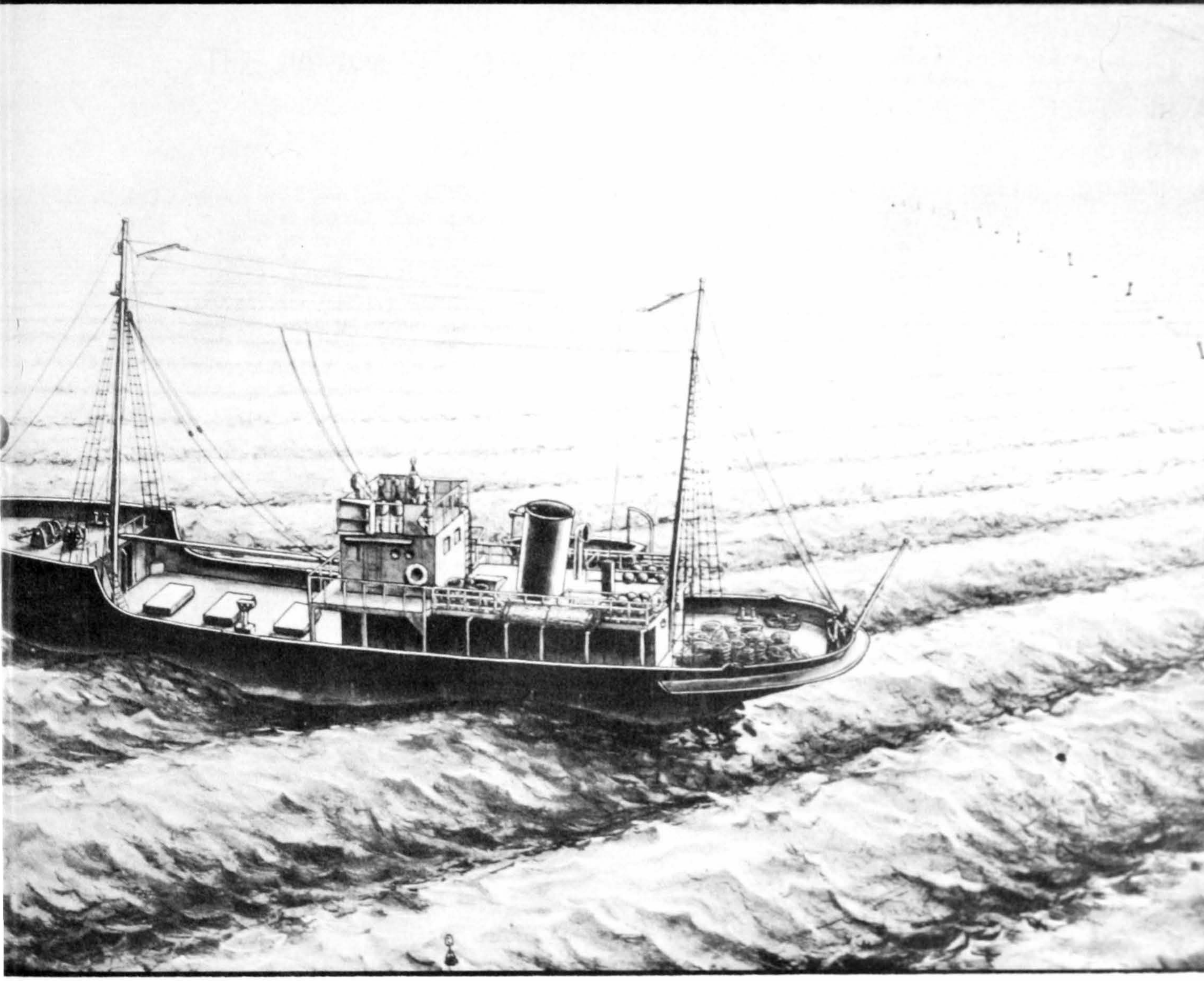
THE JAPANESE LONG-LINE FISHERY FOR TUNAS

By Sidney Shapiro



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By Sidney Shapiro*

ABSTRACT

Under normal conditions, the Japanese fishing industry has been able to produce the largest tuna catch made by any single nation--recording during the prewar years (1936-40) an annual catch in the neighborhood of 400 million pounds. Of this amount, about 65 percent (or 260 million pounds) was taken by the surface-fishing pole-and-line gear and 25 percent (or 100 million pounds) by the subsurface-fishing long-line gear. Other gear of minor importance, such as, the set net, drift net, circling net, and trolling jig, accounted for the remaining 10 percent of the catch.

The long-line gear is essentially a method by which hooks are lowered to fishing depths of about 100 to 350 feet below surface level. The Japanese have thus been able to obtain a part of their tuna catch at times and from places which could otherwise not be tapped by the surface-fishing methods widely in use in Japan and other nations throughout the world. Among the more important of the areas developed by the Japanese long-line fishermen are the winter albacore grounds located near Midway Island in the mid-Pacific, the tuna grounds of the Ryukyu Archipelago, and the yellowfin tuna grounds in the southwest Pacific Ocean.

Two main types of long-line gear, the construction and use of which are described in this report, have been developed by the Japanese--the albacore type for subsurface fishing at depths of about 100 to 200 feet, and the black-tuna type for deeper fishing at about 150 to 350 feet. The albacore-type gear generally catches albacore and big-eyed tuna, the black-tuna type takes black, big-eyed, and yellowfin tunas. Although each type of gear yields primarily an abundance of the species for which it has been designed, the catch composition is usually varied, and some marlins, swordfish, and sharks, as well as the various tunas, may be taken on an albacore or black tuna long line.

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NOTE: The data presented herewith have been obtained during an 18-month tour of duty with the Fisheries Division, Natural Resources Section, Supreme Commander for the Allied Powers (SCAP), Tokyo, Japan. Assistance in arranging field trips to observe the operation of the long-line gear and in supplying detailed information regarding its construction and use has been given by Mr. Shigene Takayama, Chief, Fishing Gear Section, Tokai Fisheries Experimental Station, Tokyo, Japan. Mr. Katsuyuki Kita, draftsman for Fisheries Division, Natural Resources Section, and Miss Alice Hunt, Pacific Oceanic Fishery Investigations, Fish and Wildlife Service, Honolulu, T. H., have prepared the illustrations. The paper was written while the author was assigned to the Pacific Oceanic Fishery Investigations of the U. S. Fish and Wildlife Service.

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The Japanese experience in developing a long-line fishery has shown that a period of intensive exploration has been necessary to locate productive fishing grounds. Since it was difficult to detect the presence of the far-ranging tunas when they are swimming at subsurface levels in many parts of a vast ocean, commercial vessels were unwilling to invest the money and effort required for initial operations. Therefore, Japanese national and prefectural fisheries organizations sponsored the exploratory phase needed to develop a sizable offshore long-line fishery. Over a period of several decades, their exploratory vessels compiled and disseminated to the industry information on the location of productive grounds and the hydrographic conditions under which the best catches were likely to be made. Thus, data on the locality of best catch, when correlated with information on optimum water temperatures, configuration of ocean bottom, and type of ocean current, have been useful in indicating to commercial vessels the situations under which the long-line gear can be operated to maximum advantage.

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INTRODUCTION

Tuna fishing is carried on to some degree by almost every maritime country located in the tropical and temperate zones of the world. However, the resource has been exploited to support thriving fisheries only where a large consumer's market for tuna exists and where fishing effort is intensive and of a progressive nature. Of the many regions where tuna fishing is practiced, the most important are those located along the Pacific coast of North and South America and in the western Pacific. Production from these regions, largely by the United States and Japan, respectively, has accounted for the bulk of the world's tuna catch. Under normal conditions these countries have taken in excess of 90 percent of all tunas caught throughout the world during the last several decades.

