An eminent Japanese scientist urges a closer look at "the skipjack era."

The Skipjack Tuna Resource *(Katsuo no Shigen ni Tsuite)*

TSUYOSHI KAWASAKI

As the demand for skipjack tuna has increased in Japan, Japanese interest in the skipjack resource has also grown. While other tuna resources are considered to have reached the level of maximum sustainable yield, it is generally believed that the skipjack resource is relatively unutilized and that there is a great development potential. With the advent of the southern fishery, it has become possible to fish for skipjack tuna on a year-round basis, thereby increasing production.

FISHERY AND DISTRIBUTION

According to the Food and Agriculture Organization of the United Nations (FAO) statistics on world skipjack landings (statistics not shown in text but given as a separate table in this same issue of Suisan Shūhō on page 158), there was a marked increase in landings around 1966. [Translator's note: The total landings in 1964 and 1965 are given as 267,000 and 251,000 tons, respectively.] Since 1966, the annual landings have been at the 300,000-ton level. Although this is largely due to increased landings by Japanese vessels, there have also been increased landings in the central eastern Atlantic by vessels from France, Ghana, Japan, Senegal, etc. There have been no noticeable differences in skipjack production in other areas.

Skipjack fisheries are not distributed evenly. Although the total world catch of skipjack is approximately 300,000 tons, about two-thirds of this catch is being taken from the northwestern Pacific by Japanese vessels. The operating range of Japanese vessels extends from lat. 45°N to the equator in the western Pacific (west of long. 160°E). The bulk of the landings is, however, made in a relatively narrow area of the western Pacific north of lat. 30°N. The area producing the next largest catch is the coastal waters of the eastern Pacific extending from Baja California to northern Chile, where 50,000 to 100,000 tons of skipjack are landed each year. Although there are skipjack fisheries in the Atlantic and Indian Oceans, their landings are quite small.

The skipjack tuna are described in English as "cosmopolitan," because they are very widely distributed. It is said that skipjack can be found in all the warm seas, wherever the water temperature is above 20°C. In biological terms, skipjack may be described as a highly adaptable species. While the fish are widely distributed, their fishing grounds are found only in very limited areas. Various reasons can be given for this, but one of the important ones concerns the problem of live-bait supply.

RESOURCE STRUCTURE

As mentioned previously, little skipjack fishing is done outside the Pacific Ocean. Consequently, research on this resource has been virtually limited to the Pacific.

Skipjack begin spawning when they attain a body length of 40-45 cm. The number of eggs spawned differs with size of the spawning fish, but appears to range from 100,000 to 2,000,000 eggs. These fish are multiple spawners, spawning several times during a season. There are 4 days between fertilization of the egg and hatching, and the newly hatched larvae are from 2.5 to 3.0 mm long.

The larvae of skipjack are distributed widely in both the Pacific and Indian Oceans (Figures 1 and 2). In the Pacific they occur in greater numbers in the west, where latitudinal distribution is also much wider. In spite of this latitudinal range, however, most of the larvae are found in equatorial waters between lat. 10°N and 10°S, and the principal spawning area in the Pacific is located in western equatorial waters. Distribution reflects oceanographic conditions, and virtually no larvae are found in waters with surface temperatures lower than 24°C.

The larvae are rather plentiful in waters near Japan during the summer, but to the south there is a progressively larger proportion of larvae occurring in winter. In equatorial waters, larvae are found throughout the year. The ratio of skipjack larvae, relative to total tuna

Tsuyoshi Kawasaki is Chief, First Resource Section, Tokai Regional Fisheries Research Laboratory, Fisheries Agency of Japan. **This paper appeared in *The Fishing and Food Industry Weekly (Suisan Shuho)* No. 660, p. 32-38, July 15, 1972. The translation, by permission of the author, was made by Tamio Otsu, NMFS Southwest Fisheries Center, Honolulu Laboratory.** **A distinguished scientist in his own right, Otsu is perhaps best known for his studies of the transpacific migrations of the albacore.**

larvae, is approximately 3 to 4 in waters west of 180° and south of lat. 25°N.

Skipjack tuna are 15 cm long at age 1, 45 cm at age 2, 63 cm at age 3, 73 cm at age 4, and 77 cm at age 5. The skipjack which originate in equatorial waters gradually spread out. At age 2, they have reached their widest distribution, having migrated to the eastern Pacific as well as to Japanese waters such as off Sanriku (Tohoku sea region).

