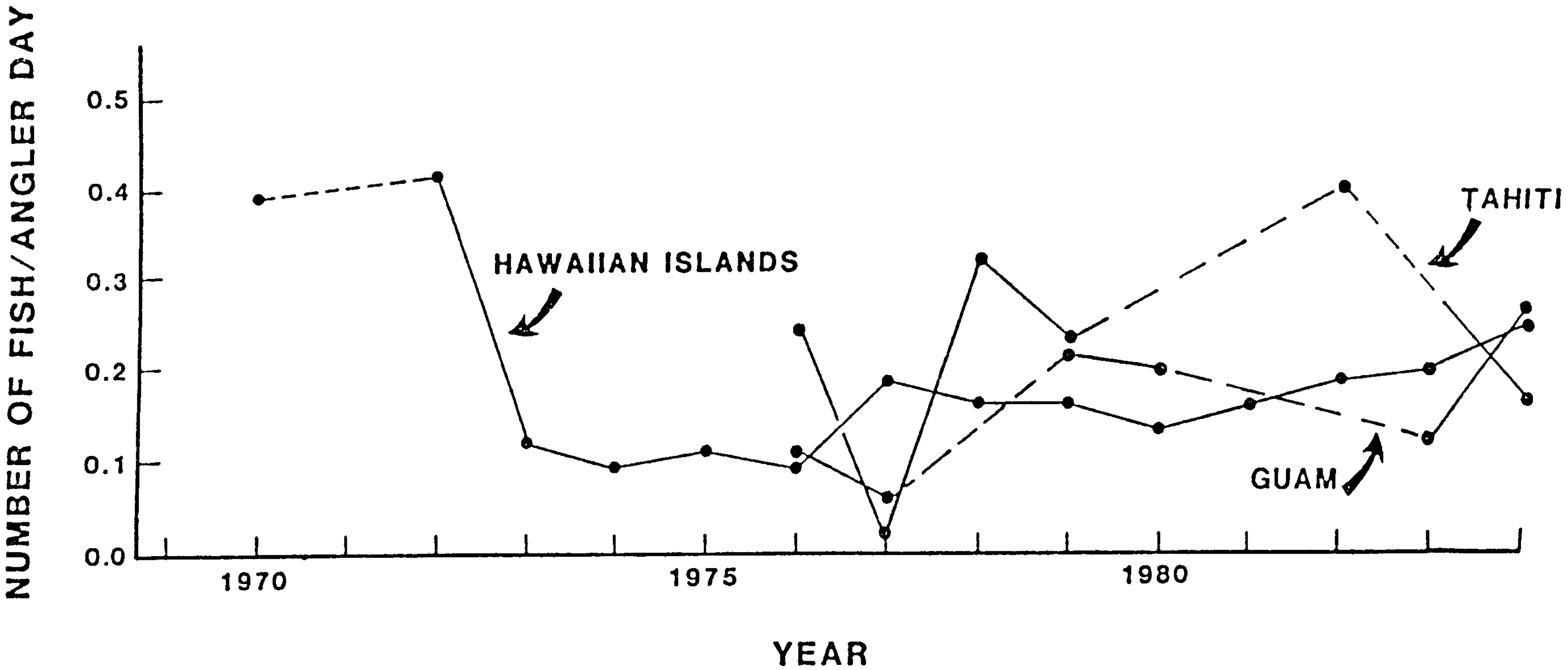

Figure 6. Average catch of blue marlin per angler day for recreational rod-and-reel fisheries in Guam, Hawaiian Islands and Tahiti. (Source: Squire 1986.)

increasing trend with the 1984 rates among the highest recorded. These fragmented information suggest that the stock might be at higher levels of abundance than in 1977 despite increased incidental catches by the purse seine fisheries.

On the other hand, the WTP purse seine fishery occurs in the high density and spawning area of the blue marlin, so it might have a disproportionate effect on the population than expected from the estimated by-catch. The fishery could have a disruptive effect on the spawning behavior of blue marlin which in turn might affect recruitment to the Pacific-wide population.

