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Patterns in Longline Fishery Data and Catches of Bigeye Tuna, *Thunnus obesus*

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ABSTRACT—Species composition of tunas caught by the large Asian longline fleets has shifted over time. Much of the observed change appears to be market driven, combined with changing economic conditions, as opposed to being driven by resource availability. As part of the strategy for change, the oriental longliners developed the ability to target on certain species with a gear previously thought relatively nonselective with respect to target species. Use of longline catch statistics for resource assessment requires an understanding of the reasons for changes in the data to avoid misuse of the statistics.

Background

Longline gear has been an effective and traditional fishing gear used to catch large tunas in the open oceans. The method was perfected by the Japanese in the 1930's, but its use did not spread outside the Japanese archipelago until after World War II (Shapiro, 1948). Currently, Japan, Korea, and Taiwan have large, specialized fleets that use longlines for catching tunas in the major oceans and seas. As many as 2,000 longline vessels are engaged in fishing primarily for tunas.

The basic design of the longline gear, a long mainline suspended from floats to which branch lines with hooks are attached, is simple and generally uniform between vessels (Shingu et al., 1980). What is unusual is that the gear can be deployed in specialized ways to catch more of certain species than others. This characteristics was most recently shown for the Japanese fleet in the Pacific Ocean. Japanese scientists showed that by removing intermediate floats from a standard longline gear, the mainline sags forming a deeper catenary so that the branch lines fish deeper. Fishermen were able to substantially improve their catch rates for bigeye tuna, *Thunnus obesus*, a preferred species, while reducing the catch rates for other tuna species (Suzuki et al., 1977). Other such techniques, e.g., night longlining for swordfish (Ueyanagi, 1974) have been described in the literature.

In this paper, we review available longline fishery statistics for the Japanese, Korean, and Taiwanese fleets for catch patterns. The patterns are then evaluated with respect to market information, which may have affected tuna fisheries (Suda, 1974; Ueyanagi, 1974; Lee, 1986; Wise and Miyake, 1982). Our emphasis is on the longline catch of bigeye tuna in the Atlantic, but we also review information on the catch of yellowfin tuna, *T. albacares*, and albacore, *T. alalunga*, from other oceans. We do not review, except in a discussion of global events, the catch of bluefin tunas, *T. thynnus* and *T. maccoyi*, because they are caught in specialized fisheries that are monopolized by the Japanese fleet.

The Longline Gear

Longline gear consists of a mainline with float lines and branch lines of baited hooks (Fig. 1). Float lines are attached to the mainline to regulate depth. This gear is deployed for tunas early in the morning and then retrieved, beginning around noon and ending frequently after midnight (Ueyanagi, 1974). Each operation or set involves setting of 150-350 baskets (the mainline is coiled in baskets) of mainline, extending over a distance of 25-75 km, with about 2,000 baited hooks.

Standard longlining fishes at a maximum depth of around 170 m, with 4-6 branch lines per basket of mainline. Deep longlining, which was introduced in the Pacific and Indian Oceans in the early 1970's and in the Atlantic in 1978, fishes at a maximum depth of about 300 m with an average of 13 branch lines per basket (Suzuki et al., 1977). Deep longlining is considered to be more effective than standard longlining for bigeye tuna in certain locations (Suzuki et al., 1977; Suzuki and Kume, 1982).

Longline vessels are categorized as deck-loaded motherships (200-1,000+ gross tons), foreign-based (50-1,000 gross tons) and home-based (30-500 gross tons). Currently, very few vessels greater than 300 gross tons or mothership category are in operation. The larger home-based vessels of 150-500 gross tons are generally modern, have supercold (−40° to −60°C) freezing capability and can remain at sea for up to 3-4 months between fueling stops. These vessels travel to various distant fishing areas, log many months (10-14 months) away from home ports and land their catch directly in Japan. Smaller vessels usually do not have such capability and are based close to the fishing areas. Some vessels rely exclusively on transshipping their catch to consigned markets.

The Markets

Markets for the annual world catch of

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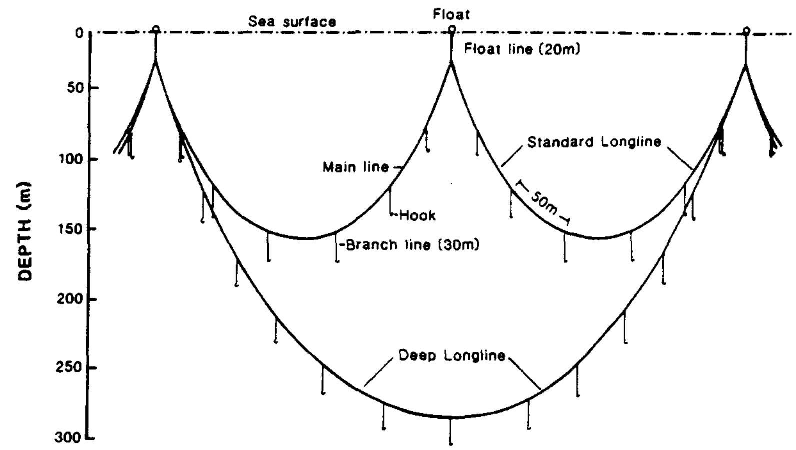


Figure 1.—Standard and deep longline gear as used by Japanese fishermen. The standard gear has an average of 6 branch lines per basket of mainline; deep-longline gear has about 13 branch lines (adapted from Suzuki et al., 1977).

