MFR PAPER 1077

7424

Opportunities exist for U.S. fishermen to expand the skipjack tuna fishery.

Walter M. Matsumoto is a member of the staff of the Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

The Skipjack Tuna, *Katsuwonus pelamis*, an Underutilized Resource

WALTER M. MATSUMOTO

INTRODUCTION

The tunas are the most important of the large fishes constituting the exploited pelagic resources of the world oceans. The largest catches of tunas, including the yellowfin tuna, *Thunnus albacares;* the bigeye tuna, *T. obesus;* the bluefin tuna, *T. thynnus;* the southern bluefin tuna, *T. maccoyii;* and the albacore, *T. alalunga,* are taken with deep-fishing longline gear in the pelagic waters of noncoastal areas. The skipjack tuna, *Katsuwonus pelamis,* is taken at the surface, mostly with purse seine and pole-and-line gear. It is also taken incidentally with the longline. Skipjack tuna constitutes about 30 percent of the total tuna catch, and in recent years has come to replace the yellowfin tuna as the dominant species.

Recent studies of longline catches indicate that, except for the bigeye tuna in the Atlantic and possibly the albacore in the South Pacific, all the tunas taken with the longline are now being exploited at or near their maximum sustainable yields in the Atlantic, Pacific, and Indian Oceans (Rothschild and Uchida, 1968; Kikawa et al., 1968; Hayasi et al., 1970; Suda, 1971; and Skillman[1]). The skipjack tuna is the only species of tuna presently exploited in large commercial quantities that can withstand large increases in fishing pressure. Unlike most other tunas that are caught in large quantities in midocean areas, the bulk of the skipjack tuna is generally taken in waters associated with land masses. Yet its occurrence in tropical and subtropical areas far removed from land, as evidenced by incidental catches on the longline gear, demonstrates that the species is not fully exploited, despite the tremendous increase in fishing in recent years in the western equatorial Pacific.

FISHERIES AND DISTRIBUTION OF FISH

The catch statistics (FAO, 1966, 1972) show that in the most recent 6 years, 1966-71, the annual world production of skipjack tuna has been maintained at the 300,000-350,000 metric ton (MT) level, up from roughly 200,000-250,000 MT in years prior to 1966 (Table 1). The total catch appears low, probably due to incomplete reporting of catches from areas that have expanded rapidly in the last few years. A most obvious discrepancy is noted in the catch from the Indian Ocean. The catches for 1970 and 1971 are given as 100 MT, but according to Sivasubramaniam (1972) catches of skipjack tuna there have increased rapidly since 1969, and at present about 45,000-50,000 MT are taken from this ocean. A recent summary of the world's catch of skipjack tuna for 1971 by Joseph (in press) shows an even greater discrepancy; his estimated total of 438,000 MT exceeds that of the FAO statistics by 108,000 MT. Joseph's breakdown of the total catch by oceans shows 82,000 MT from the Atlantic, 39,000 MT from the Indian, and 317,000 MT from the Pacific. In all three oceans his catch estimates exceed the totals of the FAO statistics.

Despite these discrepancies, the FAO records are useful for determining long-term catch trends. The catch records (Table 1) reflect the fact that skipjack tuna is fast becoming, if it is not already, the dominant species in the catches of tunas. Prior to 1966 the yellowfin tuna dominated the catch, but in the 6 years beginning in 1966, skipjack tuna has dominated the world catch in 3 and possibly 4 years. Joseph's estimates for 1971 show that the skipjack tuna catch exceeded that of yellowfin tuna by 130,000 MT.

Up to recent years, the major skipjack tuna fisheries were concentrated in only a few places in the Pacific Ocean; the U.S. fishery in the eastern Pacific off the coasts of Baja California, Central America, and northern

Table 1.—Annual landings (in 1,000 metric tons) of skipjack tuna from the major oceans (FAO, 1966, 1972).

	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Atlantic Ocean	0.3	0.3	2.2	1.4	10.0	10.4	13.0	24.3	18.3	34.7	36.0
Northwest	No breakdown by area				0.0	0.0	0.0	1.8	0.4	0.7	1.5
Western central					1.0	1.0	1.1	1.7	1.2	1.4	1.5
Eastern central					7.1	6.0	8.4	15.8	14.4	31.6	32.0
Southwest					0.5	0.6	1.5	0.8	0.4	0.0	0.0
Southeast					1.4	2.8	2.0	4.2	1.9	1.0	1.0
Indian Ocean	—	—	—	—	0.1	0.1	0.2	0.3	0.3	0.1	0.1
Western	No breakdown by area				0.1	0.1	0.2	0.2	0.2	0.1	0.1
Eastern					0.0	0.0	0.0	0.1	0.1	0.0	0.0
Pacific Ocean	219.0	252.4	200.8	226.5	237.4	310.1	337.4	275.1	271.1	288.5	294.0
Northwest	No breakdown by area				145.8	208.4	176,0	147.6	163.1	166.2	206.8
Northeast					0.2	—	0.1	—	0.1	0.2	0.3
Western central					—	35.7	35.2	42.3	41.5	53.6	0.7
Eastern central					76.2	54.1	106.9	74.4	51.4	58.3	79.0
Southwest					1.6	1.6	1.7	1.9	1.6	1.5	1.5
Southeast					13.6	10.3	17.5	8.9	13.4	8.7	5.7
Total	219.3	252.7	203.0	227.9	247.5	320.6	350.6	299.7	289.7	323.3	330.1

[1] Skillman, R. A. 1973. An evaluation of the South Pacific albacore, *Thunnus alalunga*, fishery and its potential for expansion. Unpublished report, 22 p., 5 tables and 11 figures. Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

South America, the northwestern Pacific fishery, which includes the fisheries off Japan, Formosa, and Ryukyu Islands, and the Japanese southern water fishery in the western equatorial Pacific. Between 1965 and 1970 the northwestern Pacific fishery contributed annually 147,000-208,000 tons to the world catch, the Japanese southern water fishery contributed 35,000-54,000 tons and the American fishery (excluding Hawaii) contributed 64,000-124,000 tons (Table 1). Since 1970 two more areas, Sri Lanka (Ceylon)-Laccadive-Maldive Islands in the Indian Ocean and the eastern equatorial Atlantic, have developed into significant fisheries, the latter contributing more than 32,000 tons. Together, these five areas contributed slightly more than 97 percent of the total world catch in 1970 and 1971.