CASE II - BAITFISHES

The second case study is that of the baitfishes used in pole-and-line fishing for tunas. Suitable bait must be located, caught, and transported live to the fishing areas for this type of fishing. In other words, the pole-and-line method is completely dependent on the availability of secondary species, the baitfishes to be successful (Ben-Yami 1980; Rothschild and Uchida 1968).

Approximately 160 species, belonging to 31 families, have been identified as suitable bait for tuna pole-and-line fishing (Baldwin 1977; Ben-Yami 1980). Of these, only about a dozen species from the families Apogonidae, Caesionidae, Clupeidae, Dussumieriidae and Engraulidae are principal bait used in the major Pacific and Indian Ocean pole-and-line fisheries.

Biology and Distribution

The principal bait species are primarily coastal inhabitants with localized distribution (Table 2; Figure 7). Some, like the Japanese sardine (*Sardinops melanosticta*) and northern anchovy (*Engraulis mordax*) are widely distributed but most have limited, localized distributions. All share a common characteristic of schooling when 4 to 14 cm long, and when suitable for tuna pole-and-line fishing.

The cardinal fishes, Apogonidae, are small (majority less than 10 cm long) reef dwellers (Herald 1961). They are nocturnal and are found throughout the tropical and subtropical Indo-Pacific. Not much is known of their life history except that many are mouth-breeders, i.e. they incubate fertilized eggs in their mouths. At times, they occur in large concentrations, schooling above coral heads.

Caesio coerulaureus belongs to the family Caesionidae and is an important bait species used in the Laccadive and Maldive tuna fisheries (Jonklaus 1967) and was once used in the tuna fishery of Truk. It is a colorful reef fish with widespread distribution

Table 2. Baitfish and tuna catches of pole-and-line fisheries of the Pacific and Indian Ocean.

Fishery Location	Major bait Species	Period	Average Annual Catch: bait (mt)	Average Annual Catch: tuna (mt)	Average Tuna Catch Per Unit of Bait (mt/mt)	Source
Eastern Tropical Pacific	Engraulis mordax Cetengraulis mysticetus Sardinops caerulea Anchoa naso	1950-69	7,304	54,602	7.5	Yoshida, Uchida & Otsu, 1977
Japan Islands	Engraulis japonicus Sardinops melanosticta	1957	19,103	186,243	9.7	Yoshida, Uchida & Otsu, 1977
Japan Islands/ Ryukyu Islands	Spratelloides spp. Stolephorus spp. Caesio spp. Apogon spp.	1966-80	272	4,328	15.9	Isa, 1970
Hawaii	Stolephorus purpureus	1950-72	194	4,478	12.1	Yoshida, Uchida & Otsu, 1977
Western Tropical Pacific/ Papua New Guinea	Stolephorus spp. Spratelloides spp.	1970-81	1,171	26,264	22.4	Anon, 1984
Western Tropical Pacific/ Solomon Island	Stolepherus spp. Spratelloides spp.	1973-80	472[1]	14,395	30.4	Argue & Kearney, 1982
Indian Ocean/ Minicoy Islands, India	Spratelloides spp. Caesio caerulaureus Archamia lineolatus Chromis caeruleus	1981-85		401	53.1-95.6	Pillai et al., 1986

[1] Converted from buckets to weight with one bucket = 2.5 kg of bait.