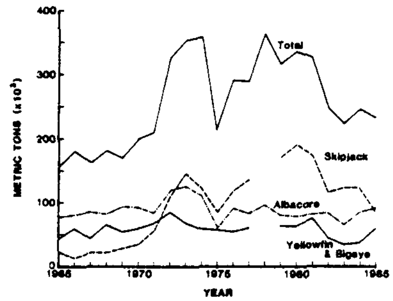


Figure 2.—Tonnage of fresh and frozen tuna by species imported into the United States. Source: Fisheries of the United States, various years.

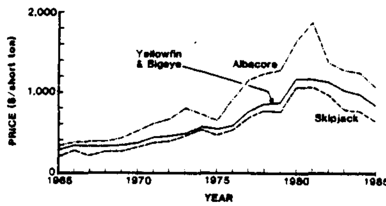


Figure 3.—Average ex-vessel prices paid for tuna delivered to U.S. canneries Source: NMFS, Terminal Island, Calif.

about 400,000 metric tons (t) of longline caught tunas are primarily two: Canned tuna market and "sashimi" market. The canned tuna market has a less stringent fish quality requirement than the sashimi market. Most of the fish for the canned tuna market are caught, refrigerated, and transhipped frozen to cannery facilities. Since the United States is the largest consumer market for canned tuna, consuming in excess of 50 percent of the world's canned tuna production (consumed about 730,000 t in 1984[1]), a significant portion of the longline catch available for canning purposes is sold to U.S. canneries. Thus, U.S. tuna ex-vessel prices and import purchases have a significant effect on the world tuna market.

Data on annual U.S. imports of frozen tuna for the past 20 years (1965-85) show fluctuations in volume (Fig. 2). Much of the fluctuation is due to imports of skipjack tuna, which are not generally caught on longline gear. Imports of the larger tunas (albacore, *Thunnus alalunga*; yellowfin tuna, *T. albacares*; and bigeye tuna, *T. obesus*), which are caught by longliners, show little change in volume over the 20 years, averaging about 75,000 t of albacore and 50,000 t of combined yellowfin and bigeye tuna per year. In other words, over the past 20 years there has not been any significant growth in the demand for longline-caught tunas in the world's largest canned tuna market.

[1]Herrick, S. F., Jr., and S. J. Koplin. 1985. U.S. tuna trade summary, 1984. Natl. Mar. Fish. Serv., SWR Admin. Rep. SWR-85-06, 24 p.

Albacore has traditionally commanded a higher price than yellowfin or bigeye tuna in the U.S. market and is packed exclusively as "white meat" tuna. Yellowfin and bigeye tunas along with skipjack tuna, *Euthynnus pelamis*, are used in "light meat" packs. Prices for these species move in tandem with each other because they are interchangable in the pack.

In the United States, the ex-vessel prices of these "light meat" species showed an upward trend from 1965 to 1981 followed by a downward trend which has continued into 1986 (Fig. 3). The fall in price has been faster for albacore than for yellowfin and bigeye tunas.[1] In 1985, the U.S. prices returned to a level equal to those in 1977 and 1978.

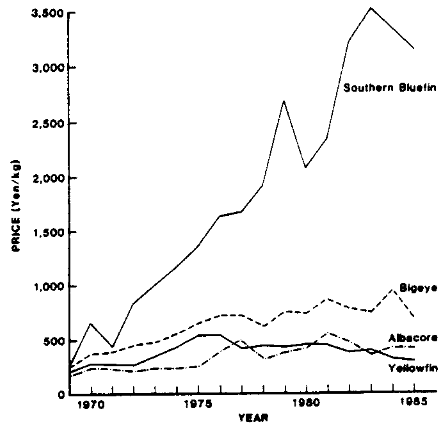
Japan is virtually the sole market for sashimi, or tuna consumed raw. This market is sensitive to both supply and quality (particularly freshness, color, firmness, and fat content) and generally deals with large tunas. About 340,000-360,000 t of both fresh and super-cold frozen tuna are sold annually by the sashimi market. This market has not shown significant growth since the 1960's[2].

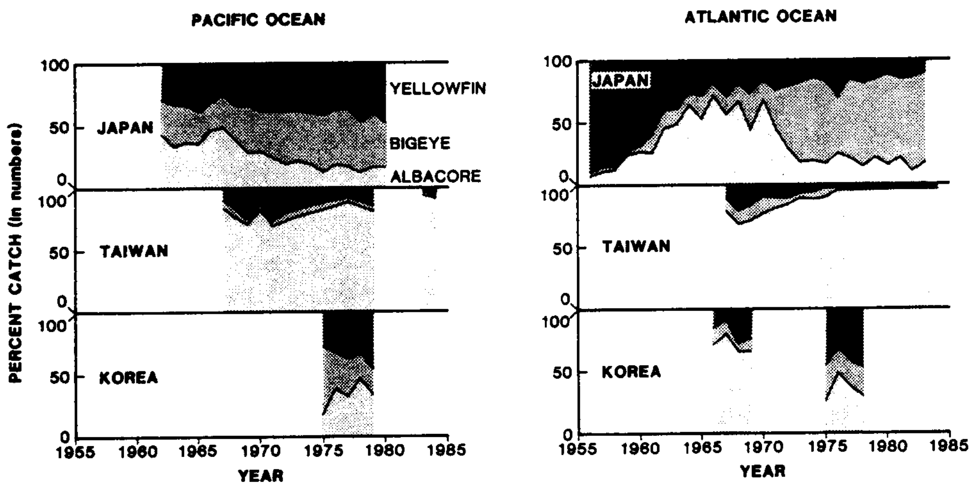
About 75 percent of the market is super-cold frozen tuna landed primarily by longliners. Japanese longliners supply most of the tuna, although recently Taiwanese and particularly Korean longliners have exported a significant amount of tuna to this market. Korean and Taiwanese vessels are supplying this market with about 90,000-120,000 t annually[2] and land most of their catch directly in Japanese ports (Uyemae, 1975).