A further comparison of production statistics shows that in the prewar years (1936-40) the Japanese recorded the largest annual catch of tuna and tuna-like fish[1] obtained by any single nation. During this five-year period an annual average production of about 400 million pounds was attained by vessels operating from Japan Proper. Although the United States tuna fisheries have expanded to major proportions during the past several decades, they have still not reached the level of normal Japanese production. The peak catch for United States tuna vessels has been recorded in the latest production figures available--the 1949 catch being 332 million pounds, or about 80 percent of the normal prewar Japanese catch.

The American catch was obtained solely by surface-fishing tuna vessels. In a representative year, 1940, the pole-and-line live-bait fishing gear contributed approximately 70 percent to the total tuna catch, and purse seines about 25 percent. Trolling for albacore accounted largely for the remaining five percent.

The major part of the Japanese catch was also obtained through the use of the pole-and-line gear. On the basis of personal observation and analysis of Japanese statistical records, the pole-and-line catch is estimated to be about 65 percent of a normal year's total. The second most important Japanese tuna gear was the subsurface-fishing long line, and this caught approximately 25 percent (or 100 million pounds) of tunas. Other gear of minor importance, such as the set (or trap) net, the drift net, the circling net, and the trolling jig, accounted for the remaining 10 percent of the catch.

The expansion of the American tuna industry has come about primarily through an increase in the Pacific fishing fleet and the continued extension of the fishing grounds to greater distances from home ports, so that many of the major fishing areas are now located in such distant regions as the ocean waters adjacent to Central and South American countries. Progress in the development of the Japanese tuna industry has been due, in part, to these same factors--the building of a larger fleet and the intensification of fishing operations from home waters to more distant localities. However, the development of the Japanese tuna fisheries has also been furthered by the introduction of the long-line gear, and exploitation of subsurface waters has thus been possible. That subsurface fishing has contributed markedly to the Japanese catch has been noted above--approximately 100 million pounds of tunas being taken from ocean waters not reached by surface-fishing gear.

American expansion in the tuna industry is continuing. This is evident from the fact that, in their search for new fishing grounds, many of the larger fishing companies have under serious consideration the possibility of extending their operations westward into the mid-Pacific regions. Indications are that such operations may eventually materialize, but it is also possible that the American fisherman has neglected sources of supply closer to home--and those are the deeper ocean waters which cannot be fished by the pole-and-line or the purse-seine gear.

The use of the long-line gear for subsurface fishing also offers the American tuna fisherman an opportunity to continue peak operations throughout the year. Although the long-line gear has been operated by the Japanese at all seasons in a

1/ Tuna long-line boats operating in the offshore pelagic waters take, in addition to tunas, a large number of marlins, swordfish, and sailfish. The Japanese generally include these species in their tabulation of the tuna catch. During the 1936-40 period, a breakdown by species was attempted and statistical records show an average yearly marlin, swordfish, and sailfish catch of slightly over 16 million pounds. However, this recorded catch may be less than the actual, since a number of vessels probably continued to report these species as tunas.

number of areas, the most important catches have been made during the winter months in the central Pacific near Midway Island and in the Ryukyu area. American fishermen now carry on the bulk of their tuna operations during the spring, summer, and fall months, with a period of minor activity during the winter months, principally January and February. The use of the long-line gear may aid in locating and making available to the Americans such desirable species as the yellowfin tuna, the bluefin tuna, and the albacore at times of the year when they cannot be caught by surface-fishing methods. In this respect the waters located at a distance off the northwestern United States might yield a winter fishery for the albacore and the big-eyed tuna (a species presently not taken by American fishermen), as they have for the Japanese in the far and midwestern Pacific. Also, yellowfin tuna grounds, which can be fished by the long-line gear throughout the year, may materialize in the tropical eastern Pacific, as they have in the vicinity of the southwestern Pacific islands.

The purpose of this report is to present material that may assist American fishermen in the construction and operation of the long-line gear. This method has produced a large over-all catch in the western Pacific, but American tuna fishermen may not consider the unit-vessel catch obtained by the Japanese sufficiently large to warrant its adoption and continued use in the eastern Pacific. Japanese tuna vessels--both those that fish with the pole-and-line gear on the surface and with the long-line gear below ocean surface--would be considered inefficient by American standards. A 100-foot Japanese vessel, with a crew of 50 to 60 men for pole-and-line fishing or 20 to 30 men for long-line fishing, will catch an average of 40 to 50 metric tons of tuna on a voyage of four to six weeks. This low efficiency of operation is typical of many Japanese fisheries, for labor costs to their vessel owners are negligible by comparison with those in the American tuna industry. Should American tuna vessels show interest in adopting the long-line gear as a major tuna-fishing method, it may be necessary to modify its operation by increased mechanization, or by more efficient handling of the gear. Thus, smaller crews may be able to operate the gear with a correspondingly larger return for the unit of effort expended. The information regarding the Japanese long-line gear is, therefore, presented to American fishermen only as an initial step in guiding them towards the development of a subsurface fishery for tunas.

ORIGIN OF THE LONG-LINE GEAR

The early development of the Japanese long-line gear was associated with the black tuna (Figure 1) fishery. Bones unearthed from excavations of shell mounds in the northeastern Kanto and the mid-central Tohoku regions of Honshu, Japan, have been indentified as those of the black tuna,[2] indicating that this species has been consumed by the people of Japan since ancient times. The flesh of this fish has always been prized by the Japanese, and is marketable in any quantity for use chiefly as "sashimi" (raw fish, sliced and eaten as an appetizer).

Prior to the advent of modern mechanized methods for commercial fishing operations, the bulk of the Japanese tuna catch was obtained from coastal waters primarily by pole and line, set (or trap) net, and drift net. The black tuna, a wide-ranging pelagic species that approaches close to the Japanese coast during its annual migration, was generally taken by huge set nets placed in shallow waters adjacent to the shore. This method of trap fishing was, and still is, used effectively to obtain the black tunas that migrate into waters less than 200 feet deep.

2/ The black tuna, *Thunnus orientalis*, is comparable to the American Pacific coast bluefin tuna, *Thunnus thynnus*, but adequate studies have not been made to determine the exact relationship of the two forms.

FIGURE 1 - BLACK TUNA (THUNNUS ORIENTALIS) LANDED AT JAPANESE FISHING PORT OF SHIOGAMA. WEIGHT ABOUT 500 POUNDS.

However, the species was also occasionally taken by hook-and-line fishermen operating boats where waters were deeper than 200 feet. Fishermen were thus aware of the possibility of expanding the black tuna fishery to deeper waters, but it was desirable that a more efficient gear be devised for obtaining large fish from levels below the surface of the water.

The long-line gear, as now used in the tuna industry, was initially constructed through the attempts of the fishermen to obtain black tunas from subsurface waters. One of the first available records of the application of a long-line gear to the capture of this species was by the fishermen of Mera, a small fishing village located at the entrance to Tokyo Bay. The original long line had been imported from Wakayama Prefecture some 250 years previously, and was used locally for diverse fishing operations; the type of operations are unknown. About 1890 the Mera fishermen adapted the gear for tuna long-line fishing with coastal sailing and hand-propelled skiffs. For a number of years the fishermen prospered and the local long-line fishery for the black tuna grew to sizable proportions. However, as the gear was operated most effectively during rough and stormy weather, many lives were lost and, after a decade or so, the fishery almost disappeared because of the fishermen's dislike for the hardships encountered while operating small motorless craft at a distance from shore.