A small-scale commercial skipjack tuna fishery dating back to the early 1900's exists in the Hawaiian Islands (June, 1951). This fishery produces about 4,600 tons per year (Rothschild and Uchida, 1968). Other small-scale fisheries in the Pacific Ocean are situated in Tahiti, where as much as 730 tons were taken in 1966 (Brun and Klawe, 1968), and in New Caledonia (Rothschild and Uchida, 1968). More recently the Japanese have begun to expand their pole-and-line fishing operations into the western Pacific, particularly in the New Guinea-Solomon Islands area. With as many as 19 boats operating at any one time in the Bismarck Sea (New Guinea), the 1971 catch of skipjack tuna totaled 16,860 MT (Kearney, 1973).

Although the major skipjack tuna fisheries are concentrated in a few places, the species is widely distributed in all oceans. It has been taken as an incidental catch on the tuna longline as far north as lat.40°N in the western part of both the Atlantic and Pacific Oceans, as far south as lat.40°S in the western part of the Indian and Pacific Oceans, and as far south as lat.40°S in the Atlantic Ocean (Fig. 1). Longitudinally, it has been taken continuously across the breadth of both the Indian and Pacific Oceans.

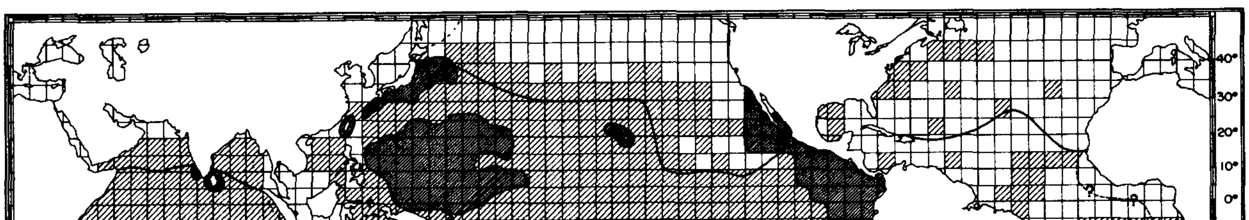
BIOLOGY AND ECOLOGY

Until recent years little fishing for skipjack tuna was done in the Atlantic and Indian Oceans. Consequently, research on the species and resource has been virtually limited to that in the Pacific Ocean.

It is now known that skipjack tuna begin spawning when they are about 40 cm long, and that each fish spawns between 100,000 and 2,000,000 eggs per spawning (Yoshida, 1966). The number of eggs spawned varies greatly with size of fish and even among fish of the same size. Spawning generally occurs throughout the year in tropical waters, but only in the warm seasons (late spring to early fall) in subtropical waters. Although spawning is greatly influenced by warm water and most skipjack tuna larvae are found in waters with surface temperature above 24°C, it is not uncommon to find them in waters below 23°C. Data collected by the Honolulu Laboratory, National Marine Fisheries Service, indicate the lowest temperature in which skipjack tuna larvae were found was 22.1°C. The larvae of skipjack tuna are distributed widely in all three oceans (Ehrenbaum, 1924; Klawe, 1960; Richards, 1969; Ueyanagi, 1969, 1971), but more so in the Pacific than in the others (Fig. 1). The distribution of larvae is narrowed latitudinally in the east and greatly expanded in the west, reflecting the response of spawning to warm water. In spite of their wide latitudinal range in the western and part of the central Pacific, most of the larvae are found in equatorial waters west of long.145°W between lat.20°N and 10°S. To the east of long.145°W the band of heavy concentration of larvae is even narrower, between lat.10°N and 10°S. The principal spawning area along this band is located in the central Pacific between long.150°E and 150°W (Fig. 2).

Although there have been a number of studies on age and growth of the skipjack tuna, only a few have attempted to assign ages to specific size groups (Aikawa and Kato, 1938; Brock, 1954; Schaefer, 1960; Yokota et al., 1961; Kawasaki, 1965; and Yoshida, 1971). Of these, even fewer agree as to the size of fish at age 1 and above age 4. The closest to an agreement is noted in fish of ages 2 and 3 (fish of 45-52 cm and 63-67 cm, respectively), which make up the bulk of the commercial catch. Prior to

Figure 1.—Areas of present skipjack tuna fisheries (dark shaded) and areas where skipjack tuna were taken incidentally on longline gear (light shaded) by the Japanese in the years 1969-71 (Fisheries Agency of Japan, 1971, 1972, 1973). The broken line off western Africa represents the estimated boundary of the eastern Atlantic skipjack tuna fishery. The northern and southern boundaries of larval skipjack tuna distribution are shown by solid lines.



their entry into the various fisheries, the young, after having spent some time within the spawning grounds, gradually spread out. (Kawasaki [1965, 1972] gives a detailed summary of the movement of skipjack tuna by age groups.) By the time the skipjack tuna have attained age 2, they have reached their widest distribution: in the west into waters off northern Japan; in the east into waters off Central America; off Baja California to the north, and northern Chile to the south. In the western Pacific these fish retreat south in the winter to spawn and return to the north as age 3 fish in the following summer. Only a small portion of older fish return north in subsequent years. In the eastern Pacific the age 2 fish make up the bulk of the fishery. These fish return to the central Pacific spawning grounds and, based on size distribution figures in Broadhead and Barrett (1964), probably reappear in the fishery as age 3 fish, off Mexico and Revilla Gigedo. A somewhat different situation exists in the central North Pacific. In waters around the Hawaiian Islands fish in their fourth year (72-84 cm) are taken in most years and these fish make up 40-80 percent of the catch during the peak fishing months, June-August (Rothschild, 1965). Equally large skipjack tuna are taken also in waters of the Marquesas and Society Islands (Rothschild and Uchida, 1968).