Prices for sashimi-quality tuna in Japan are quite variable. In general, highest prices are paid for bluefin tuna, *T. thynnus* (southern and northern) followed by bigeye tuna, yellowfin tuna,

[2]Fujinami, N. 1986. Option for distant water countries. Manuscr. pres. at Tuna Workshop on Options for Cooperation in the Development and Management of Global Tuna Fisheries, 29 June-3 July 1986. Vancouver, B.C., 16 p.

Figure 4.—Average wholesale price of sashimi-grade tuna sold at the Yaizu fish market in Japan. Source: Shingu et al., 1980.





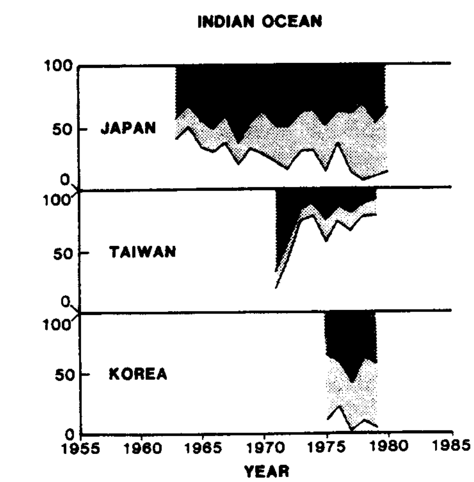


Figure 5.—Species composition of longline catches (in numbers of fish) by fleets from the Pacific, Atlantic, and Indian Oceans.

and albacore in that order (Fig. 4). To ensure the highest prices, longliners that fish tuna for this market must maintain high fish quality by landing the tuna fresh or by freezing the tuna with super-cold freezing equipment and landing them directly in Japan.

Global Patterns

Catches for the Japanese, Korean, and Taiwanese fleets were tabulated by ocean and species from published records: "ICCAT Statistical Bulletin" (ICCAT, Madrid), "Annual report of effort and catch statistics by area on Japanese longline fishery" (Fisheries Agency of Japan, Tokyo), "Annual report of catch and effort statistics and fishing grounds on Korean tuna longline fisheries" (Fisheries Research and Development Agency, Pusan), and "Annual catch statistics of Taiwanese tuna longline fishery" (Tuna Research Center, Taipei). A pattern can be seen in the proportion of species in the catch of the different fleets (Fig. 5). The data clearly show a fleet-specific pattern that is fairly independent of the ocean fished.

The Japanese fleet aggressively pursued yellowfin tuna and albacore until about 1970 to supply the growing U.S. canned tuna market. Then the fleet began a gradual and dramatic switch to bigeye tuna, which currently accounts for more than 50 percent of the catch. This switch to bigeye tuna is probably less a reflection of changes in the relative availability of the species, and more a reflection of changes in Japanese government policies and market forces, because the timing of the shift was the same in all oceans.

In the 1970's, fuel oil prices began to rise substantially, e.g., $0.03/l in 1970 versus $0.06/l in 1973[2], and fuel actually became unavailable in some strategically located ports used by the Japanese fleet (Uyemae, 1975). In 1970, high mercury levels in tuna were reported, and U.S. canneries refused to buy the large tunas because they often contained high levels of mercury (Peterson et al., 1973). Japanese labor costs also increased as the overall Japanese economy grew and prospered.[2] At the same time, the emergence of the 200-mile economic zones resulted in increased costs to vessel owners as license fees had to be paid for access to some choice fishing areas. Ex-vessel prices of tuna for canning, on the other hand, were rising only about half as fast as costs (Fig. 3). This resulted in several bankruptcies and threatened the long-term survival of the entire Japanese fleet. The strategy adopted by Japan to cope with these economic forces was threefold: 1) a 21 percent reduction in the number of vessels between 1975 and 1984, while retaining the more efficient vessels[2]; 2) greater utilization of the super-cold freezing technology to produce quality fish for the sashimi market; and 3) the value of each load of tuna was enhanced through emphasis on higher valued species. In other words, the strategy was to reduce production that supplied the low-valued export canning market (100 percent in 1955) and to emphasize production of tunas to supply the high-valued sashimi market of Japan (80 percent in 1985).[2] Since bigeye tuna commands a higher price than yellowfin tuna or albacore in the sashimi market (Fig. 4), Japanese longliners began using special techniques to enhance their catch of bigeye tuna.