With the introduction of engined vessels into the Japanese tuna fisheries in 1906, a major shift in the intensity of fishing operations resulted and the emphasis changed from coastal to offshore operations. The advent of motorized

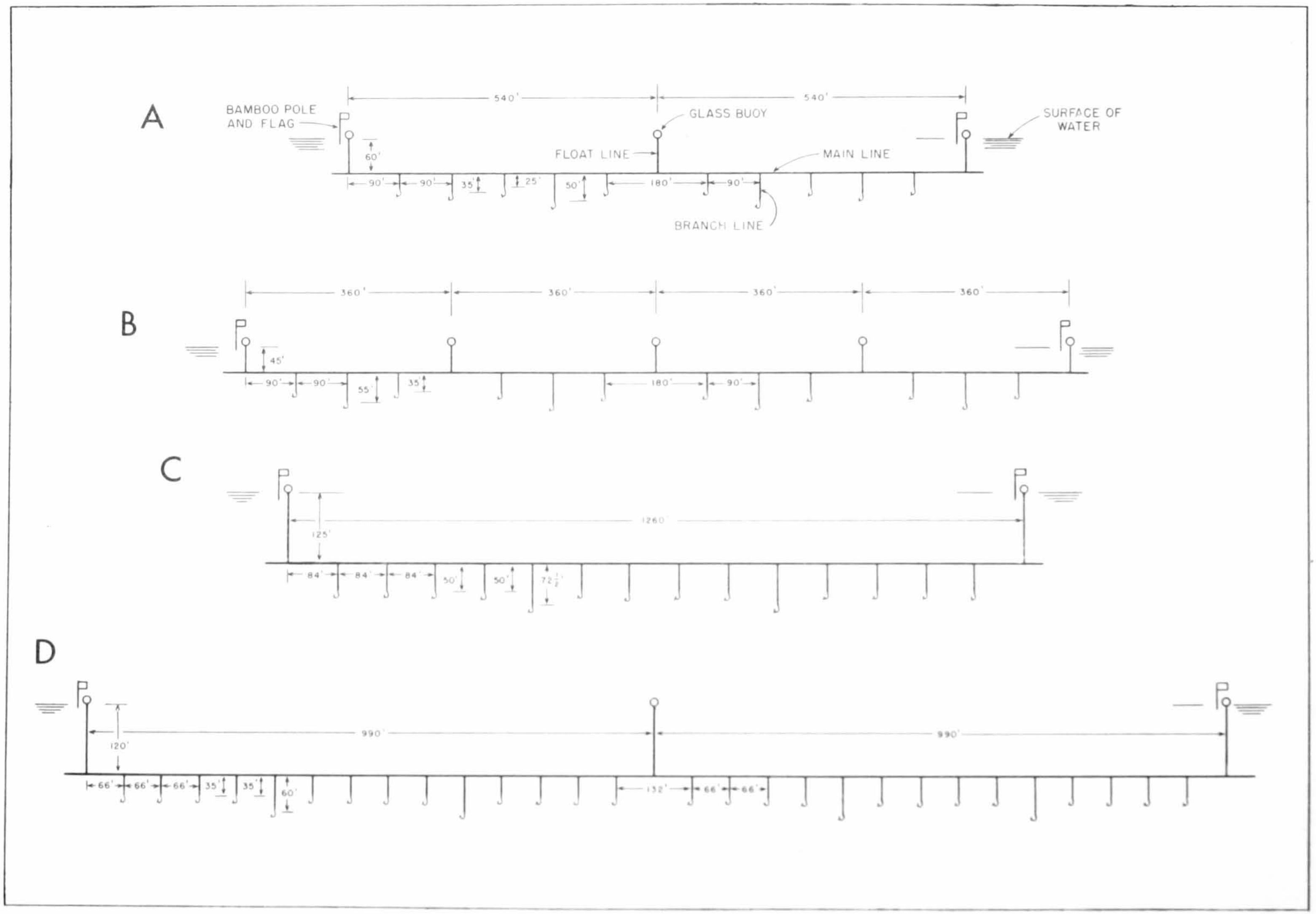

FIGURE 2 - TYPES OF ALBACORE LONG-LINE GEAR FOR SHALLOW SUBSURFACE FISHING. ALBACORE AND BIG-EYED TUNA ARE CAUGHT PRIMARILY WITH THESE GEAR. EACH BASKET (THE DISTANCE BETWEEN TWO FLAG BUOYS) MAY CONTAIN FROM 10 TO 30 BRANCH LINES. SINCE ALL BASKETS OF A LONG LINE ARE SIMILAR, ONLY A SINGLE BASKET OF EACH TYPE IS SHOWN.

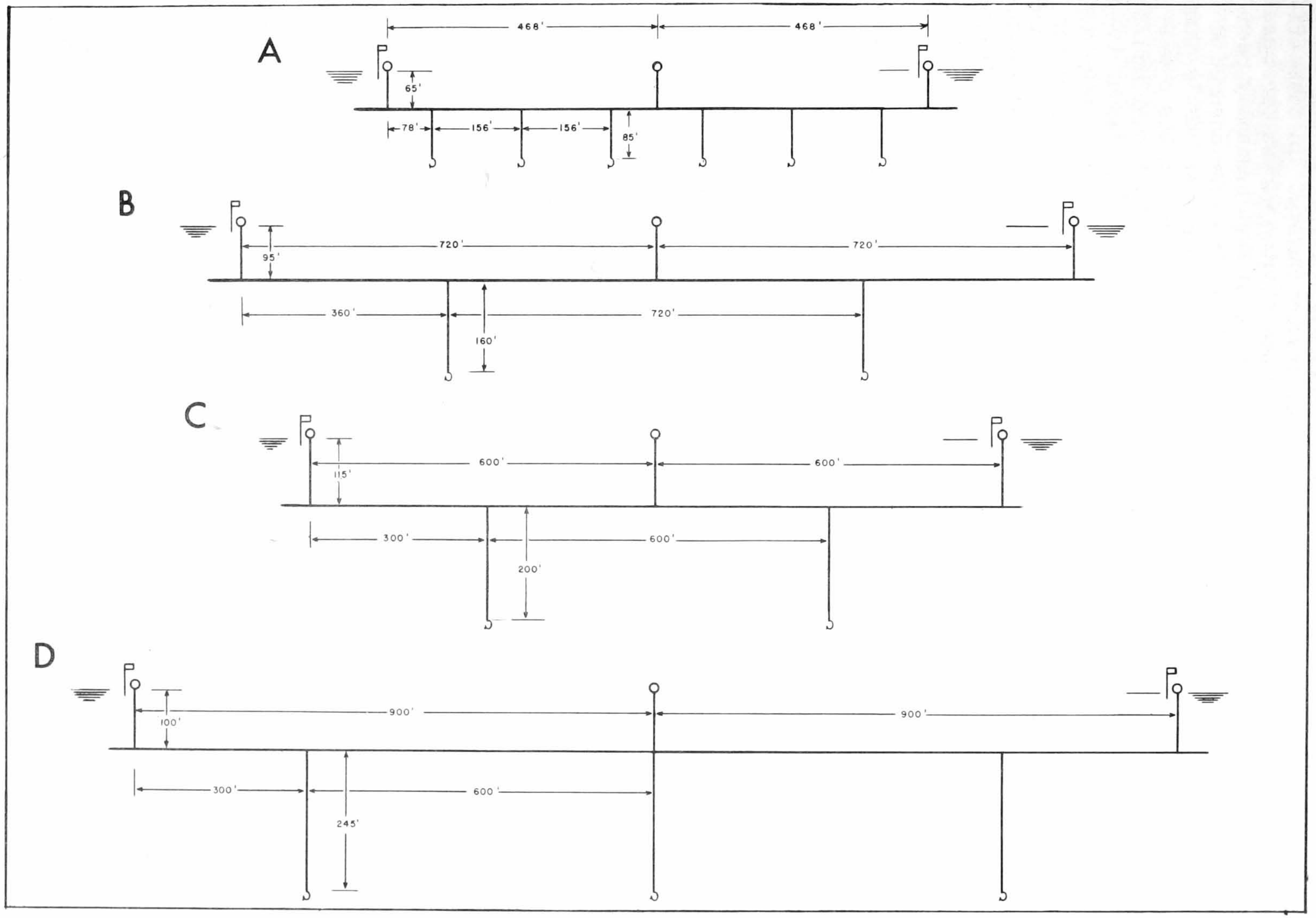

FIGURE 3 - TYPES OF BLACK TUNA LONG-LINE GEAR FOR DEEP SUBSURFACE FISHING. BLACK, YELLOWFIN, AND BIG-EYED TUNAS ARE TAKEN PRIMARILY WITH THESE GEAR. EACH BASKET (THE DISTANCE FROM ONE FLAG BUOY TO THE NEXT) MAY CONTAIN FROM TWO TO TEN BRANCH LINES. THE DEEPER THE GEAR IS DESIGNED TO FISH THE FEWER THE NUMBER OF BRANCH LINES USED. SINCE ALL BASKETS OF A LONG LINE ARE SIMILAR, ONLY A SINGLE BASKET OF EACH TYPE IS SHOWN.