The 3-year-old fish are not as widely distributed as are the 2-year-olds, but in Japanese waters they are found in such areas as the Izu Archipelago and Satsunan sea regions. At age 4 and older, the fish return to the equatorial region to spawn. The skipjack that migrate into Japanese coastal waters are probably fish that originate in northern summer spawning. It is believed that fish originating in southern summer spawning distribute themselves in the South Pacific.

The skipjack arrive in Japanese waters in the spring. They enter the Tohoku sea region, Izu Archipelago region, and Satsunan sea region, remaining there until fall with relatively little interchange between areas. Recently, the Tohoku Regional Fisheries Research Laboratory conducted large-scale tagging in waters south of the Sakishima Islands (Ryukyu Islands). Although there were year-to-year differences, a large proportion of the tagged fish were recaptured in the Satsunan sea region. Tagged fish which migrated into the Izu Archipelago and on into the Tohoku sea region comprised only about 10% of the total tag recoveries (Table 1).

Among fishes in general, each species may be divided into a number of subpopulations. A subpopulation consists of fish with a separate spawning area and whose progeny do not freely intermingle with progeny from other subpopulations. The subpopulation represents essentially an independent unit.

For example, the mackerel ("masaba") of the Japanese waters can be clearly separated into those related to the Kuroshio and those of the Tsushima Current. There is virtually no interchange between the two groups, and these groups are considered separate subpopulations.

It is vitally important to clarify the subpopulation structure of a resource before proceeding with estimates of fishing conditions, or with assessment of the resource.

With regard to the skipjack tuna of the Pacific, there appears to be very little spawning taking place in the eastern part of the ocean. Fish tagged off Baja California have been recovered off Hawaii as well as off Christmas Island (Figure 3). These facts indicate that at least those skipjack which occur off Baja California originate in the central Pacific. The problem is to clarify the areas of origin of fish that migrate in Japanese coastal waters.

The skipjack landings in the eastern Pacific, Hawaii, and the Tohoku sea region show considerable similarity in annual fluctuations. Also, judging by the winter skipjack catches of longline vessels, it is clear that the fish are distributed continuously between Japan and Hawaii. From these facts, I first proposed that the equatorial waters between long. 160°E and 140°W are the common spawning area of the skipjack, or in other words, their place of origin. However, it is now obvious that the western limit at long. 160°E was in error, and that the spawning area is probably between long 120°E and 140°E. In any case, I hypothesized in 1964 that all Pacific skipjack had a common source.

Regarding this problem, Dr. Fujino (Dr. Kazuo Fujino) at the Biological Laboratory in Hawaii (presently with