A discussion of events shaping this global pattern would not be complete without mention of events in the Japanese southern bluefin tuna fishery. The development of this fishery was spurred by high catch rates combined with a strong demand for southern bluefin tuna in the sashimi market and development of the super-freezing technology. Prior to the development of the super-cold freezing technology, longlined bluefin tuna destined for the sashimi markets from distant waters in the southern Indian and Pacific Oceans had to be quickly caught and transported to Japan at high cost. The super-freezing technology reversed this need for swift vessels and short fishing trips.

The strong market for southern bluefin tuna contributed to increasing fishing effort and catch and catch rates began to decline in the early 1960's. The stock began showing the effects of overfishing as the number of small fish in the catch increased and the catch rate declined with increasing effort (FAO, 1980; Murphy and Majkowski, 1981). In 1972, faced with substantial hikes in fuel prices and declining catch rates, the Japanese fleet was in financial trouble. The fleet adopted voluntary measures to stabilize fishing effort in this fishery (ICCAT, 1986). Despite this, catch and catch rates continued to fall. We suspect that difficulties in this major Japanese longline fishery precipitated the adoption of a new strategy. The new strategy allowed the Japanese to shift excess capacity out of the southern bluefin tuna fishery into an underdeveloped bigeye tuna fishery to supply the domestic market, while retaining its modern, specialized longliners with super-cold freezing capacity.

Taiwan entered the longline industry during a period when the Japanese fleet was undergoing modernization and expansion in the late 1950's to early 1960's (Uyemae, 1975). Used Japanese vessels were purchased and put into operation by Taiwanese fishermen. They quickly specialized in production of the high-valued albacore for export to the U.S. canning market. Vessels were primarily based in foreign ports, close to the fishing areas and their catch either landed at a cannery port (e.g., American Samoa) or transshipped to canning facilities (e.g., Puerto Rico).

During the 1970's, when the Japanese fleet switched to catching bigeye tuna, the Taiwanese fleet benefited by the reduced competition. Apparently, unlike the Japanese fleet, lower operating costs, particularly for labor, and marginal increases in tuna prices allowed this fleet to continue to survive on catches of albacore for the canned tuna market during the 1970's. Recently, however, sharp declines in the price of albacore have caused cutbacks in operations of this fleet (Yang, 1985), but albacore production continues to be the strategy followed by most of the Taiwanese vessels. More than 80 percent of the catch currently is of albacore.

Like the Taiwanese fleet, used Japanese vessels were purchased by Koreans in the mid-1960's and put into operation from foreign bases to supply U.S. tuna canneries (Uyemae, 1975). Korean fishermen quickly discovered that this market was not growing for longline-caught fish. Rising fuel prices and marginal increases in tuna prices also threatened profitability. These realizations, along with encouragement from

Japanese trading companies, caused some vessels to switch fishing for the canned tuna market and to concentrate on the higher value sashimi market. The Koreans were successful in adapting technology for fishing bigeye tuna and in using import privileges that allowed direct landings in Japan. By 1974, direct landings by Korean longliners in Japan were 40,000 t of primarily sashimi-grade tuna (Uyemae, 1975). Further advances included adopting supercold freezing capability and acquiring larger vessels resulted in the current catch pattern for the Korean fleet being nearly identical to that of the Japanese fleet (Fig. 6). By 1982, Korean vessels landings in Japan grew to 56,000 t. The net effect for the Korean fleet is an evolution from solely supplying the canned tuna market to supplying primarily the sashimi market. This has placed this fleet in direct competition with the Japanese fleet and has caused disruption of the once orderly Japanese sashimi market as supplies from Korean vessels have contributed to surpluses substantially above the demand[3]. Continued access to the Japanese market will likely determine the economic survival of the Korean fleet.

Patterns in the Atlantic

Over the past decade, longliners accounted for the major share of the bigeye tuna catch from the Atlantic, more than 62 percent (Kume, 1985). In 1984 the total bigeye tuna catch of the Atlantic Ocean was 64,600 t, of which 64 percent was taken by longliners. Japanese longliners caught 24,300 t, Korean longliners caught 10,900 t, Taiwanese longliners caught 800 t and other nations the remainder.

The catch is principally taken in three regions (Fig. 7): A) northwestern Atlantic, off the U.S. and Canadian coasts; B) northeastern Atlantic from Cape Verde to Azores; and C) southeastern Atlantic off Angola and Nambia (Sakagawa, 1976). Longline fishery statistics for these three regions were tabulated by fleets. The purpose was to determine whether the ocean-wide profile would persist if the data were tabulated on a smaller, regional scale and whether the patterns are related to variation in fishing effort.

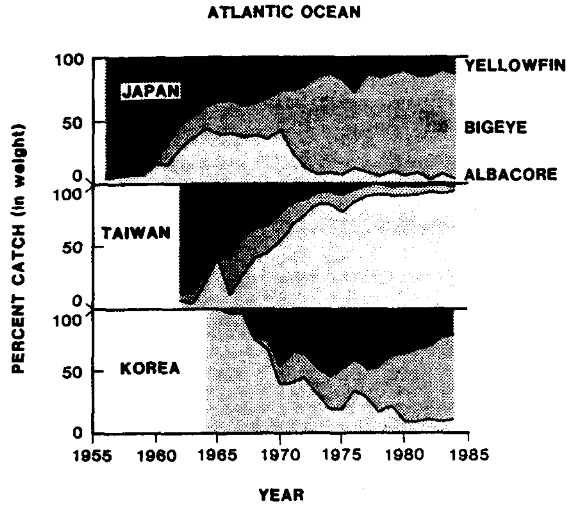


Figure 6.—Species composition of longline catches (in weight) from the Atlantic Ocean.