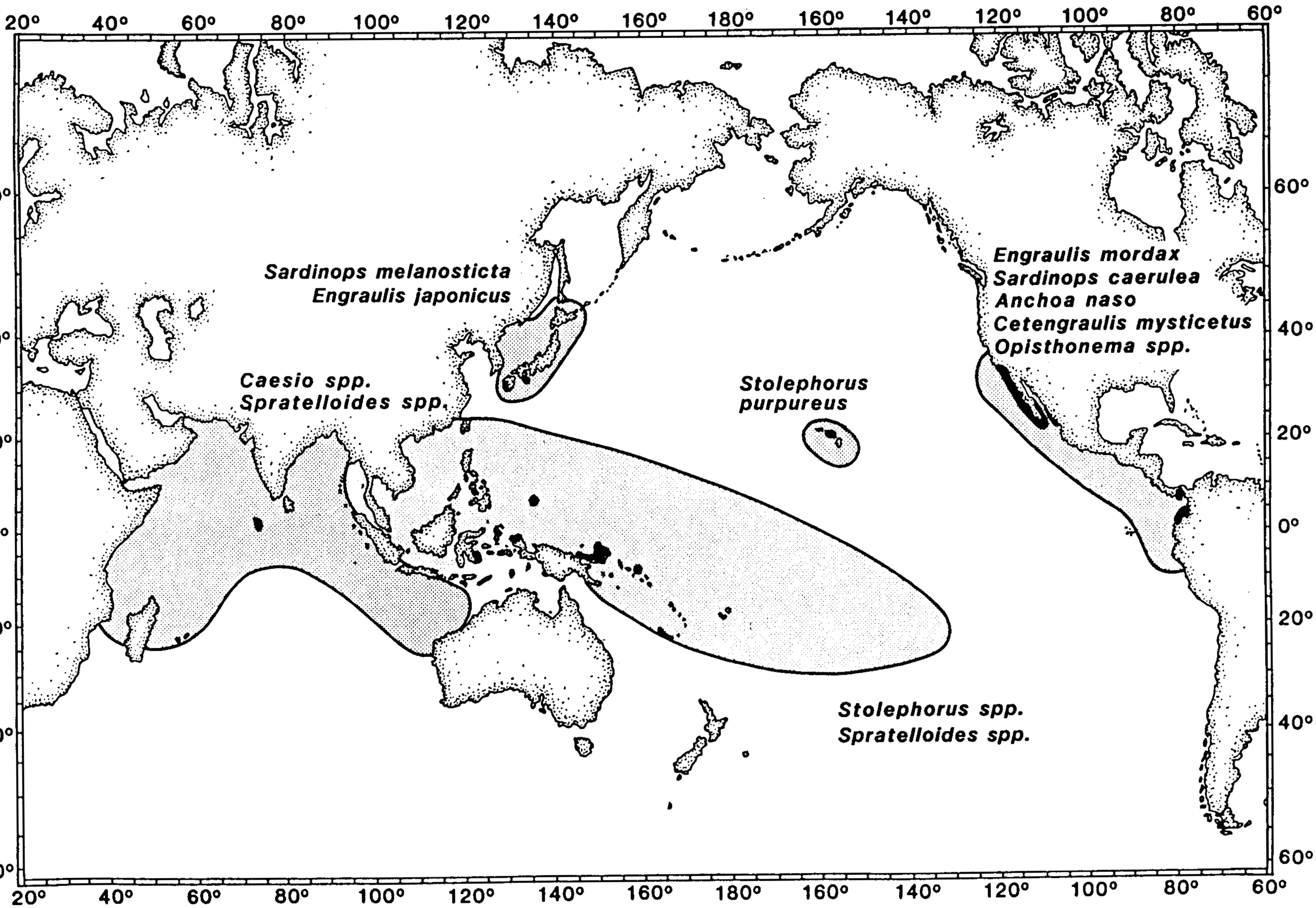

Figure 7. Distributional range of principal baitfishes for tropical tuna fisheries and location of baiting grounds (darkened) in the Pacific and Indian Oceans.

in tropical and subtropical regions of the Indo-Pacific. Individuals grow to a maximum length of about 30 cm, but only juveniles are used for bait.