vessels made it possible for larger boats to be constructed for offshore tuna fishing and thus the fisherman could be assured of greater safety. In these offshore operations the pole and line for skipjack surface fishing was at first used exclusively, but deep subsurface fishing with the long-line gear gradually reentered the tuna fisheries. In the course of time, the long-line gear assumed a position of importance since it proved to be more efficient and less costly than other forms of tuna gear, such as, the drift net. Moreover, through its operation the Japanese were able to fish with the long-line gear at times and in places where other fishing methods might not be practical. As vessels and engines improved, so did the long-line catch. Furthermore, the development of foreign export markets after 1929 acted as an additional incentive to produce larger quantities of higher-priced fish. Refinements of the long-line gear were also introduced to fish specifically during different seasons of the year and in different localities for such desirable species as the albacore and the yellowfin tuna.

TYPES OF LONG LINES

Most present-day Japanese long lines are of two general types: the albacore type (Figure 2, see p. 6), which has been developed only within the past several decades for shallow subsurface tuna fishing and the black-tuna type (Figure 3, see p. 7), which is patterned after the original long line used in the early days of deep subsurface tuna fishing.

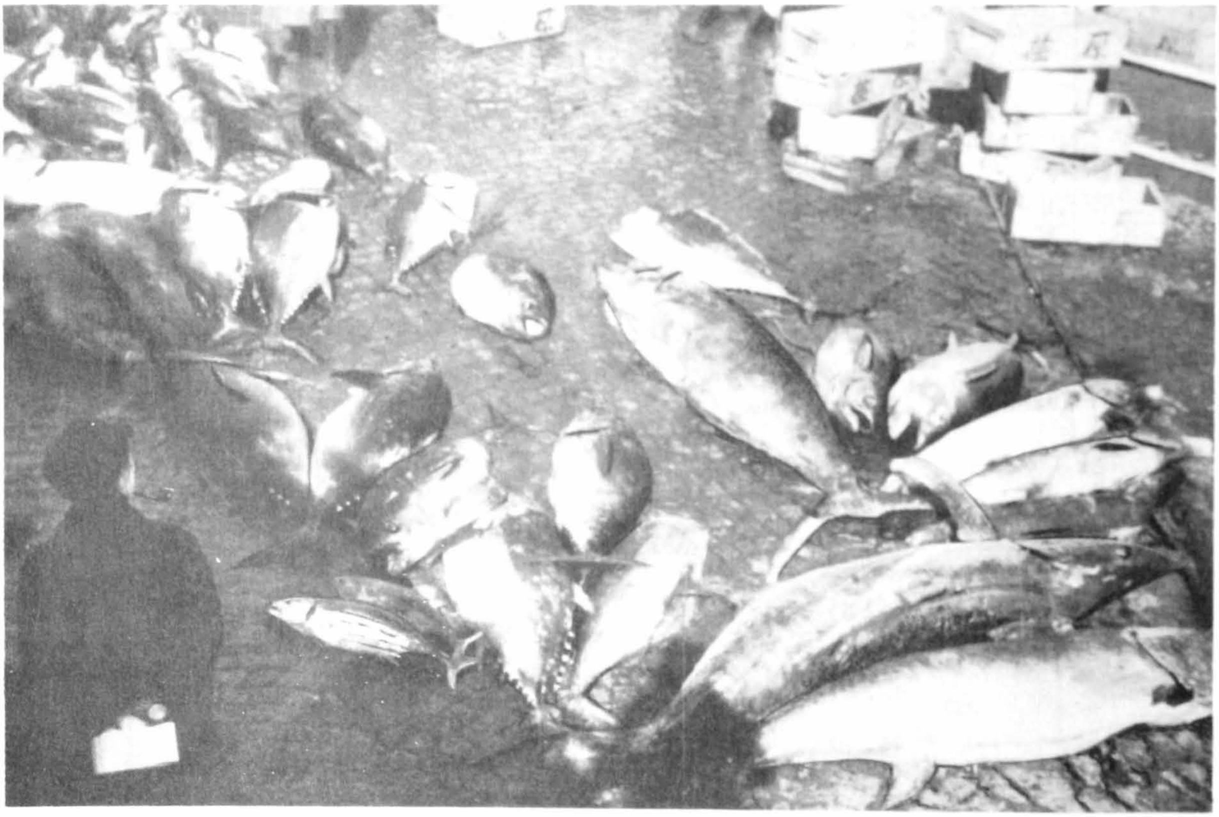

FIGURE 4 - LONG-LINE CATCH LANDED AT TOKYO FISH MARKET. BIG-EYED AND YELLOWFIN TUNAS, MARLINS, AND SWORDFISH PREDOMINATE IN THIS CATCH.