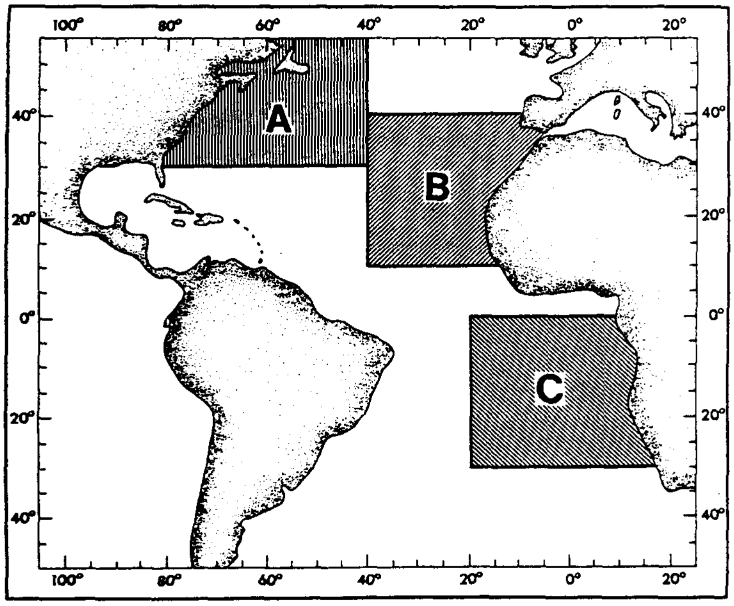


Figure 7.—Major longline fishing regions for bigeye tuna in the Atlantic Ocean.

[3]Yamashita, H. 1986. Current trends in industry, Japan. Manuscr. pres. at Tuna Workshop on Options for Cooperation in the Development and Management of Global Tuna Fisheries, 29 June-3 July 1986, Vancouver, B.C., 16 p.

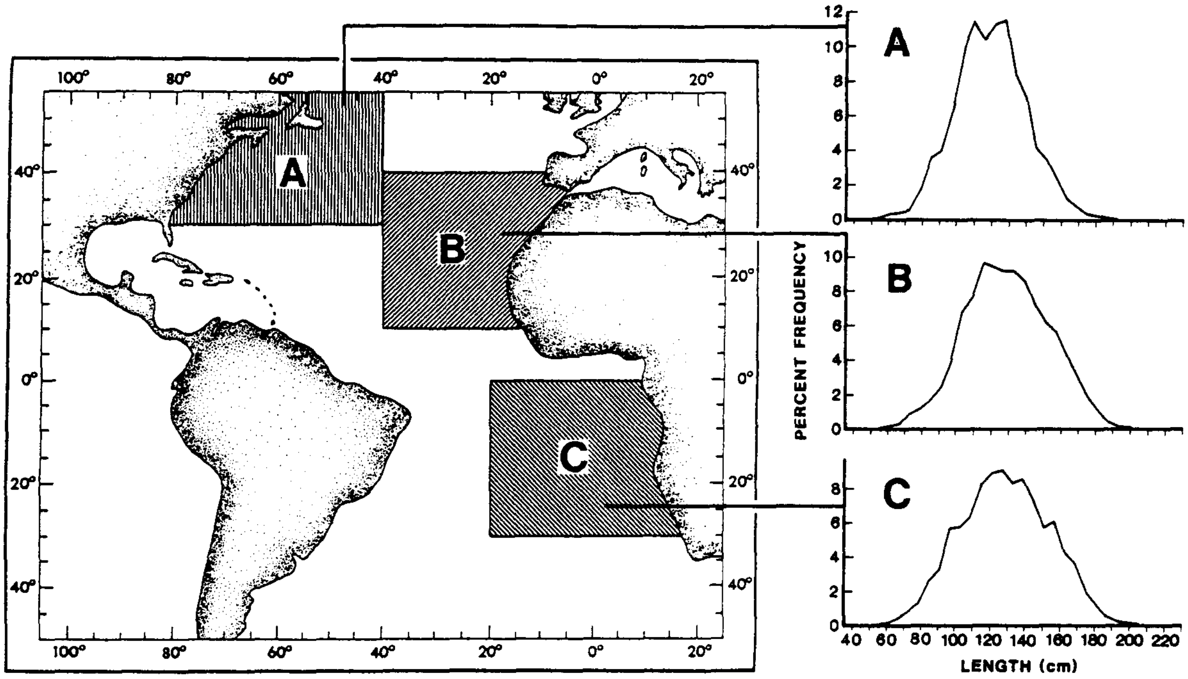


Figure 8.—Size composition of bigeye tuna caught by longliners in the bigeye tuna fishing regions of the Atlantic.

The sizes of bigeye tuna caught in the three regions are identical and consist of fish that are primarily of spawning age (Fig. 8). This consistency in size frequency has led to the general belief that the longline gear is selective in catching only large sizes of bigeye tuna.

Species Composition

The species composition profiles based on numbers of fish or weight show particular patterns. For the Japanese fleet, regions B and C yield primarily bigeye tuna, but region A yields about an equal mixture of both bigeye tuna and albacore (Fig. 9).