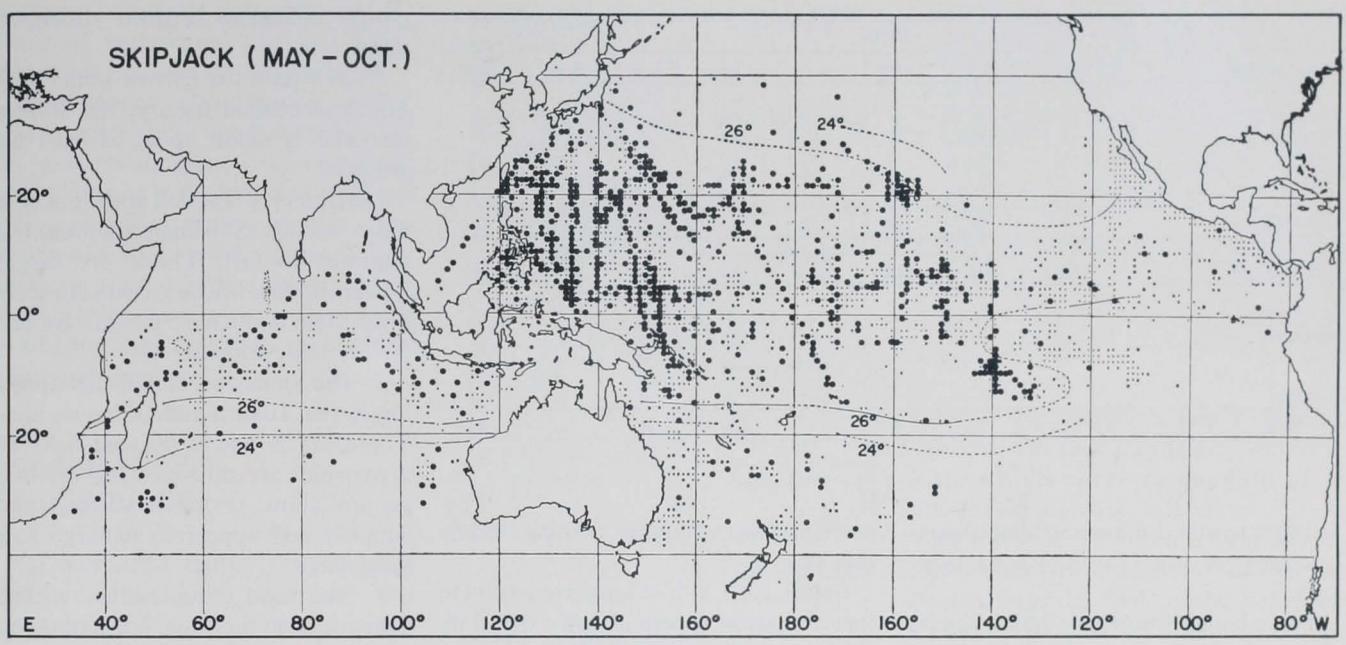

Figure 1.—Areas where skipjack larvae were collected during May-October (from Ueyanagi, 1969). Large dots indicate larvae present, small dots indicate larvae absent; dotted lines indicate 24° and 26°C surface isotherms.

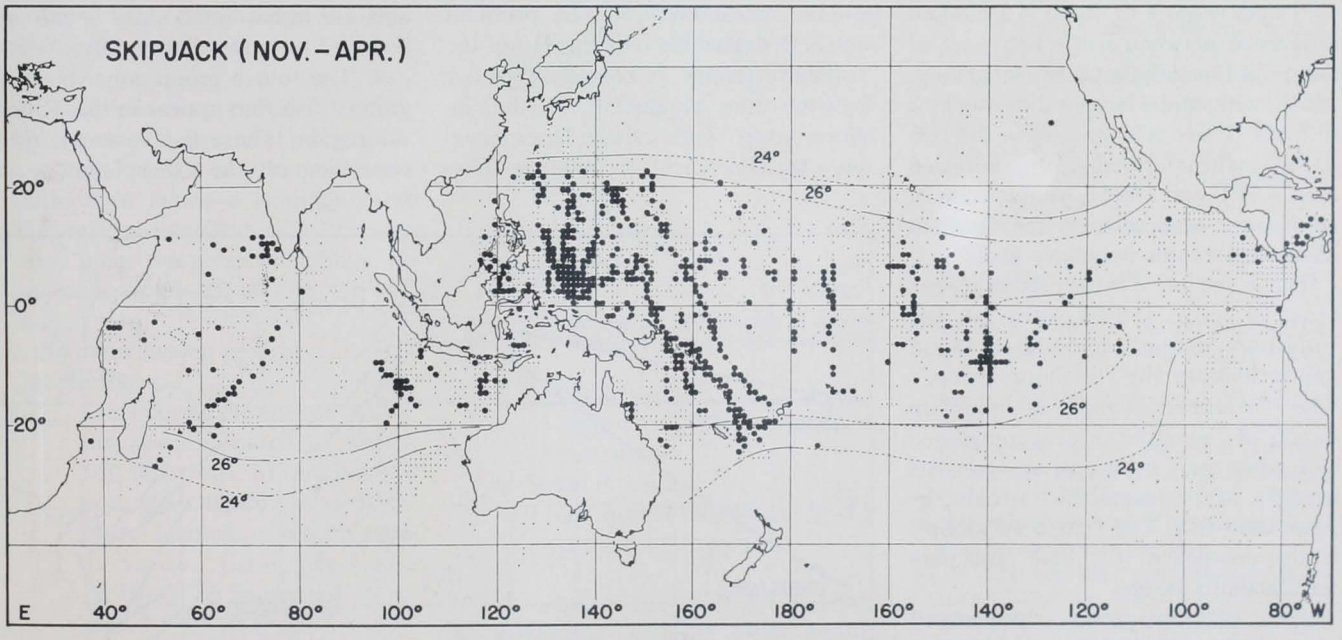

Figure 2.—Areas where skipjack larvae were collected during November-April (from Ueyanagi, 1969). Large dots indicate larvae present, small dots indicate larvae absent; dotted lines indicate 24° and 26°C surface isotherms.