The northward and southward expansion of the skipjack tuna distribution follows a regular seasonal cycle (Matsumoto[2]). In both northern and southern hemispheres maximum poleward movement of fish occurs in their respective summer-fall season. In addition to this north-south seasonal movement the skipjack tuna also move along with the prevailing ocean currents (Fig. 3), foraging on organisms that are being transported therein. The combination of these two movements thus produces a roughly circular path, so that the resultant movement of skipjack tuna is counterclockwise in the South Pacific and clockwise in the North Pacific, except in the eastern part where it is counterclockwise (Fig. 4), similar to the current flow around the North Pacific Equatorial Water mass. Although Matsumoto's study was based on catches made with the longline, a gear that normally takes the larger and deeper-swimming tunas, the results are applicable to surface caught skipjack tuna, since the longline gear is capable also of taking skipjack tuna as small as 45 cm, the modal size common to most of the surface fisheries.

[2] Matsumoto, W. M. In preparation. Distribution, relative abundance, and movement of skipjack tuna, *Katsuwonus pelamis*, in the Pacific Ocean based on Japanese tuna longline catches, 1964-67. Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

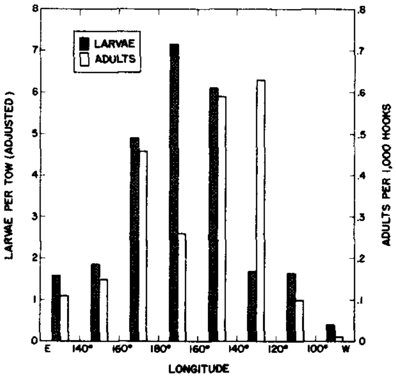


Figure 2.—Larval and adult skipjack tuna abundance across the Pacific Ocean between lat 20°N and 10°S (from Matsumoto[2]).

Before proceeding with resource assessment it is important that the population structure of the skipjack tuna be reviewed. Fujino (1970, 1972) has concluded, on the basis of serological studies, that in the Pacific Ocean a western subpopulation of skipjack tuna exists in both the northern and southern hemispheres west of a line running from southeastern Japan through the Bonin, Mariana, Marshall, and Gilbert Islands, between New Hebrides and Fiji Islands, and between Australia and New Zealand; and that this subpopulation is genetically distinct from the central-eastern Pacific subpopulation(s) to the east of this line. Fujino further noted that although both types of fish are found in Japanese waters, fish of the western subpopulation depart from the area within a few days of the entry of fish of the eastern-central Pacific subpopulation in September. This has been corroborated by length-frequency data showing two groups of 2-year-old skipjack tuna appearing in southeastern Japan during August (Kawasaki, 1972) with modal lengths differing by 5 to 6 cm.

It is not unlikely that the movement patterns shown in Figure 4 represent movements of stocks of skipjack tuna. The two westernmost stocks, one each in the northern and southern hemispheres, clearly belong to the western subpopulation and all other stocks to the east are of the eastern-central subpopulation. The intersecting of movement patterns from one stock to the next in the central and eastern Pacific gives rise to the thought that the progeny, if not the adults, could move from east to west in the northern hemisphere and from west to east in the southern hemisphere (Matsumoto[2]). Matsumoto has also shown that the skipjack tuna can move back and forth across the North Equatorial Countercurrent.

RESOURCE ASSESSMENT

Several estimates have been made of the potential yield of skipjack tuna in the Pacific Ocean. With the present state of knowledge about the parameters governing the dynamics of skipjack tuna populations, the estimates obtained thus far must be considered tentative and should be used with great caution. The pitfalls in such preliminary estimates are numerous, the most dangerous being that once an estimate is made, "it tends to stand by itself" (Kawasaki, 1972), and may be quoted out of context and become accepted as fact without reference to the author's qualifying assumptions and conditions. Such has been the fate of the estimates given by Rothschild (1966) and the Japan Fisheries Agency. The latter is summarized in Kawasaki (1972). Let us examine some of these.

Rothschild (1966), using the Beverton-Holt method, estimated the yield potential of skipjack tuna in the central Pacific Ocean. His estimates represented the potential yield of the escapement stock (fish that leave the fishery) of the eastern Pacific fishery in the event that the fishery continued to harvest these fish during their return to the central Pacific. He gave two estimates, one computed for a sojourn time of 2 months (sojourn time was defined as the time a fish spends in the fishing area), which he obtained from tag returns and which he considered rather short, and the other for a more conservative sojourn time of 6 months, selected arbitrarily. The first estimate was a fivefold to seventeenfold increase in yield and the second a twofold to sixfold increase. Using 70,000 tons as the annual average, these estimates correspond to increased annual catches of from 350,000 to 1,200,000 tons and from 140,000 to 420,000 tons.

Silliman (1966), employing a population-simulation method to the eastern Pacific fishery catch data, estimated a maximum yield of 225,000 tons, an increase of 155,000 tons or about twice the annual average catch. This estimate falls within the range of Rothschild's estimates based on a 6-month sojourn time. However, as noted by Rothschild, since the escapement stock almost certainly mixes with skipjack tuna that never circulate through the eastern Pacific fishery area, the estimates of yield must be highly conservative. This would apply also to Silliman's estimate.