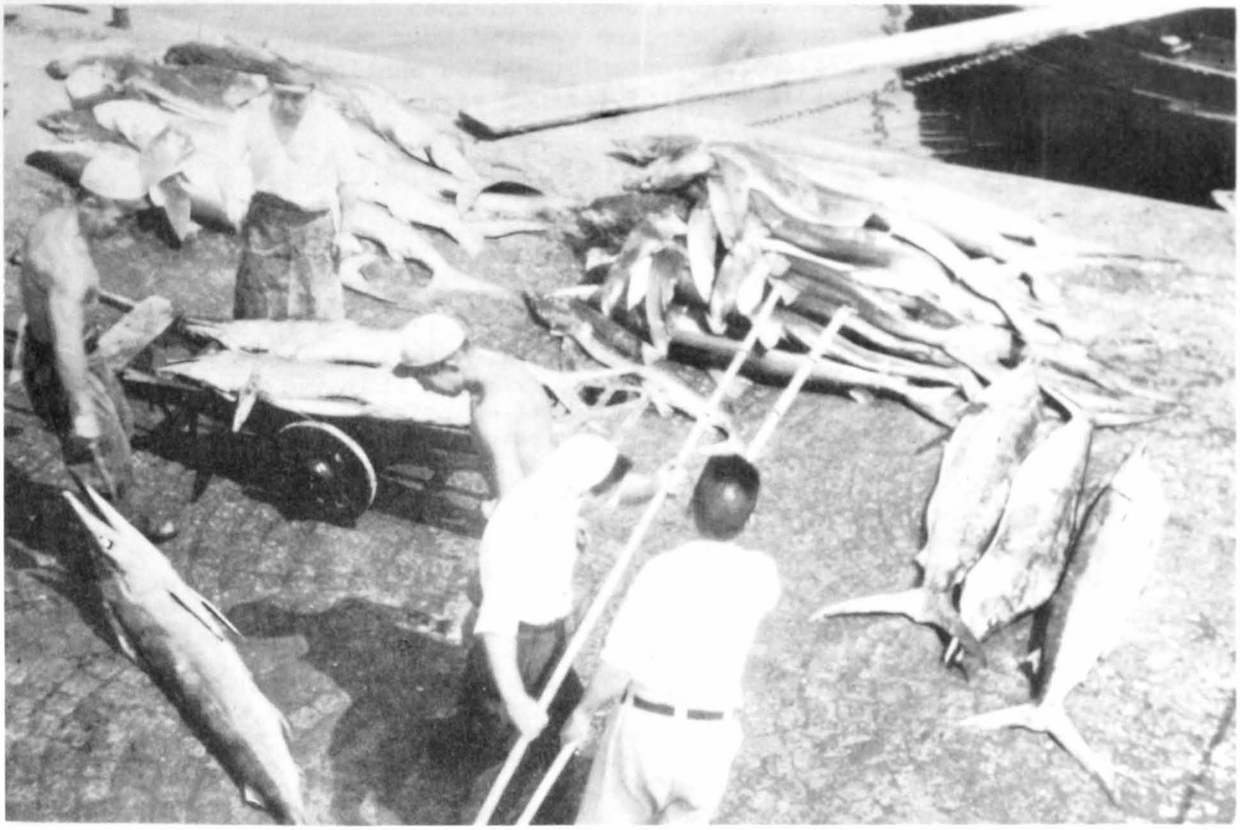

FIGURE 5 - MARLINS AND SHARKS FROM A LONG-LINE CATCH. TOKYO FISH MARKET.

Long lines, specifically designed for catching albacore (Thunnus germo), rapidly came into use when the large export market for canned and frozen white-meat tuna developed subsequent to 1929. Exploratory surveys indicated that albacore, generally, were found swimming closer to the surface than the black tuna and were more densely schooled. As a result, the long lines were constructed to fish at depths of about 100 to 200 feet, and the distance between branch lines was reduced to as little as 50 or 60 feet. Baskets of albacore-type gear were designed to contain from 10 to 30 branch (or hook) lines.

The black tuna long line is used to fish at comparatively deep levels, about 150 to 350 feet or more, and generally the branch lines are spaced at intervals of about 150 to as much as 600 feet. A basket of black tuna gear may contain from 2 to 10 branch lines; the deeper the gear is designed to fish, the fewer the number of branch lines used. In the initial stages of its use, black tunas taken in the deeper waters close to the Japanese coast composed the bulk of the catch but, as fishermen gradually extended their operations further offshore, other species of tunas, such as the yellowfin tuna (Neothunnus macropterus) and the big-eyed tuna (Parathunnus mebachi), were taken in large numbers.

Although each type of gear tends to catch primarily the species for which it has been designed, the catch composition during fishing operations is usually varied (Figures 4 and 5) and marlins (Makaira mitsukurii, M. mazara, and M. marlina), swordfish (Xiphias gladius), sailfish (Istiophorus orientalis), and sharks, as well as the various tunas, may be taken on an albacore or a black tuna long line. In some areas sharks may compose from 10 to 25 percent of the total long-line catch.

Long lines are sometimes designed to fish at both shallow and deeper levels. In recent years such construction has been favored by many fishermen, since the addition of several deeper-fishing branch lines to a shallow-type gear (Figure 2) permits the catching in certain areas of a wider variety of species.

BASIC FACTORS IN CONSTRUCTING A LONG LINE

The captain of a long-line vessel considers many factors in constructing the gear and determining the dimensions of the different parts. Among the most important of these are:

1. If the main line were placed on or near the surface of the ocean, passing vessels could cut or tangle it in their propellers. Moreover, wave action, if sufficiently severe, could snap this line. For these reasons the main line is suspended by float lines to a depth of at least 40 to 50 feet below surface level (Figures 2 and 3). Often, captains may design their gear with float lines up to 125 feet long--thus enabling them to use shorter branch lines. If the float line is longer, the branch lines can be made correspondingly shorter and more can be suspended from the main line (see page 16 and Figure 2--C and D).

2. The parts of the long-line gear should be arranged so that they may be set quickly while the vessel is running at a uniform speed. Although the long line is composed of numerous parts, all are put together in a manner so as to expedite the handling of the gear (Figures 6 and 7). Before a fishing voyage starts, float, main, and branch lines (including hooks) are tied together and arranged in a basket in proper sequence for setting out (Figure 8). When the long line is used during the actual fishing operation, only flag markers (bamboo poles) and buoys need be added and the hooks baited.

3. Many Japanese vessels, especially those that operate considerable distances from shore, handle large amounts of long line. These vessels may set as much as 50 miles of gear during a single operation. To haul this gear aboard, either by hand or by using a niggerhead, would be a wearisome task. Modern long-line vessels all carry a line hauler (Figure 9), the sheaves of which are coupled either to gears driven by an electric motor or to gears which operate from a shaft powered by the main-engine drive. In order to permit the ready passage over the sheaves of the knots which attach float and branch lines to the main line, the parts of the long line are tied together with knots that are not bulky (Figures 6 and 7). This is an additional convenience in permitting the main line to be hauled in without too much need for stopping the line hauler. A great deal of stopping and starting cuts down sharply on the amount of line that can be handled during a daily operation. Moreover, air compression for excessive starting and stopping of the main engine becomes a serious consideration for the engineer.

4. In the early days of exploratory and commercial long-line fishing operations, data were gathered which showed that the behavior of each tuna species in a particular area was distinctive and that the greatest commercial concentrations of each were found at almost specific depths. For example, the species composition of the long-line catch during the winter season in the waters east and southeast of Japan proper is