In the Clupeidae, the Pacific sardine (Sardinops caerulea) and Japanese sardine are the principal species used in the Pacific tuna fisheries. These are coastal pelagic species, found in temperate and subtemperate regions of the Pacific Ocean. The Pacific sardine grows as large as 28 cm FL and reproduces at about 20 cm FL (Murphy 1976, 1977). The Japanese sardine reaches a smaller maximum size of about 22 cm FL, and reproduces at 14 cm FL (Kondo MS). Both species are very abundant, but their stock sizes are extremely variable; survival of their young is largely determined by environmental factors (Blaxter and Hunter 1982). Besides their use as bait, they support major commercial fisheries for primarily reduction purposes.

Two species in the family Dussumieriidae, Spratelloides gracilia and S. delicatulus, are used as baitfishes (Lewis, Smith and Ellway 1983). They are widely distributed in the Indo-Pacific and are found in dense schools in clear coastal waters, often near or above coral reefs. They grow to a maximum size of 6-7 cm long. Life histories of these species are largely unknown.

Several species of baitfishes belong to the family Engraulidae. The principal temperate species, northern anchovy and Japanese anchovy (Engraulis japonica), live in coastal pelagic waters of the eastern Pacific and western Pacific respectively. They are fast growing and attain a maximum size of 30 cm long for E. mordax (Clark and Phillips 1952) and 16 cm long for E. japonica (Hayasi 1967). They characteristically have large variations in population abundance. In the tropical Pacific, Stolephorus spp. are the principal engraulid species used by the pole-and-line fisheries, e.g., Hawaii. They are found in a wide range of habitats with high concentrations occurring in estuarine waters and in clear coastal waters near coral reefs. They are small, short-lived fishes that reproduce year-round. The young inhabit coastal areas after a pelagic larval stage (Wetherall 1977; Tester 1955). They are more susceptible to overfishing than other engraulid species because of their other smaller, localized populations.

Fishery

Major pole-and-line fisheries are located in the eastern tropical Pacific, western tropical Pacific, off Japan and off the Maldives (Figure 8). Except for the fishery off Japan (May-September) all are year-round operations. These fisheries initially developed in locations where bait supply was readily available. Through the years, both political and economic forces have modified the manner in which these fisheries operate. For example, the limited supply of bait in the south Pacific together