The Taiwanese fleet has a profile that is consistent for all three regions when viewed by numbers or weight, i.e., predominantly albacore (Fig. 9). In regions B and C, which Japanese data indicate are bigeye tuna fishing areas, less than 10 percent of the Taiwanese catch is bigeye tuna and more than 80 percent is albacore. In terms of numbers, Taiwanese longliners caught 191,000 albacore in region B and 203,000 albacore in region C in 1983. Japanese longliners caught only 5,000 albacore in region B and 4,000 albacore in region C, but bigeye tuna catches were high, 69,000 and 188,000, respectively, in 1983.

Time series of Korean longline statistics are incomplete, but, from data available for comparison, this fleet seems to be the most flexible and adaptive of the three fleets (Fig. 9). In region A, albacore is the target species; in region B, both yellowfin and bigeye tuna are targets; in region C it is bigeye tuna.

The conclusion is that the ocean-wide patterns persist in the three regions for the Taiwanese fleet, two regions for the Japanese fleet, and one region for the Korean fleet. Thus, regional fishing areas and fleet operations both determine what species are caught and their ratio in the catch.

Catch Rates

It might be argued that patterns in species composition of the catch are due to a normal evolution of a multispecies fishery in which declining catch rate for one species results in switching to another species with a higher catch rate. We examined this hypothesis using nominal catch rates by fleets and regions.

The catch rates for the Japanese fleet vary within a region, but there is a clear pattern (Fig. 10). The high catch rates for albacore (average of 30 fish/1,000 hooks in regions A and C) were followed by sharp declines in the early 1970's when switching to bigeye tuna occurred. This was followed by a leveling off of the albacore catch rate at a low level. The catch rate for bigeye tuna in comparison shows less variation. Since 1970 it has fluctuated between 5 fish/1,000 hooks and 20 fish/1,000 hooks, and since 1974 it has surpassed the albacore rate in nearly all years. The effect of deep longlining, i.e.,

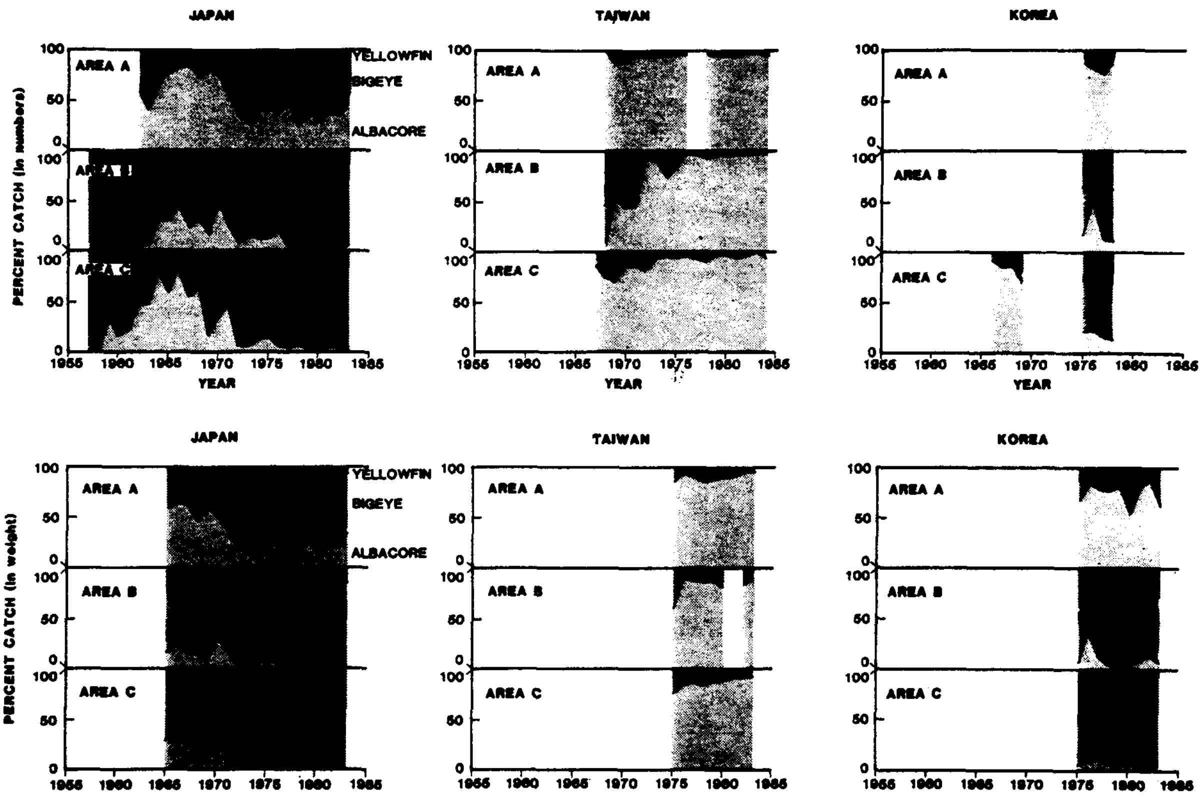


Figure 9.—Species composition of longline catches (in numbers of fish and weight) by fleets from bigeye tuna fishing regions of the Atlantic Ocean.

superior catch rate for bigeye tuna, since 1978 is not evident in the data possibly due to limited amounts of effort by this gear; so, we conclude that its effect, if any, is negligible.