The Japanese have come up with various estimates of potential yields of skipjack tuna for the Pacific as well as the Atlantic and Indian Oceans.

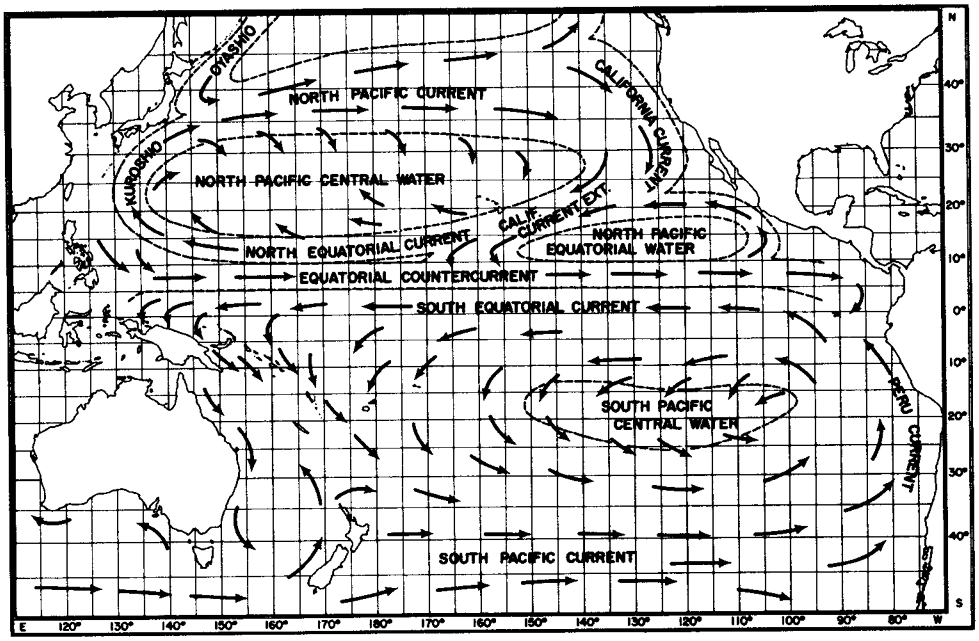


Figure 3.—Schematic diagram of the principal currents and water masses in the Pacific Ocean (from Matsumoto[2]).

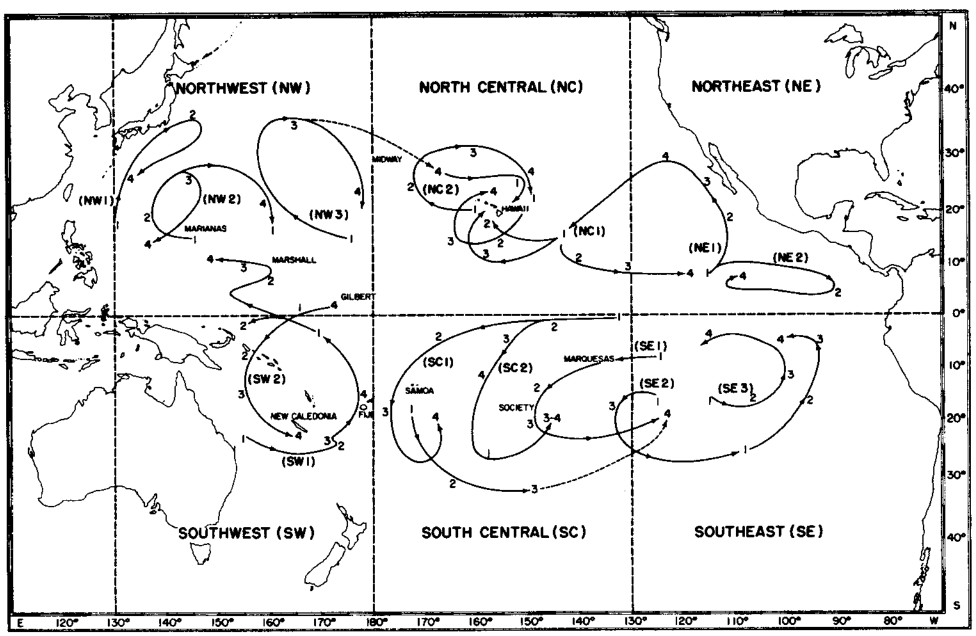


Figure 4.—Assumed movement of the various stocks of skipjack tuna in the Pacific Ocean. The numerals along the migratory routes represent quarters and locations of high catch-per-effort cells of skipjack tuna taken by the Japanese longline fishery, 1964-67. Stock designations are shown in parentheses.

According to Kawasaki (1972), the estimated yields published by the Japan Fisheries Agency are as follows:

Area	1,000 tons
1. Japanese coastal	Increase of 200-400
2. Entire Pacific	Increase to 1,000
3. Indian Ocean	200-300
4. North Atlantic	100
5. South Atlantic	100-150

The author of these estimates is not known; however, in 1971 Akira Suda, Far Seas Fisheries Research Laboratory, Shimizu, Japan, in commenting on his estimate of potential production of skipjack tuna in the Pacific Ocean of between 800,000 and 1,000,000 tons, explained the method used in arriving at his estimate (excerpts from talk given at the June 1971 Conference of the Japan Fisheries Resources Convention Association. *In* Kawasaki, 1972.). He based his estimate on the premise that since from 1.7 to 1.8 times more skipjack tuna larvae were taken than larvae of other tunas, the spawning stock of skipjack tuna was also from 1.7 to 1.8 times (rounded off to 2) that of other tunas, and that therefore the potential production of skipjack tuna should be 2 times 400,000-500,000 tons, the production of other tunas. The method used to obtain 1 and 2 above could be similar to this.