the Kitasato University in Japan) concluded, on the basis of serological studies, that the western Pacific skipjack belong to a subpopulation separate from fish of the central and eastern Pacific (the latter belonging to one or more subpopulations). The boundary was reported to be near the international dateline and thus fish distributed in Japanese coastal waters, the Marianas, and Palau would be separate from those occurring off California, in Tahiti, the Line Islands, and Hawaii. Furthermore, it was suggested that in the Tohoku sea region, the fish of the western Pacific subpopulation are replaced in the early fall by fish of the central-eastern Pacific subpopulations.

Table 1.—Recoveries of skipjack tagged by the *Miyazaki Maru*, by month and sea area (from Kasahara et al., 1971).

Sea area/1968	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
South of 25°N	—	—	—	1	—	—	—	1
Satsunan	—	15	30	12	13	3	—	73
Kinan	—	—	1	—	—	—	—	1
Izu	—	—	—	4	—	—	—	4
Tohoku	—	—	3	—	1	—	—	4
Total	—	15	34	17	14	3	—	83

Sea area/1969	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
South of 25°N	3	1	—	—	—	—	—	4
Satsunan	—	3	3	—	2	2	3	13
Kinan	—	1	4	1	—	—	—	6
Izu	—	—	1	—	—	—	—	1
Tohoku	—	—	—	—	2	—	1	3
Total	3	5	8	1	4	2	4	27

In other words, Fujino postulated separate areas of origin for the Pacific skipjack.

From length-frequency data it can be shown that two groups of skipjack are present among the 2-year-olds which appear in Tohoku waters during August. For example, as may be seen in the 1951 data (Figure 4), there is a marked difference between fish taken west of long. 154°E and those taken east of long. 156°E, with modal lengths differing by 5 to 6 cm. There is a mixture of the two groups in the intermediate area between long. 154°E and 156°E. An intrusion of cold water originating in the Oyashio characterizes this boundary area.

Those fish found in the offshore areas (east of long. 156°E) were labeled "offshore group" and those found closer inshore the "inshore group." The "offshore group" is made up largely of "sumure" or unaccompanied fish, while the "inshore group" consists largely of "sametsuki" or shark-associated fish. The "offshore group" is also composed of "fatter" fish than the "inshore group."

The "offshore group" disappeared abruptly from the fishing grounds after 1952. It finally reappeared in 1958, and from July to the end of the fishing season these fish occurred indiscriminately in coastal and offshore waters, being taken as readily as fish of the "inshore group," generally the principal component of the catch. This occurrence was not typical, but probably reflected the particular sea condition existing during that year.

In any case, it had long been known that a separate group of fish existed in offshore waters of the Tohoku sea region. It was Fujino's findings, however, which suggested that this may be a group of fish possessing different genetic characteristics. The problem now is to determine whether or not the "offshore group" is composed of fish from the same subpopulation as the "inshore group" with certain heterogeneous characteristics, or whether these groups belong to separate subpopulations.

Even within the narrow limits of the Japanese coastal fishery, the skipjack resource is made up of at least four groups:

1. Migratory fish that appear near the Goto Islands (Satsunan sea area) from summer to fall. These are largely 2-year-old fish whose growth is exceedingly rapid and whose gonads are completely undeveloped.

2. The shoal-associated fish appearing in the Tokara and Okinawa areas. These are 2- and 3-year-old fish. The 2-year-olds are slow growing. Both age groups show sexual development in summer and appear to undergo some spawning.

3. The third group occurs virtually year-round in the shoal areas of the Izu and Ogasawara sea regions. The fish generally resemble those in the Tokara and Okinawa areas, and also undergo some spawning in summer. The 3-year-olds are rather small early in the year but tend to grow very rapidly.