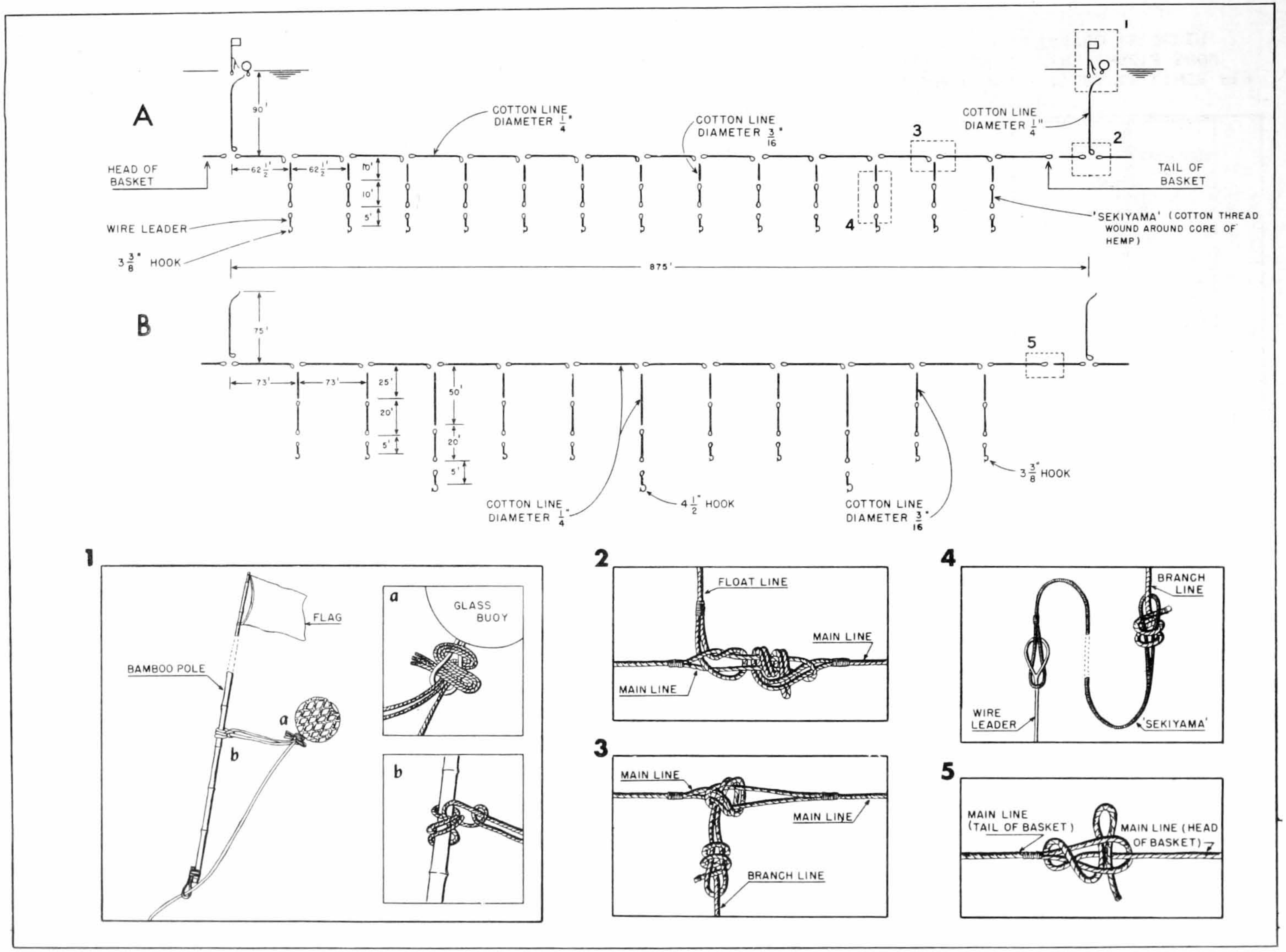

FIGURE 6 - DETAILED DESIGN OF TWO LONG LINES ILLUSTRATING ALBACORE-TYPE GEAR. GEAR A HAS 13 BRANCH LINES OF EQUAL LENGTH ON EACH BASKET OF MAIN LINE; GEAR B HAS 11 BRANCH LINES OF UNEQUAL LENGTH. THE INSETS SHOW THE MANNER IN WHICH THE PARTS OF THE LINE ARE TIED TOGETHER. THIS METHOD OF TYING IS THE MOST RECENT DEVELOPED BY THE JAPANESE FISHERMEN.

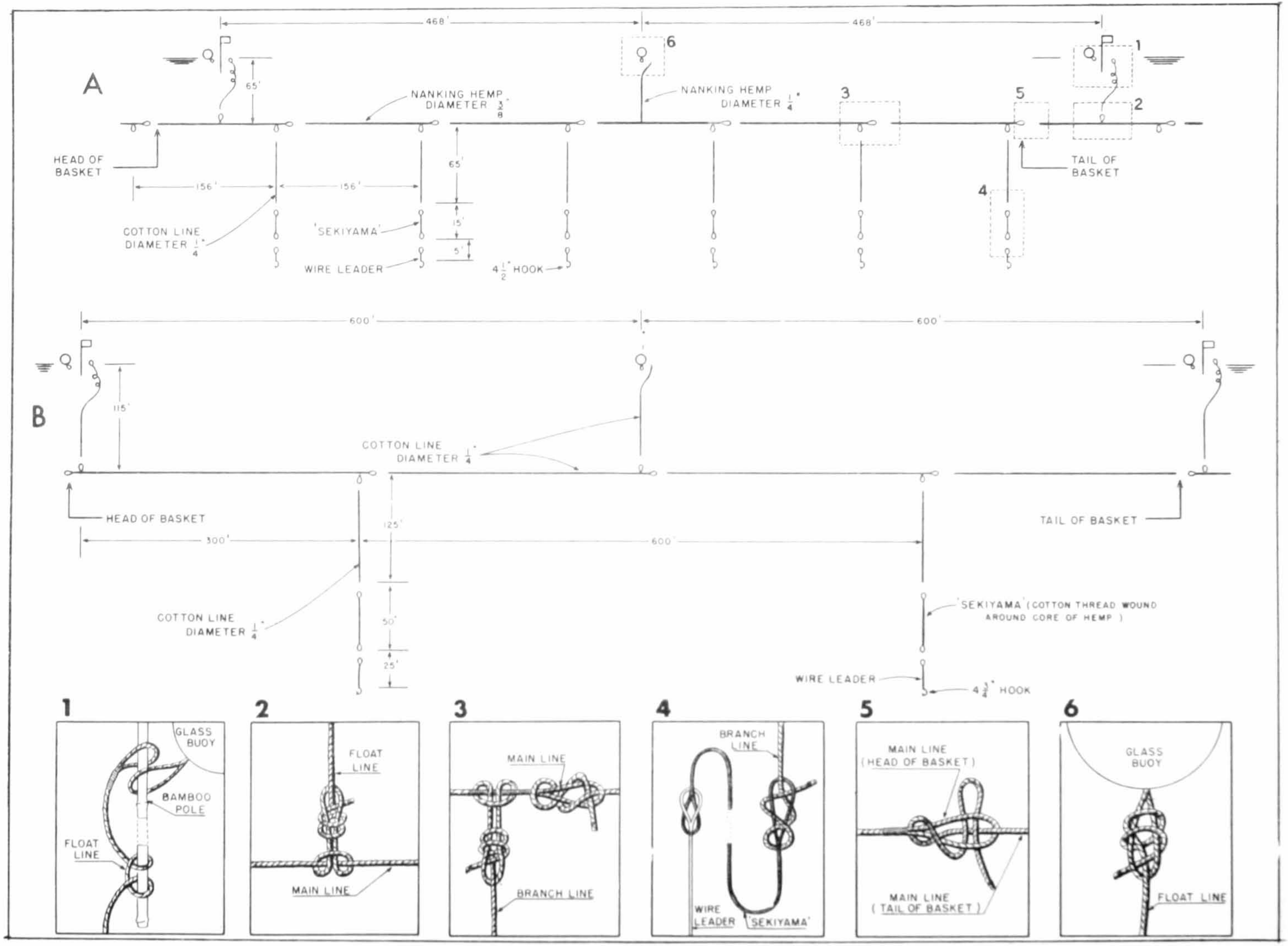

FIGURE 7 - DETAILED DESIGN OF TWO LONG LINES ILLUSTRATING BLACK TUNA-TYPE GEAR. GEAR A HAS SIX BRANCH LINES PER BASKET; GEAR B IS DESIGNED FOR DEEPER FISHING AND, ACCORDINGLY, HAS ONLY TWO BRANCH LINES. THE INSETS SHOW ANOTHER OF THE MANY METHODS OF TYING TOGETHER THE PARTS OF THE LONG LINE. THE METHOD ILLUSTRATED IS OLDER THAN THE ONE SHOWN IN FIGURE 6 AND IS AT PRESENT NOT AS WIDELY USED.

largely black, yellowfin, and big-eyed tunas taken from depths between 250 and 350 feet; whereas, during the winter season in the area nearby Midway Island, albacore and big-eyed tuna, in the proportion of two to one, have been taken in large numbers from depths of about 100 to 200 feet. Accordingly, the captain of a vessel designs his gear for the types of tunas he prefers to catch and the area in which he wishes to operate.