The conclusion that the skipjack tuna yield should be twice that of all other tunas because there are twice as many skipjack tuna larvae seems to be an oversimplification of a complex conversion. If we look at the various factors permitting such a conversion, we find that this 2:1 ratio advantage in favor of the skipjack tuna soon disappears. First, let us say that to produce a 1:1 ratio of skipjack tuna larvae to all other tuna larvae, there should be 4 times as many skipjack tuna as all other tunas, since the fecundity of the skipjack tuna is roughly one-fourth that of other tunas (comparison made on the median number of eggs for skipjack tuna and for yellowfin and bigeye tunas). To produce a 2:1 ratio of larvae there should be 8 times more skipjack tuna as all other tunas. But since it requires roughly eight skipjack tuna to equal the average weight of all other tunas (taking 4.5 kg as the average weight of the skipjack tuna and 35.5 kg as the average weight of other tunas), the conversion factor for skipjack tuna yield to that of other tunas approaches a 1:1 ratio, far different from the 2:1 ratio used by Suda.

Other factors, either not considered or assumed to be equal for all tuna species in the above estimates are the mortality rates of eggs, larvae, and juveniles of the different species and the capability and efficiency of the various fishing gear used. Corrections for these factors could change the estimates further. Estimates 3, 4, and 5, based on yields proportional to that estimated for the Pacific (2), relative to the areas occupied by the skipjack tuna (or larvae) in the respective oceans, are equally speculative.

Despite the weaknesses in the various estimates of potential yield, sizable increases are still possible in most existing fisheries. The increases could come from harvesting more of the fish that escape capture within the fishing area by improving the gear or by following the fish further along the escape route, as noted by Rothschild (1966). This is especially applicable to the eastern Pacific fishery. In the western Pacific Ocean the situation is different. The escapement stocks from the Japanese coastal fishery, which include skipjack tuna of two subpopulations, are already being fished in the Japanese southern water fishery. The reduction in the catch rates noticed in the latter fishery (Kasahara, 1971), especially in the western sector or original fishing grounds, indicate that exploitation of skipjack tuna of the western Pacific subpopulation is nearing the maximum sustainable level. The increases in the western Pacific Ocean, therefore, must come from fish of the central-eastern Pacific subpopulation in the eastern sector of the Japanese southern water and coastal fisheries.

Sizable increases in yield should also be possible in several areas outside the present commercial fisheries. The locations of skipjack tuna stocks (Fig. 4), and the plots of catch rates of skipjack tuna taken on the tuna longline in 1969-71 (Fig. 5) should be useful in pointing out areas that could develop into new fishing grounds. In the Pacific Ocean most of such areas are in the southern hemisphere: the Marquesas-Tuamotu-Society Islands, the Phoenix-Tokelau-Samoa Islands, and the Tonga-Fiji-New Hebrides-New Caledonia Islands. A recent attempt at fishing in Tahitian waters (Society Islands) by a pole-and-line boat from Hawaii resulted in a catch of 182 tons of skipjack tuna in a 3-month period (January-March 1973). The catch compared favorably with that taken in the Hawaiian fishery during the peak months of the season (June-August). Commercial operations by the Japanese pole-and-line vessels in the waters of Papua-New Guinea, the Solomon Islands, and New Caledonia-New Hebrides Islands also have produced favorable results.

Worthy of investigation is the Leeward Islands area extending northwestward from the Hawaiian Islands to Midway. There are ample reports of tuna school sightings, based on a number of exploratory fishing cruises, to indicate possible concentrations of skipjack tuna there (Rothschild and Uchida, 1968). Farther to the northwest of the Leeward Islands, Japanese bait boats ventured to the Milwaukee Bank area (lat.31°-36°N, long.170°-174°E) in the summer (July-September) of 1972. Although the catches were small, the landings per boat-trip averaged 109 tons, much better than the average landings (71.9 tons) of boats fishing in the Japanese southern water fishery.

Skipjack tuna have not been taken as consistently in the Atlantic Ocean as in other oceans with the longline gear, and therefore other means must be used to locate possible areas of skipjack tuna abundance. On the basis of similarities in the westward flow of equatorial currents and their deflections to the north and south at the western extremities of the Atlantic and Pacific Oceans, it is reasonable to assume that skipjack tuna would be similarly distributed in both oceans. If so, areas favorable for skipjack tuna concentrations in the Atlantic Ocean should be off the southeastern coast of Brazil and from off the northeastern coast of Brazil through the West Indies. The eastern Atlantic area off the coast of Senegal to Angola is already developing into a fishery of major importance.

In the Indian Ocean the likely sources of skipjack tuna should be in the northwestern part from Madagascar to the Arabian Sea, and around the southern part of India beyond the