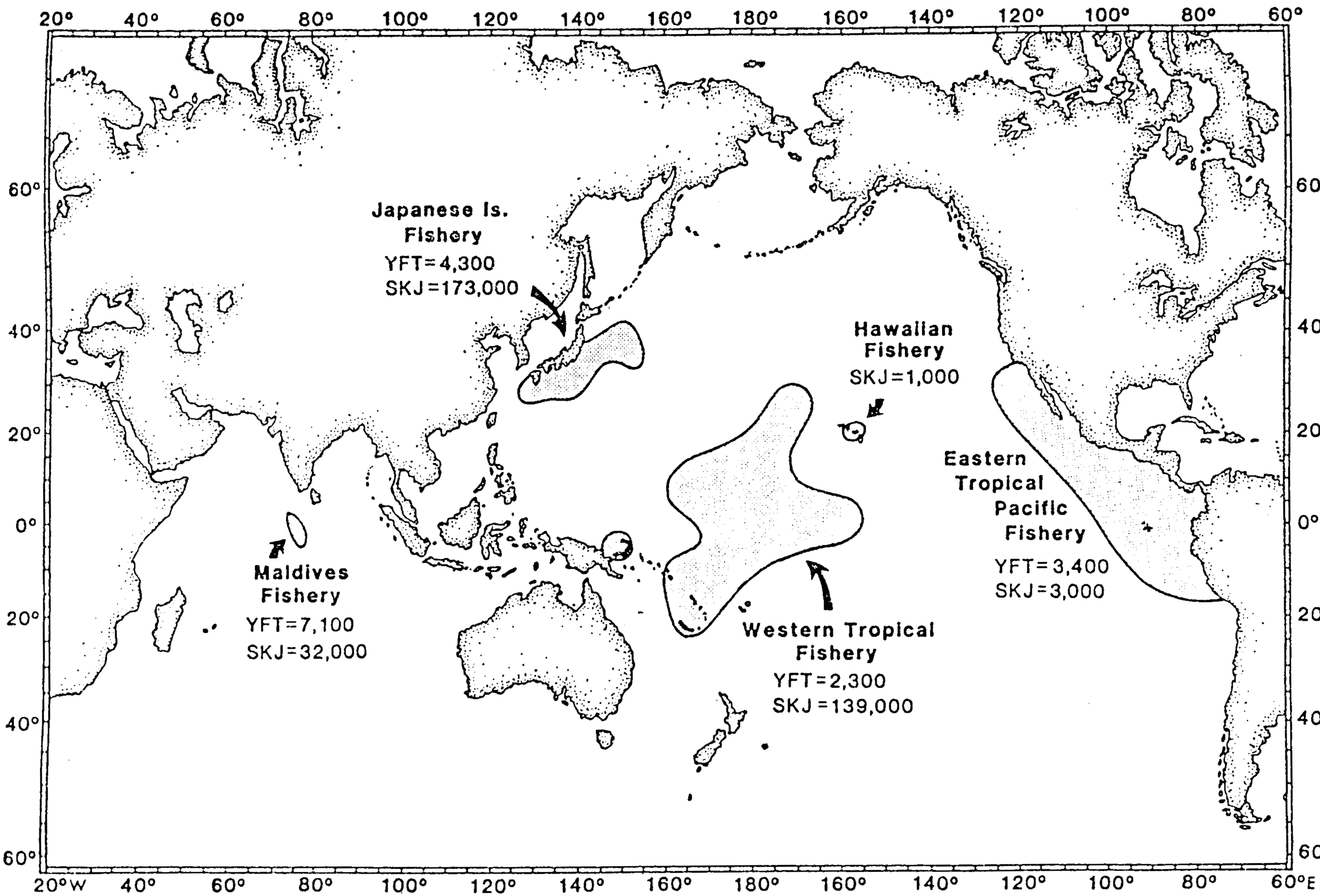

Figure 8. Location of some pole-and-line fisheries for tropical tunas in the Pacific and Indian Oceans. Catches for yellowfin tuna (YFT) and skipjack tuna (SKJ) are for 1984.

with limited access to inshore baiting areas, encouraged the Japanese to develop a system of transporting bait from their home islands to the southern fishing area. Japanese anchovy and sardine are caught off southern Japan, held in holding pens for a period of "ageing", and then transported live aboard the fishing vessels to the south Pacific. This system was developed in the early 1970's (Maruyama 1980) and is currently used by about 100 vessels to produce approximately 70,000 mt annually of skipjack tuna from the south Pacific (Miyoshi 1982).

Besides the Japanese pole-and-line fleet, other fleets based in Indonesia, Papua New Guinea, Solomon Islands, and Kiribati in the western Pacific participate in the WTP fishery. Total skipjack-yellowfin catch for the WTP pole-and-line fishery was 141,500 mt in 1984.

In the eastern tropical Pacific, the pole-and-line fishery has diminished since its heyday in 1951 when 228 boats were active (McNeeley 1961). Economic factors, including high cost in securing bait, encouraged fishermen to abandon this form of fishing for purse seining. In 1984 only 40 pole-and-line boats were active and they landed 6,400 mt of yellowfin and skipjack tuna. A variety of baitfishes is used by the ETP fishery (Bayliff 1967; Yoshida et al. 1977): United States vessels use primarily E. mordax and S. caerulea from southern California and Baja California; Mexican vessels use E. mordax, Opisthonema spp. and Cetengraulis mysticetus; and Ecuadorian vessels use Anchonaso and C. mysticetus.

Off Japan, Japanese pole-and-line vessels fish for skipjack and small yellowfin tuna from about May to September. They produced 177,600 mt of skipjack and yellowfin tuna in 1984. The bait used is primarily Japanese anchovy and sardines caught in the coastal waters.