4. The fourth group consists of migratory fish that appear in the Tohoku sea region. These fish resemble those appearing off the Goto Islands, and

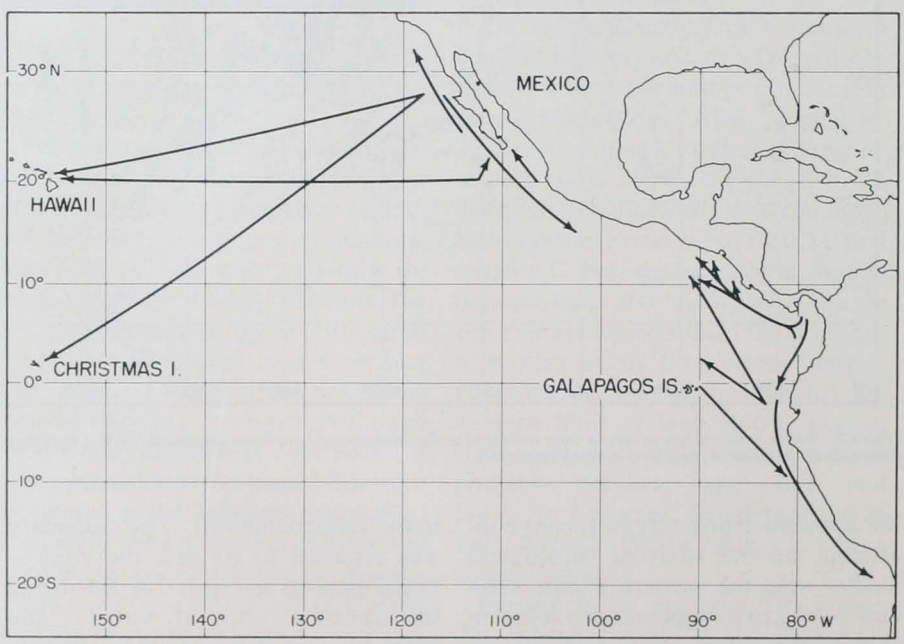

Figure 3.—Results of skipjack tagging in the central and eastern Pacific.

most are 2-year-old fish showing evidence of very rapid growth. Their gonads are completely undeveloped.

These groups, with differing ecological characteristics, are believed to result from environmental differences. In other words, it is thought that although they are of common origin, the 2-year-old fish which migrate into Japanese coastal waters in the spring develop their characteristics depending on whether they first enter open-sea or shoal environments.

ASSESSMENT OF THE RESOURCE

As mentioned earlier, strong sentiment exists today regarding the tremendous potential of the skipjack resource. According to "On the possibility of developing marine fishery resources" issued by the Fisheries Agency of Japan in June 1968, the potential for increased skipjack production is as follows:

1. Coastal fishing grounds—Pacific
   With the development of purse seining techniques, it should not be too difficult to increase landings from Japanese coastal waters by two or three times the present landings, or an increase of 200,000 to 400,000 tons.
2. Offshore fishing grounds
   a. Pacific
      Considering the entire Pacific, the present catch of about 500,000 tons [Translator's note: This figure probably includes landings of species such as *Sarda, Auxis,* etc.] can probably be increased to at least 1,000,000 tons.
   b. Southwest Pacific
      Development of fishing grounds around Indonesia and the South Pacific islands can be anticipated.
   c. Indian Ocean
      New fisheries producing 200,000 to 300,000 tons can be anticipated.

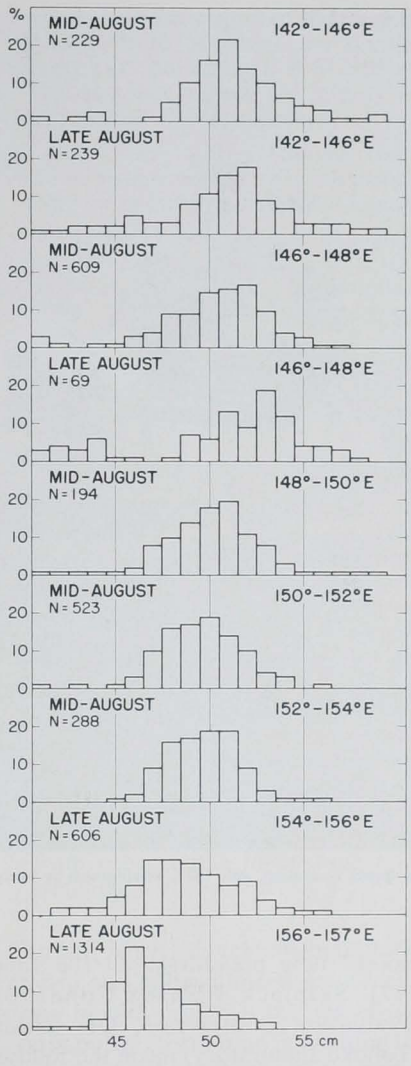

Figure 4.—Length-frequency distributions of skipjack tuna, by longitudes, in the Tohoku sea area during 1951.