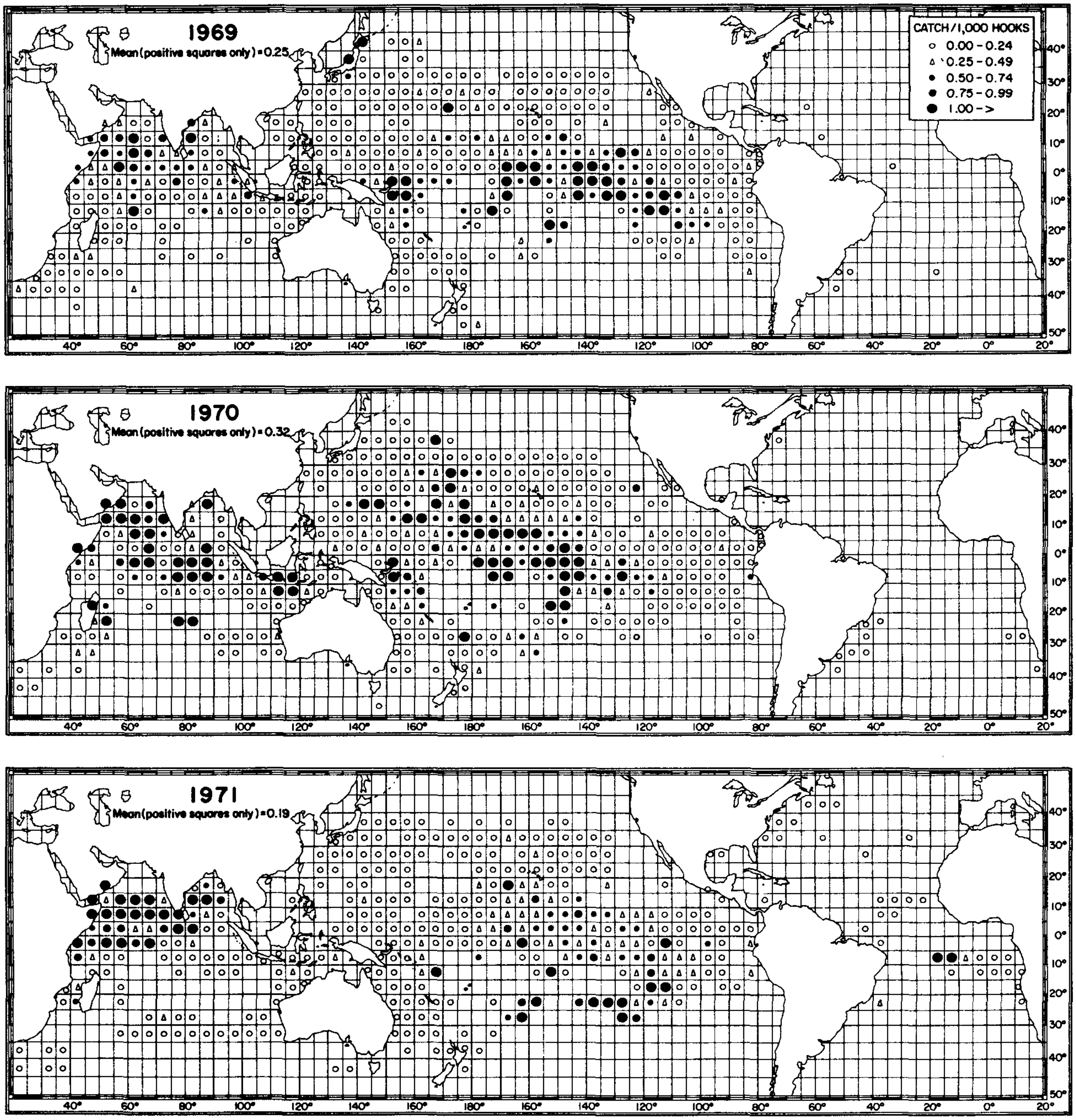


Figure 5.—Catch rates of skipjack tuna taken in the Japanese tuna longline fishery, 1969-71 (Fisheries Agency of Japan, 1971, 1972, 1973).

limits of the present drift-net fishery. Other possible areas are in waters off Sumatra and Java.

HARVESTING

The bulk of the skipjack tuna catches in the major oceans are made either by pole-and-line gear using live bait as chum or by purse seine. Both types of gear are used in the eastern Pacific, the Japanese near-coastal, and the eastern Atlantic fisheries. In the Japanese southern water fishery in the Pacific, however, the pole-and-line gear accounts for virtually the entire commercial catch of skipjack tuna.

There are advantages and disadvantages to either type of fishing. In pole-and-line fishing, the biggest problem is its dependence upon live bait. Not only must the bait be available, but the suitability and hardiness of the baitfish and the capability of keeping them alive over long periods must be adequate. Because of these problems, fishing by this method was for years limited to coastal waters. In recent years the Japanese have expanded their pole-and-line fishery into waters of the United States Trust Territory of the Pacific Islands by transporting baitfish from Japan. Because of the long distances to the fishing grounds and the need for large bait holding capacities, only large vessels (> 100 tons) were involved. At the present stage of capability in bait handling and bait holding techniques, these vessels have about reached the limit of their operational distance. Further expansion into the southern hemisphere or up to and beyond the international date line in the northern hemisphere has to resort to the use of baitfish taken within the fishing area. However, most small Pacific islands lack suitable baitfish in sufficient quantities to support any sizable fleet of large fishing vessels. An additional problem involved in this type of fishing is the response of skipjack tuna to the bait. Not all of the schools sighted are fished and not all of the schools fished result in catches. In the Hawaiian skipjack tuna fishery, for example, about 50 percent of the schools fished (chummed) do not result in catches (Rothschild and Uchida, 1968). There are advantages, however, to this type of fishing: (1) it can be done from small vessels, (2) any size school may be fished, and (3) it is not hampered by oceanographic conditions such as clear water and thermocline depth, nor by fast moving schools.

In purse seine fishing, problems associated directly with baitfish are eliminated, but other problems such as deep thermocline, clear water, and size and mobility of schools, are encountered. The traditional purse seine fisheries for skipjack tuna have been successful because the fishing area was characterized either by murky waters, shallow thermocline, or the presence of a marked front between warm and cold currents. In equatorial waters, however, the waters are exceptionally clear and the thermocline is deep enough to permit fish schools to escape by diving beneath the net before it has been pursed. This is not to say that there are no suitable seining sites in the equatorial areas. There are areas with shallow thermocline, especially along the edge of the equatorial counter-current, but the skipjack tuna are not limited in their distribution to these areas alone. Recent developments in net design, such as using monofilament nylon netting to make it lighter and increasing the size of the net, have improved the efficiency of the gear, but more improvement is needed in gear modification and specialized techniques if we wish to harvest skipjack tuna in equatorial waters.