In the Indian Ocean, there is a substantial pole-and-line fishery for tunas in the Maldives and a modest fishery off India. Production by the Maldives fishery was about 39,100 mt of predominantly skipjack tuna in 1984 (H. Maizan, Ministry of Fisheries, Maldives, pers comm.). The principal bait used by this fishery is C. coerulaureus (Jonklaas 1967) and Spratelloides spp. Production by the Lakshadweep Islands fishery of India averages 3,100 mt annually of mostly skipjack tuna. The principal bait used is Spratelloides delicatus and Anchamia lineolatus (Silas et al. 1986).

In 1974 Yoshida et al. (1977) reviewed information up to 1971 on bait used in pole-and-line fisheries of the Pacific Ocean. Their findings show that an average of about 27,000 mt of bait was used to produce a catch of approximately 245,000 mt of tuna. Since 1971, there has been substantial changes in the Pacific and Indian Ocean pole-and-line fisheries.

I compiled statistics on bait and tuna catches from published sources to compute catch per unit of bait (CPUB). The results show high CPUB for fisheries in the western tropical Pacific, Hawaii and Lakshadweep Islands fisheries, and low CPUB for the eastern tropical Pacific and Japanese Island fisheries (Table 2). This pattern was also noted by Yoshida et al. (1977) who implicated size of bait, species of bait, number of men fishing and abundance of tuna as causal factors. Relative availability or abundance of bait might also be a factor, as scarcity of bait should encourage a more sparing use of bait.

I estimated the amount of bait used by each major fishery in 1984 using the estimated CPUBs, tuna catches and some assumptions. For the ETP fishery, an average CPUB for 1950-69 of 7.5 tons of tuna per ton of bait (Table 2) is assumed to be applicable for the 1984 season. Dividing this rate into 6,400 mt gives 900 mt of bait used by this fishery in 1984.

The pole-and-line tuna catch of the Japanese Island fishery, 177,600 mt, was combined with the tuna catch by Japanese vessels from the western tropical Pacific fishery, 112,000 mt. The bait and mode of operation of the Japanese vessels in both these fisheries are assumed to be identical, with an average CPUB of 9.7 (Table 2). The estimated bait used by the Japanese fleet is 29,900 mt.

The balance of 29,500 mt of tuna caught in 1984 in the WTP pole-and-line fishery was landed primarily by the Indonesian pole-and-line fleet. To estimate the bait used for this catch, I assume that the average CPUB of Papua New Guinea and Solomon Islands fleets is applicable. The average CPUB is 24.7 (Table 2). Dividing this rate into the catch yields 1,200 mt of bait.

The Maldives-Lakshadweep Islands fishery produced 42,200 mt of yellowfin and skipjack tuna in 1984. Some information on CPUB is available for part of this fishery. I assume that the CPUB is 53.1 (Table 2), which is unusually high. Dividing this rate into 42,200 mt, yields 800 mt of bait.

Summing up all of these estimates, a grand total of 32,800 mt of bait is computed for the major pole-and-line fisheries of the Pacific and Indian Oceans for 1984. This total is probably an underestimate because a substantial amount of bait is lost during the capture and holding period, and not normally reported. Losses as high as 50 to 90% from injury, predation, trauma of capture and handling, high water temperatures in holding facilities, etc., have been mentioned as common (Smith 1977; Maruyama 1980). In other words, as much as 328,000 mt of baitfishes might be involved in supporting the major Pacific and Indian Ocean tuna pole-and-line fisheries.

Effects

About 90% of the bait used by the pole-and-line tropical tuna fisheries of the Pacific and Indian Oceans are caught off Japan. The bait consists of principally the Japanese sardine and anchovy from stocks that are also exploited for fish reduction products.