   d. North Atlantic
      Landings of 100,000 tons can be expected.
   e. South Atlantic
      Landings of 100,000 to 150,000 tons can be expected.

If the various estimates are totaled, the potential skipjack yield would amount to 1.6 to 2.0 million tons, or five or six times the present landings.

In "Basic data relating to marine resources of the future" issued by the Science Technology Agency in July 1971, the following was included:

> "The skipjack spawn chiefly in tropical and subtropical waters, but there is also some spawning in temperate waters. Thus, skipjack spawn over a very extensive area. Also, skipjack juveniles appear in large numbers in stomachs of other tunas and billfishes which inhabit the same waters, as do the skipjack. It can be assumed from these facts that the skipjack resource is at least several times as great as the resource of the other tunas and the billfishes. In spite of this, the skipjack catch from both offshore and coastal waters in 1968 amounted to a mere 190,000 tons."

If we take these various estimates into consideration, it appears that the skipjack resource is capable of a severalfold increase in landings.

At the June 1971 conference of the Japan Fisheries Resources Convention Association, Dr. Suda of the Far Seas Fisheries Research Laboratory commented as follows:

> "The number of skipjack larvae collected in past studies is 1.7 to 1.8 times that of other tunas. The quantity of adult skipjack should be correspondingly large. There are also very large numbers of skipjack juveniles found in stomachs of large tunas and billfishes. They number five to ten times more than juveniles of all the other tunas. Considering the ecological differences between skipjack and other tunas, it seems appropriate to use the frequency of appearance of larvae as a basis for estimating the spawning stock. According to this, it would appear that the volume of skipjack spawning stock is 1.7 to 1.8 times that of the total of all the other tunas. Considering also that the relative occurrence of juveniles in the stomach contents is so much greater, it would probably be reasonable to assume a skipjack spawning stock which is about twice that of the other tunas.
>
> "The annual production of large tunas from the Pacific is 400,000 to 500,000 tons. Thus, we can very roughly estimate the potential production of skipjack tuna in the Pacific at between 800,000 and 1,000,000 tons.
>
> "Furthermore, judging by the ocean area [Translator's note: Probably of areas suitable for skipjack] in the Atlantic and Indian Oceans, we believe that there is a standing stock of 200,000 to 400,000 tons of skipjack in each of those oceans."

No. 2. Fukukyu Maru of Yaizu in central Northern Pacific skipjack operation, July 1972. Photograph by Hiroyo Koami, Institute of Sea Sphere and Tsukiji Fish Market Company, Tokyo.

Turning now to outside Japan, in 1966 Dr. Rothschild of the Biological Laboratory in Hawaii used the Beverton-Holt method to estimate the potential yield of skipjack tuna in the central Pacific Ocean. He stated that:

> "If the skipjack that migrate from the eastern Pacific fishing grounds into the central Pacific are harvested, the potential yield would be 2 to 17 times the present eastern Pacific yield of 68,000 tons. Since there are skipjack in the central Pacific that do not enter the eastern Pacific, the potential yield in the central Pacific may be even greater."

Such emphasis on the great potential of the skipjack resource has resulted in accelerated research aimed at resource development, and scientists of the Tohoku Regional Fisheries Research Laboratory, who have a long history of skipjack studies, have voiced some concern over this "development mood" now prevailing. At the June 1971 Skipjack Fishing Condition Evaluation Conference, Dr. Ishida (Tohoku Laboratory) made the following remarks:

> "Because of the stagnation in the tuna longline fishery, interest has turned to skipjack tuna. Government authorities hold high expectations that this is now the era of the skipjack. However, particularly in southern waters, which are the source of coastal water skipjack, our studies indicate that school sightings are unexpectedly few, and fishing was indeed poor last year. It is necessary to clarify whether or not the skipjack resource might already be declining as are the other resources."