The difficulties and problems faced in fishing for skipjack tuna by both pole-and-line and purse seine methods in distant waters certainly will not be solved overnight. Yet from the evidence presented in the foregoing discussions, it is more than likely that skipjack tuna are available in sizable quantitites in many areas not now fished commercially. For the immediate future, at least until modifications to the purse seine for mid-oceanic use have been made and tested successfully, the development of techniques to transport live baitfish over great distances could be the surest way to take advantage of the resource in the central Pacific.

The Japanese southern fishery operation has shown that the anchovy, *Engraulis japonicus*, can be transported successfully for distances up to nearly 2,000 miles. Furthermore it has been reported that this baitfish can normally survive for about 5 weeks (Yabe, 1972). If the eastern Pacific northern anchovy, *E. mordax*, which are plentiful in waters off California, are as hardy as their western Pacific counterpart, they or some other suitable baitfish could be transported to Hawaii and to other South Pacific islands. And, if the transporting of such a bait can be done quickly and in large enough quantities (a study has now been initiated by the Honolulu Laboratory to ship baitfish from California to Hawaii in sufficient quantities to supply the Hawaiian skipjack tuna fishing fleet), it should be possible for large bait boats stationed in Hawaii to exploit the Leeward Islands area up to and even beyond Midway and waters to the west and south of the Hawaiian Islands, well beyond the present 30- to 50-mile range of the Hawaiian fishery.

OPPORTUNITIES FOR THE UNITED STATES

Two points are brought to focus from the foregoing discussions. First, although all the large tuna species have already reached or are fast approaching their maximum sustainable yield levels, the skipjack tuna shows no such signs, except in the western equatorial Pacific. This is true in spite of the fact that the skipjack tuna is today the biggest yield producer among the species of tunas favored for commercial uses. Second, there are vast areas in the Pacific and other oceans that have not been fished, except by local, small-scale subsistence-type fisheries. In some areas not even this type of fishing has been done. The opportunities for development of the skipjack tuna fisheries in the Pacific hold true also in the Indian and Atlantic Oceans.

That the successful development of the skipjack tuna resource will be beneficial to the U.S. economy in many ways cannot be doubted. It will be a source of additional high-quality raw material for U.S. packers and reduce our dependence on foreign sources; it will increase employment opportunities for U.S. vessels and fishermen now restricted by catch quotas; it will in turn increase economic activity in other industries related to fishing; and finally, it will expand the economic base of the Pacific Islands, thus making their people more self-reliant and self-sufficient.

Although the resource is there, it remains fair game to all nations with the capability, desire, and willingness to develop it. In the Pacific, Japan has already begun to shift her emphasis from longlining for tunas towards fishing for skipjack tuna, and has entered into joint venture operations to fish in the Papua-New Guinea and Solomon Islands area. Fishing has been going on there since 1970. Japanese vessels also have begun to expand their operations into waters northwest of Midway. Other nations that have been longlining for tunas, such as Korea and Taiwan, have also come to realize that their future in fishing is in the skipjack tuna. In Korea a training center is now turning out skipjack tuna fishermen and both Korea and Taiwan are beginning to build up a fleet of skipjack tuna fishing vessels. If the United States is to get a fair proportion of the skipjack tuna resource, much has to be done and done quickly.

LITERATURE CITED

Aikawa, H., and M. Katō. 1938. Age determination of fish. (Preliminary report 1). [In Jap., Engl. synop.] Bull. Jap. Soc. Sci. Fish. 7:79-88. (Engl. Transl., 1950, U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 21, 22 p.)

Broadhead, G. C., and I. Barrett. 1964. Some factors affecting the distribution and apparent abundance of yellowfin and skipjack tuna in the Eastern Pacific Ocean. Bull. Inter-Am. Trop. Tuna Comm. 8:419-473.

Brock, V. E. 1954. Some aspects of the biology of the aku, *Katsuwonus pelamis*, in the Hawaiian Islands. Pac. Sci. 8:94-104.

Brun, M., and W. L. Klawe. 1968. Landings of skipjack and yellowfin tuna at Papeete Market (Tahiti). Commer. Fish. Rev. 30(4):62-63.

Ehrenbaum, E. 1924. Scombriformes. Report on the Danish Oceanographical Expeditions 1908-10 to the Mediterranean and adjacent seas, No. 8, 2(Biology), A.11, 42 p.

Fisheries Agency of Japan. 1971. Annual report of effort and catch statistics by area on Japanese tuna longline fishery, 1969. Fish. Agency Jap., Res. Div., 299 p.

________. 1972. Annual report of effort and catch statistics by area on Japanese tuna longline fishery, 1970. Fish. Agency Jap., Res. Div., 326 p.

________. 1973. Annual report of effort and catch statistics by area on Japanese tuna longline fishery, 1971. Fish. Agency Jap., Res., Div., 319 p.

Food and Agriculture Organization of the United Nations. 1966. Yearbook of fishery statistics, catches and landings, 1965. FAO (Food Agric. Organ. U.N.) 20(C):40-43.

________. 1972. Yearbook of fishery statistics, catches and landings, 1971. FAO (Food Agric. Organ. U.N.) 32:411-420.

Fujino, K. 1970. Immunological and biochemical genetics of tunas. Trans. Am. Fish. Soc. 99:152-178.

________. 1972. Range of the skipjack tuna sub-population in the western Pacific Ocean. *In* K. Sugawara (editor), The Kuroshio II, Proceedings of the Second Symposium on the Results of the Cooperative Study of the Kuroshio and Adjacent Regions, Tokyo, September 28-October 1, 1970, p. 373-384. Saikon Publ. Co., Tokyo.

Hayasi, S., T. Koto, C. Shingu, S. Kume, and Y. Morita. 1970. Status of the tuna fisheries resources in the Atlantic Ocean, 1956-67. [In Jap. and Engl.] Far Seas Fish. Res. Lab., S Ser. 3:1-72.