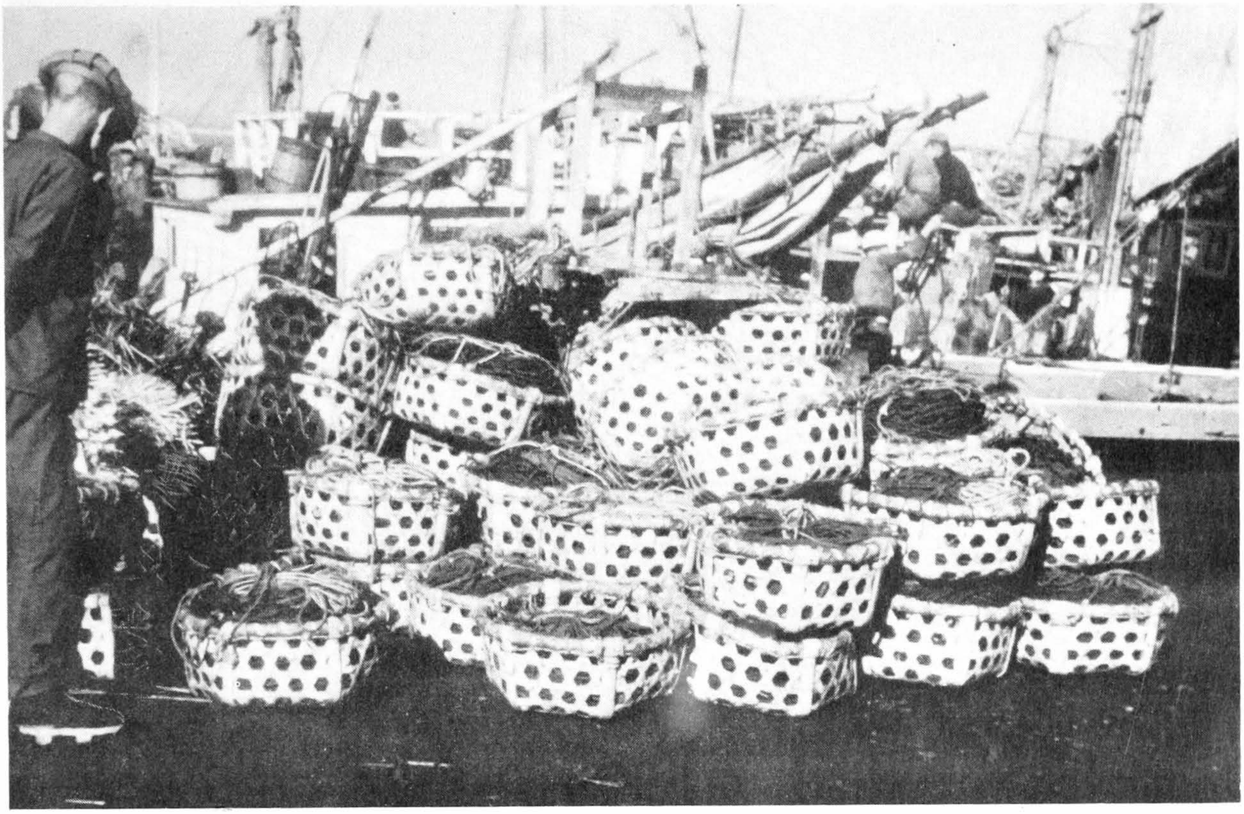

FIGURE 8 - BASKETS OF LONG-LINE GEAR READY TO BE STOWED ABOARD VESSEL. EACH BASKET CONTAINS FLOAT, MAIN, AND BRANCH LINES (INCLUDING HOOKS) ARRANGED IN PROPER SEQUENCE FOR RAPID HANDLING DURING THE SETTING-OUT OPERATION.

5. Recent developments in the long-line fishery have indicated that the same species of tuna inhabits different levels of water in different regions. For example, black tuna long-line fishing is carried on in two major areas off the Pacific coast of Japan--during the winter, in the warm Kyushu sea region and during the summer and fall, in the cold Hokkaido sea region. In the Kyushu area, the fish are quite deep; whereas, in the northern waters they approach closer to the surface. Fishermen often operate in both areas during their respective peak seasons, using the same gear but adjusting the level of the main line by shortening or lengthening the float line. Once constructed, the main and branch lines are used without changing their lengths.

6. The length of the float line plus the length of the branch line is only one of several factors determining the depth at which the hooks will fish. When the long-line gear is placed in water, the main line tends to sag where it is not supported by float lines. In a single basket, the number of float lines in relation to the length of the main line is thus an additional factor in determining the fishing depths of the various branch lines. Adding more float lines between the flag buoys will reduce the amount of sag. The captain can also control the fishing depths of the various hooks during a particular operation by either giving the main line more or less slack when it is set out (see page 20).

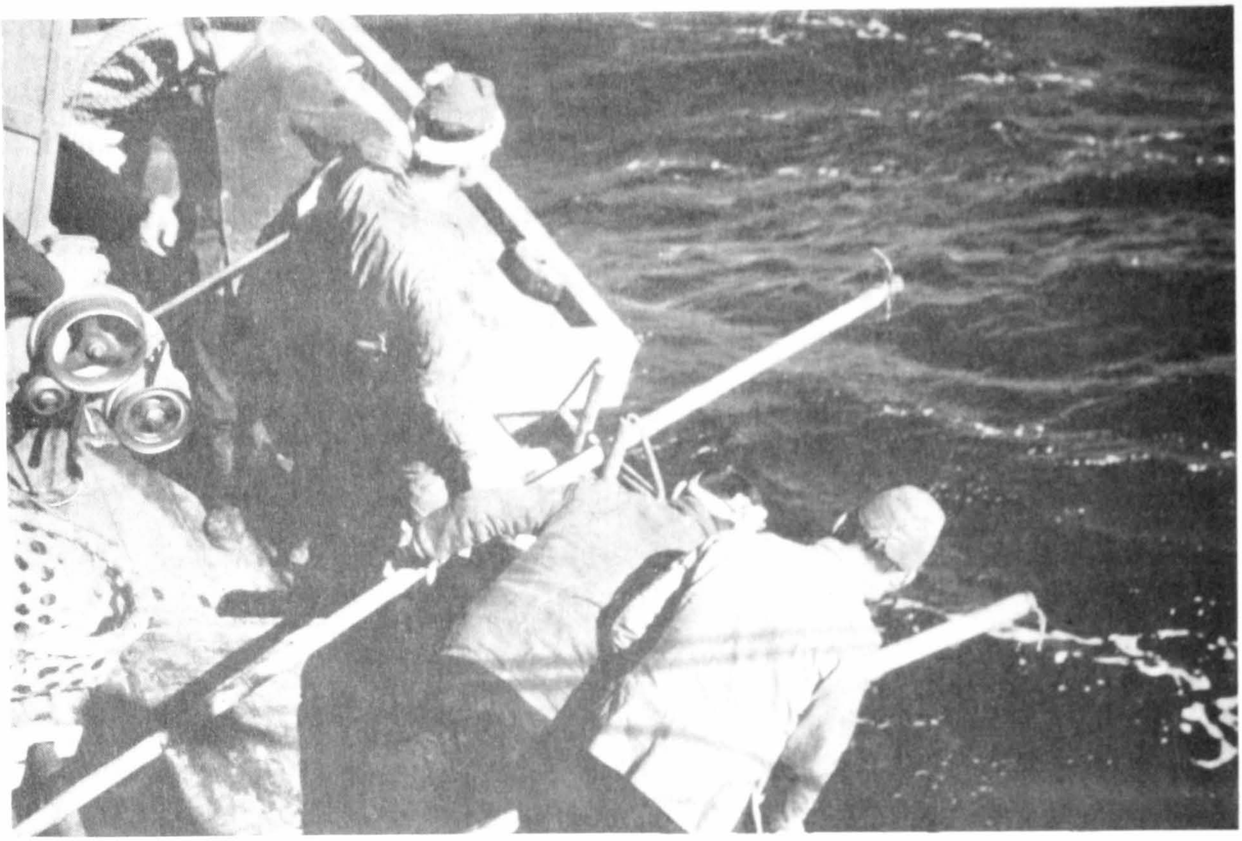

FIGURE 9 - LINE HAULER ON FORWARD WELL DECK OF LONG-LINE VESSEL. THE MAIN LINE PASSES OVER THE ROLLER WHICH IS SET ON THE DECK RAIL AND IS FED INTO THE HAULER SHOWN AT THE LEFT-OF THE PHOTOGRAPH.