Also, Dr. Kasahara (Tohoku Laboratory) reported in October 1971 [Suisan Sekai 20(10)] the following:

> "While the fishing effort is on coastal water skipjack, its effect on the resource should not be very great. However, the fishing effort in the southern waters, which is the base of the skipjack distribution, may have some direct effects on the resource, perhaps affecting its reproductive capacity or its recruitment potential. The skipjack resource is believed to hold considerable potential for development. It is believed that skipjack will replace the larger tunas which are already at a level of maximum production. However, research on skipjack is not sufficient at present. Even the estimates of the resource size appear to be in need of further evaluation. Even if the resource is as large as estimated, it is certainly not inexhaustible. In order not to let the skipjack resource follow in the footsteps of some other unfortunate species, it is desirable to base its utilization on sound considerations."

Kasahara further noted that for one area of the southern fishery subject to

considerable fishing effort, the catch per day's fishing has decreased rather markedly from year to year. However, the average catch per day's fishing in the southern fishery as a whole did not show such a noticeable decrease, during the same period, which indicates that in addition to the principal fishing grounds, new grounds are being discovered from time to time, resulting in a stabilized overall catch rate.

Thus, regarding the development potential, there is some difference between the general optimistic view and the more cautious views of the Tohoku Laboratory scientists. Let us further examine this matter. In 1965 I presented my views on this subject in my paper, "Skipjack ecology and resource," as follows:

> "I believe that the skipjack resource as a whole has considerable potential. This can be seen from the following:
>
> "1. Among the skipjack and other tunas which inhabit the Pacific Ocean, the skipjack resource is the largest. For example, of the juveniles of skipjack and other tunas occurring in stomach contents of tunas and billfishes, a significant proportion consists of skipjack. Also, among the tunas, skipjack are the most adaptable to varying environmental conditions (generally, fish species that are most adaptable to their environment tend to be more abundant).
>
> "2. The principal skipjack fishing grounds are the Japanese coastal waters and the waters of the eastern Pacific, both of which are on the fringes of the skipjack distribution. The skipjack taken are largely of only one or two age groups.
>
> "3. Other than in Hawaii, there are no fisheries which exploit principally the spawning group of skipjack.
>
> "4. The Japanese coastal fishery that takes the most skipjack is a pole-and-line fishery. This method relies heavily on the physiological response of the fish.
>
> "I emphasized that there is a vast difference between the potential size of a resource and its potential production.
>
> "Figures are very definite. Regardless of the numerous assumptions that go into making these estimates, once a figure is advanced, it tends to stand by itself. As Kasahara has stated, it is difficult to accept the accuracy of the estimates of the resource size. Take Suda's estimate, for example. To say that the skipjack resource is twice the size of all other tunas resources combined simply because there are twice the number of skipjack larvae appears to be rather an oversimplification. It would appear necessary to at least consider that skipjack differ greatly from other tunas in average body weights."

Today, when "development of undeveloped and under-utilized resources" is one of two principal themes of our fishery policy, there is an inclination toward increased production without due regard for "efficient utilization" of the resource.

We should avoid the same serious situation that has overtaken other tuna fisheries. "If there are no other tunas, there is still the skipjack" is an expression that should be eliminated. What is now necessary is to conduct a thorough study of the resource structure and condition. Specifically, it would be desirable to conduct large-scale tagging on skipjack of the Tohoku sea region and in the southern fishing grounds. It should not be too late to begin the move to increase production after attaining a thorough knowledge of the resource.

It is now becoming an international trend to advocate the rational use of living resources (e.g., whale resources, at the Conference on the Human Environment held in Stockholm). Rather than go ahead with development and perhaps regret later, it is better to base the development on sound scientific grounds.

LITERATURE CITED[1]

Kasahara, K., M. Yao, A. Naganuma, M. Anraku, and M. Asano. 1971. Studies on the movement of the skipjack in the Japanese waters by tagging experiments. I. (In Japanese, English summary). Bull. Tohoku Reg. Fish. Res. Lab. 31:141-152.

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 Japanese.) Bull. Far Seas Fish. Res. Lab. 2:177-256.

[1]Added by Translator.

MFR Paper 977. The paper above is from Marine Fisheries Review, *Vol. 35, Nos. 5-6. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*