In comparison, the Taiwanese fleet shows catch rates of albacore that are high although variable (Fig. 10). The catch rates are comparable to rates that the Japanese fleet was experiencing before the switch to bigeye tuna occurred in the early 1970's and are substantially higher than catch rates for bigeye tuna. The reduced competition by Japanese longliners for albacore in region B appears to have contributed to improved catch rates for Taiwan longliners operating in that region. The Taiwanese fleet appears to have selected the species with the highest catch rate.

Incomplete data for the Korean fleet prevent a thorough analysis. However, available data (Fig. 10) suggest that the pattern of catch rates is more like that of the Japanese fleet than the Taiwanese fleet.

These results indicate that the hypothesis that declining catch rate of one species triggers switching to another species with a higher catch rate in longline fisheries is unsupported. Nominal catch rates for albacore in all three regions are substantially higher than for bigeye tuna or yellowfin tuna, yet only the Taiwanese fleet concentrates on fishing for albacore. The Japanese fleet abandoned the high catch rates for albacore in 1970-71 to concentrate on bigeye tuna with a lower catch rate. Similarly, the Korean fleet is not pursuing the species with the highest catch rate, but concentrating on a mixture of species dominated by bigeye and yellowfin tunas.

Fishing Effort

Another factor that might explain the difference in patterns in species composition is the seasonal distribution of fishing effort. Seasonal variation in longline fishing effort within regions of the Atlantic Ocean is well known (Shingu et al., 1980; Yang, 1980). But is the variation so different between the Japanese and Taiwanese fleets to cause one fleet to catch a significantly higher proportion of bigeye tuna while the other does not?

The seasonal pattern of fishing effort by fleet for 1983 (Fig. 11) indicates that in region A, both fleets have similar patterns. In region B, the Japanese fleet em-

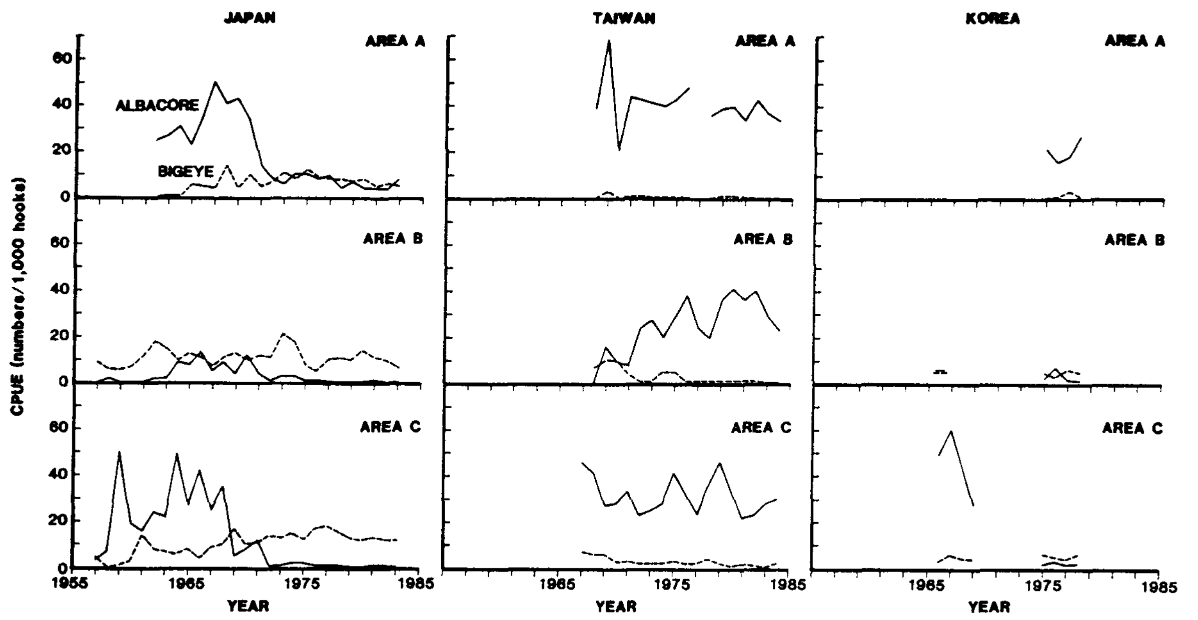


Figure 10.—Catch rates for longline fleets fishing in the bigeye tuna fishing regions of the Atlantic Ocean.

phasizes spring and summer months, whereas the Taiwanese fleet emphasizes the summer and fall. In region C, the difference is in the spring and summer months when the Japanese fleet is not operating, whereas the Taiwanese fleet is active.

Within regions B and C, besides differences in seasons fished, fishing effort for the Japanese fleet tends to be concentrated towards the equator, whereas the Taiwanese fleet concentrates in areas toward the poles. Thus, in regions B and C, seasonal differences in fishing effort are a factor causing more of one species to be caught than another. However, this is obviously not the sole factor, since in region A the two fleets fishing similar locations and seasons but caught different proportions of tuna species.

Basis for Patterns

Longlining is considered a labor-intensive form of fishing with catch rates relatively low compared with other forms of tuna fishing. Fuel and labor constitute 75 percent of the expenses of operating a longline vessel (Uyemae, 1975). It is estimated that a 300 gross ton Japanese vessel spends about $500,000 for expenses on a 10-month fishing trip which, on the average, results in a full load (Uyemae, 1975). Obviously, even at the highest historical prices offered by U.S. canneries (Fig. 3), a longliner can barely break even, whereas with prices for sashimi-grade bigeye tuna (about $2,300/t) a profit is possible. Market forces thus have played a major role in influencing the fleets to specialize and concentrate on certain species.