Japanese catches of sardines and anchovy for primarily reduction products have been increasing and currently exceed 4 million mt annually (FAO 1984). Compared to this total, the catch for bait purposes is insignificant and a minor source of fishing mortality for the Japanese sardine and anchovy populations.

Likewise, in the eastern tropical Pacific, bait species used by the pole-and-line fishery also support directed fisheries. The catch of the directed fisheries is in excess of 800,000 mt annually (FAO 1984) and is used for animal and human consumption. The catch for tuna bait purposes, 900 mt, in comparison is small.

In the western Pacific and Indian Ocean, the tuna bait species are also caught for human consumption. The catch for this purpose is not well documented but is probably in excess of 200,000 mt annually.

There is growing pressure among developing states of the tropical Pacific and Indian Ocean to exploit the surface skipjack and yellowfin tuna resource in that region by themselves (Kearney 1979; Silas et al., 1986). A tempting way for these island nations to do so without large investments in advanced fishing equipment is through use of the pole-and-line technique. Live bait, a mixture of species but primarily *Stolephorus* spp. and *Spratelloides* spp., would be relied upon to produce a tuna catch with coastal vessels. The difficulty with this concept is that the bait resources of the tropics are limited and susceptible to depletion with modest levels of fishing effort (Kearney 1979; Lewis 1977; Muller 1977). Furthermore, it is possible that baitfishes in the region attract tunas to the coastal areas where they are within easy reach of artisanal fishermen. With reduction of the baitfish resources, the ecological mechanism (Gilmartin and Revelante 1974; Rothschild and Yong 1970) that result in high availablity of tunas in the coastal areas or around islands could very well be weakened; thus setting in motion a process that could result in the production of the fishery to dwindle to an uneconomical level. By contrast, if development of a tuna fishery is with imported bait from outside the local region, such as is being practiced by the Japanese pole-and-line fishery in the south Pacific, the ecological mechanisums are undisturbed and the fishery production could be maintained at a high level.

Another effect of increased exploitation of baitfish resources for tuna fishing in the tropics is competition with directed fishery for the baitfishes. Many baitfish stocks in the tropics are exploited directly for human consumption or consists of juveniles of species that are exploited as adults for food particularly around population centers. The centers have facilities for supporting a pole-and-line fleet, and are the favored locations for basing fishing fleets. The baitfish stocks adjacent to the centers consequently are the first to be depleted and the directed fisheries close to the population centers are the first to experience the immediate effects of a pole-and-line fishery.

Management Implications

There is a wide range of different types of interactions involved in the tropical tuna fisheries. Some are unique to specific areas and fisheries, e.g., yellowfin tuna-dolphin interaction in the ETP purse seine fishery (Perrin 1969), while others are more common, e.g. dependence on baitfishes of pole-and-line fisheries (Ben-Yami 1980). Too often, discussion of tuna fisheries interaction is too narrowly focused on competition for tunas among different fisheries. A broader focus seems more appropriate since solutions to real or perceived problems with tuna fishery interaction involve more than competition or just the tuna resource.

The two examples discussed in this paper highlight the need for a broad focus in dealing with tropical tuna fishery interaction issues in the Indo-Pacific region. Competition for the tuna resource among the fisheries is an immediate issue. A solution that encourages expansion of the purse seine fishery without simultaneously considering how to limit the incidental catch of blue marlin could be counterproductive if there is a desire to maintain high abundance of blue marlin for other uses, such as developing recreational rod-and-reel fisheries. Likewise, a solution that encourages the expansion of pole-and-line fisheries based on local sources of bait in the tropics would almost certainly exert substantial fishing pressure on fragile, local baitfish stocks. The effect would be eventual depletion of the baitfish resources as more effort is expanded to maintain or improve overall tuna production, and reduced yield of the bait species for human consumption. Studies that would broaden the focus to include more than target-species competition is needed to provide the scientific basis for informed management decisions that balance the need for tuna fishery development, equitable allocation and overall resource conservation of the region.

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