Joseph, J. In press. The scientific management of the world stocks of tunas, billfishes and related species. FAO (Food Agric. Organ. U.N.) Technical Conference on Fishery Management and Development, Technical Session IV, 13-23 February 1973, Vancouver, Canada.

June, F. C. 1951. Preliminary fisheries survey of the Hawaiian-Line Islands area. Part III—The live-bait skipjack fishery of the Hawaiian Islands. Commer. Fish. Rev. 13(2):1-18.

Kasahara, K. 1971. Skipjack tuna resource and fishing grounds (Katsuo gyojyo to sono shigen). Suisan Sekai 20(10):30-37. (Engl. transl., 1972, 20 p.; available Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812).

Kawasaki, T. 1965a. Ecology and dynamics of the skipjack population. I. Resources and fishing conditions. Nihon Suisan Shigen Hogo Kyokai, Suisan Kenkyu Sosho (Stud. Ser. Jap. Fish. Resour. Conserv. Assoc.) 8(1):1-48. (Translated by M. P. Miyake, Inter-Am. Trop. Tuna Comm., 1967, 54 p.)

________. 1965b. Ecology and dynamics of the skipjack population. II. Resources and fishing conditions. Nihon Suisan Shigen Hogo Kyokai, Suisan Kenkyu Sosho (Stud. Ser. Jap. Fish. Resour. Conserv. Assoc.) 8(2):49-108. (Translated by U.S. Joint Publ. Res. Serv., 1967, 79 p.)

________. 1972. The skipjack tuna resource (Katsuo no shigen ni tsuite). [In Jap.] The Fishing and Food Industry Weekly (Suisan Shūhō) 660:32-38. (Engl. transl., 1972, 15 p.; available Southwest Fish. Cent. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.) (Also Mar. Fish. Rev., 1973, 35(5-6):1-7.)

Kearney, R. E. 1973. A brief outline of the first years of the Papua New Guinea skipjack fishery. South Pac. Isl. Fish. Newsl. 9:32-37. [Noumea.]

Kikawa, S., T. Koto, C. Shingu, and Y. Nishikawa. 1968. The status of the tuna fisheries of the Indian Ocean as of 1968. [In. Jap. and Engl.] Far Seas Fish. Res. Lab., S Ser. 2:1-28.

Klawe, W. L. 1960. Larval tunas from the Florida Current. Bull. Mar. Sci. Gulf Caribb. 10:227-233.

Richards, W. J. 1969. Distribution and relative apparent abundance of larval tunas collected in the tropical Atlantic during Equalant Surveys I and II. Proc. Symp. Oceanogr. Fish. Resour. Trop. Atl., Abidjan, Ivory Coast, 20-28 Oct. 1966, Rev. Pap. Contrib., p. 289-315. UNESCO (U.N. Educ. Sci. Cult. Organ.), Paris.

Rothschild, B. J. 1965. Hypotheses on the origin of exploited skipjack tuna (*Katsuwonus pelamis*) in the eastern and central Pacific Ocean. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 512, 20 p.

________. 1966. Preliminary assessment of the yield potential of the skipjack tuna in the central Pacific Ocean. *In* T. A. Manar (editor), Proceedings of the Governor's Conference on Central Pacific Fishery Resources, p. 251-258. State of Hawaii, Honolulu.

Rothschild, B. J., and R. N. Uchida. 1968. The tuna resources of the oceanic regions of the Pacific Ocean. *In* D. Gilbert (editor), The future of the fishing industry of the United States, p. 19-51. Univ. Wash., Publ. Fish., New Ser. 4.

Schaefer, M. B. 1960. Report on the investigations of the Inter-American Tropical Tuna Commission for the year 1959. [In Engl. and Span.] Inter-Am. Trop. Tuna Comm., Annu. Rep. 1959:39-156.

Silliman, R. P. 1966. Estimates of yield for Pacific skipjack and bigeye tunas. *In* T. A. Manar (editor), Proceedings of the Governor's Conference on Central Pacific Fishery Resources, p. 243-249. State of Hawaii, Honolulu.

Sivasubramaniam, K. 1972. Skipjack tuna (*K. pelamis*, L.) resource in the seas around Ceylon. Bull. Fish. Res. Stn., Sri Lanka (Ceylon) 23:19-28.

Suda, A. 1971. Tuna fisheries and their resources in the IPFC area. [In Engl. and Jap.] Far Seas Fish. Res. Lab., S Ser. 5, 58 p.

Ueyanagi, S. 1969. Observations on the distribution of tuna larvae in the Indo-Pacific Ocean with emphasis on the delineation of the spawning areas of albacore, *Thunnus alalunga*. [In Jap., Engl. synop.] Bull. Far Seas Fish. Res. Lab. 2:177-256.

________. 1971. Larval distribution of tunas and billfishes in the Atlantic Ocean. FAO (Food Agric. Organ. U.N.) Fish. Rep. 71:297-305.

Yabe, H. 1972. Skipjack fishery development by purse seining (Makaimi de shingyojyo kaitaku wo). The Fishing and Food Industry Weekly (Suisan Shūhō) 660:68-72. (Engl. transl. 1973, 9 p.; available Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.)

Yokota, T., M. Toriyama, F. Kanai, and S. Nomura. 1961. Studies on the feeding habits of fishes. [In Jap., Engl. summ.] Rep. Nankai Reg. Fish. Res. Lab. 14, 234 p.

Yoshida, H. O. 1966. Skipjack tuna spawning in the Marquesas Islands and Tuamotu Archipelago. U.S. Fish Wildl. Serv., Fish. Bull. 65:479-488.

________. 1971. The early life history of skipjack tuna, *Katsuwonus pelamis*, in the Pacific Ocean. Fish. Bull., U.S. 69:545-554.

MFR Paper 1077. From Marine Fisheries Review, *Vol. 36, No. 8, August 1974. Copies of this paper, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*