These market forces through time have influenced the operations of the longline fleets and have shaped their strategy so that each specializes in certain species for particular markets. This is remarkable, given that the longline gear is often

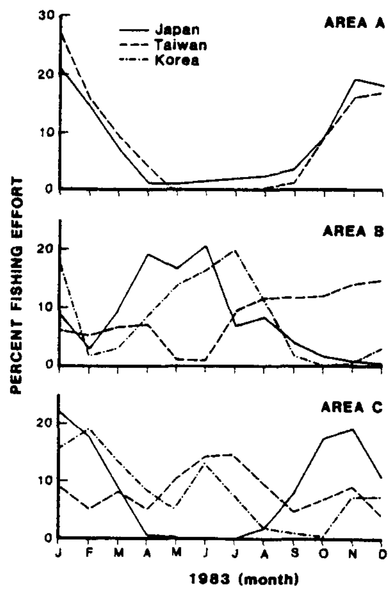


Figure 11.—Seasonal distribution of fishing effort for the Japanese and Taiwanese longline fleets by bigeye tuna fishing regions of the Atlantic Ocean.

thought of as an indiscriminate, nonselective gear. It is obvious that in skillful hands, this gear is capable of being deployed to catch a particular mix of tuna species with significantly different proportions of one species over another. How this is done has not yet been fully explained.

Hanamoto (1976) contends that the deeper the branch lines are the greater the catch of bigeye tuna. Suda et al. (1969) postulated that the habitat of bigeye tuna is between the mixed layer and subpolar waters, i.e., in the thermocline region. Depending on how the gear is deployed relative to the thermocline and the preferred temperature of 20°C bigeye tuna would be caught. Suzuki and Kume (1982) conducted an experiment to test this hypothesis in the western Pacific Ocean. Their experiment yielded highest bigeye hook rates for the deepest sets (up to 225 m) and good catches in and below the thermocline in temperatures of 11°-26°C. Their good catches, however, were for both yellowfin and bigeye tunas in approximately the same proportions.

A series of similar experiments were carried out by Laurs and coworkers[4] (Laurs et al., 1981) in exploratory fishing for albacore in the eastern north Pacific Ocean. They used vertical and horizontal temperature profiles to select fishing areas and to position their longline gear. They concluded that thermal fronts with temperatures of 16°-19°C tend to concentrate albacore. Good catches of albacore were obtained while fishing in the top half of the thermocline where the 16°C isotherm was located. Their experiment produced catches of both albacore and bigeye tuna, but albacore made up more than 90 percent of the catch.

Tracking experiments of tunas tagged with ultrasonic transmitters have been conducted to study the vertical and horizontal movements of tunas. While experiments so far have used tunas smaller than those of average size in longline catches, which may make the results somewhat atypical for larger fish, the results do provide biological support for the hypothesis that albacore, bigeye, and yellowfin tunas are relatively separated in the water column. Results of sonic tracking of albacore[4,5], show that albacore tend to occupy the upper portion of the thermocline during daylight hours with few radical excursions above or below the thermocline. At night albacore are found above the thermocline with rather large excursions upward and downward below the thermocline. By contrast, bigeye tuna were found generally below the thermocline, deeper at night than during the day.[6] Yellowfin tuna tend to swim deeper than albacore but not as deep as bigeye tuna and prefer the warmer mixed layer.

A definitive explanation of how the fleets specialize in catching particular tuna species is not possible without more detailed observations on the actual operations of the vessels and on the behavior of large tunas typically caught by the fleets. However, some understanding of "how" is emerging from findings so far.

A combination of several factors appears to be used by the fleets in catching selective species. Season is one, but perhaps most important are areas fished and gear deployment. Fishing for albacore is concentrated in temperate regions where albacore is the dominant species and where they occur frequently along thermal fronts created by polar waters meeting warmer waters. The 16°C isotherm is used as an indicator of preferred water. Vertically, fishing in the thermocline or just above it in 16°-19°C waters assures catches to be predominantly albacore.

Fishing in the tropical and subtropical regions results in primarily bigeye and yellowfin tuna catches. Yellowfin tuna occupies primarily the mixed layer but extends into the thermocline. Bigeye tunas are found deeper, within the thermocline and below in 11°-26°C water. Gear deployment in these regions requires more skill for targeting on one species. The gear is probably fished in the lower half of the thermocline and slightly below for enhanced catches of bigeye tuna. Electronic equipment, probably chromoscopes, are used to find bigeye tuna more accurately in and below the thermocline and for precise deployment of the gear.[7]

The results of our review point out the role of market forces in determining the species composition of the longline catch and of technological developments in providing fishermen with the capability to effectively target on certain species. Our results also point to the need for extreme caution in utilizing a time series of longline fishery statistics to determine stock condition without a thorough understanding of the underlying economic events that influenced the time series of data. The frequent assumption made when using such statistics is that the catchability of a unit of longline fishing effort remains constant throughout a time series. This assumption is obviously not true. The fleets have evolved in response to forces that are not completely biological. The data on catch and catch rates must be adjusted to account for these responses, and it is likely that current practices do not fully accomplish this.

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