PARTS OF A TYPICAL LONG LINE

BASKET: The long-line gear is essentially a method by which numerous hooks are lowered to depths at which it is desired to fish. A vessel of large size will generally set out many miles of line. In order to handle complex gear, which can easily tangle during any part of an operation, the main line is divided into baskets or sets (Figures 6 and 7). Each basket, from its head to the tail, is identical in construction; therefore, it will only be necessary to describe and illustrate the parts of a single basket.

MAIN LINE: The portion of the gear that is suspended horizontally below the surface of the water is known as the main line. To it are tied the lower ends of the float lines and the upper ends of the branch lines. The length of a single basket of main line varies with the preference of the individual fisherman and may be from 800 to 2,000 feet long.

The main line is prepared by first measuring out sections of cotton, hemp, or Manila line; the number of sections usually correspond to the number of hooks in a basket of gear (Figures 6 and 7). One length of line can be used for the entire main line of a basket, but the handling of such a length is more difficult than is the case where the main line is made up of sections. Then, should the main line kink or twist when being hauled in, the knot joining any two sections may be untied and the gear straightened out in order for it to come aboard properly. Moreover, as occasionally happens, the current will put too much slack in the main line, causing the branch lines to tangle about it. To prevent this, the slack can be reduced by removing from the water a number of sections of the main line without interrupting the fishing operation.

The material most often used for the main line is tightly-woven cotton line of medium to hard lay, with a diameter varying from 1/8 inch to 1/4 inch. The line of larger diameter is generally preferred by a long-line vessel, but some captains, fishing solely for albacore, may utilize the less expensive line of smaller diameter. In addition to cotton line, Nanking hemp (diameter 3/8 inch), Manila line (diameter 3/16 inch), or a mixture of cotton and Nanking hemp (diameter 1/4 inch) have been used for the main line by some Japanese long liners.

FLOAT LINE: The main line is suspended to its horizontal position by float lines, which are attached to floats or buoys. The length of the float line is similar for all baskets on the same gear but, as noted previously, different captains favor different lengths; these lengths may vary from 45 to 125 feet (Figures 2 and 3).

A float line, with a buoy at the top to keep the line suspended vertically and a bamboo flagpole to serve as a marker, is always put on the main line at the beginning or head of each basket. Other float lines may or may not be used to hold the main line of a basket in a horizontal position. This is entirely a matter of preference for the individual fisherman. Using more float lines per basket of gear reduces the sag in the central part of the main line. Thus, by either constructing gear with one or more float lines in the central part of the basket, or without any, it is possible to control to some extent the depth to which the hooks in the center will descend. Many fishermen prefer considerable sag, for the hooks will then fish at various depths.

The material used for the float line is often the same as that used for the main line. However, it is possible to utilize cotton, hemp, or Manila line of slightly smaller diameter than the main line. Old or slightly worn main line may sometimes be used as a float line.

FLAGPOLE: Bamboo poles with a small piece of colored cloth or a tuft of bamboo twigs on the upper tip are used, generally one to a basket, to serve as a marker in indicating the whereabouts of the long line in water. The float line and a buoy are attached to the flagpole in a manner so as to keep the pole upright during the fishing operation (Figures 6-A-1 and 7-A-1).

BUOYS: Three types of buoys are in use--glass, metal, or wood. Glass or metal buoys, with a diameter of 10 to 12 inches, are preferred because of their greater buoyancy and, since they do not become water-soaked, can be used over a long period of time. Floats of paulownia wood, having a diameter of about four inches and a length of three to four feet, are utilized by some vessels. Other vessels may use glass and wood buoys alternately—a glass buoy at the head of the float lines that are attached to the flagpoles, followed by a wood float tied to the float lines in the center of the baskets. A wood float has the advantage in that, if the line is tied to one end of the float, the float will serve as a signal to indicate that there is a fish on the section of the basket below it. The weight of the fish pulls on the float line causing the wood float to stand erect or wave about. This arrangement is especially desirable where the long-line gear should be patrolled at frequent intervals and the fish removed because of the presence of sharks or seals. On occasions when an extremely large fish has taken the hook, its weight pulls the long line down and the buoy with it. In these instances failure to sight a buoy indicates a fish on the line and it is removed.

BRANCH LINES: The lines that do the actual fishing are suspended from the main line at pre-designated intervals. Branch lines are almost always made up in the following order (Figures 6-A-4 and 7-A-4): a length of line, either cotton, hemp, or Manila; a "sekiyama" (cotton wound around a core of ramie, wire, or Japanese hemp); a wire leader; and a tin-plated iron hook. The only exception to this arrangement is that the "sekiyama" and the wire leader are sometimes omitted in long lines designed specifically for albacore fishing. This is possible since the fish taken by such long lines are generally below 60 pounds in weight. The branch line is permitted to hang freely; no lead weight being used to hold it down.

Swivels are often placed at some point along the branch line to minimize twisting when a hooked fish is threshing about.

For the most efficient operation, and to prevent tangling of adjacent branch lines, the distance between two branch lines is greater than their individual lengths. Thus, the longer the branch lines, the further apart they are placed and the fewer the number suspended from the main line.

There is sound justification for the use of a "sekiyama" between the line and the wire leader. Ordinary line is apt to twist and kink when hanging free in the water, whereas the tightly-wound "sekiyama" is rigid and tends to hold the baited hook away from entanglement with the line above it.

For the upper section of the branch line many vessels prefer cotton line, which is of the same or slightly smaller diameter than that of the main line. Nanking hemp or Manila line is occasionally used by some captains. The core of the "sekiyama" is either 30-thread hemp or ramie, or 9-strand wire. Cotton line (usually 3-strand, 9-thread) is wound crosswise about the core. The wire core, although desirable for its strength, has the disadvantage of rusting. The wire leader used varies from 9 to 16 strands, and the tin-plated iron hook, which must be stout in order not to be broken at the shank or straightened out, measures (in its extended length) from $3\frac{1}{2}$ to $5\frac{1}{2}$ inches. It has been noted that some long lines are designed to fish at both shallow and deeper levels. If this is the case, the shorter branch lines are usually constructed with thinner line and wire and with smaller hooks (Figure 6B). There appears to be a correlation between the size of the fish and the depth of the water; the larger fish are taken from deeper levels and the branch lines are accordingly made stouter the deeper they are expected to fish.

TYPES OF LONG-LINE VESSELS

It is possible to operate a tuna long line from most any type of fishing vessel, and many craft designed for other operations will fish with the long line during months that would otherwise be inactive (Figure 10). However, the Japanese have settled on standard plans for constructing long-line vessels that will operate the long-line gear solely (see front-cover photo). The trend in recent years has been to build large vessels, since most of the major tuna operations are carried on at considerable distances from home ports.

Long-line vessels from the most widely used standard classes have the following dimensions:

Category		Length	Breadth	Depth	Horsepower
Construction	Gross Metric Tons*				
		.....	(Feet)	.....	
Steel	195	110.1	21.7	10.7	400
	160	103.5	20.4	10.2	320
	135	97.9	19.7	9.7	250
Wooden	95	81.5	18.1	9.0	210

*The volume of the entire vessel divided by 100 cubic feet.

Vessels of 195 gross tons may operate as many as 200 baskets of gear during a single day's fishing. The smaller vessels handle a correspondingly smaller amount of gear; a 95-gross-ton long liner generally operates in the neighborhood of 100 baskets. The Japanese have recently constructed a few vessels of more than 200 gross metric tons, and these fish up to 300 baskets of gear.

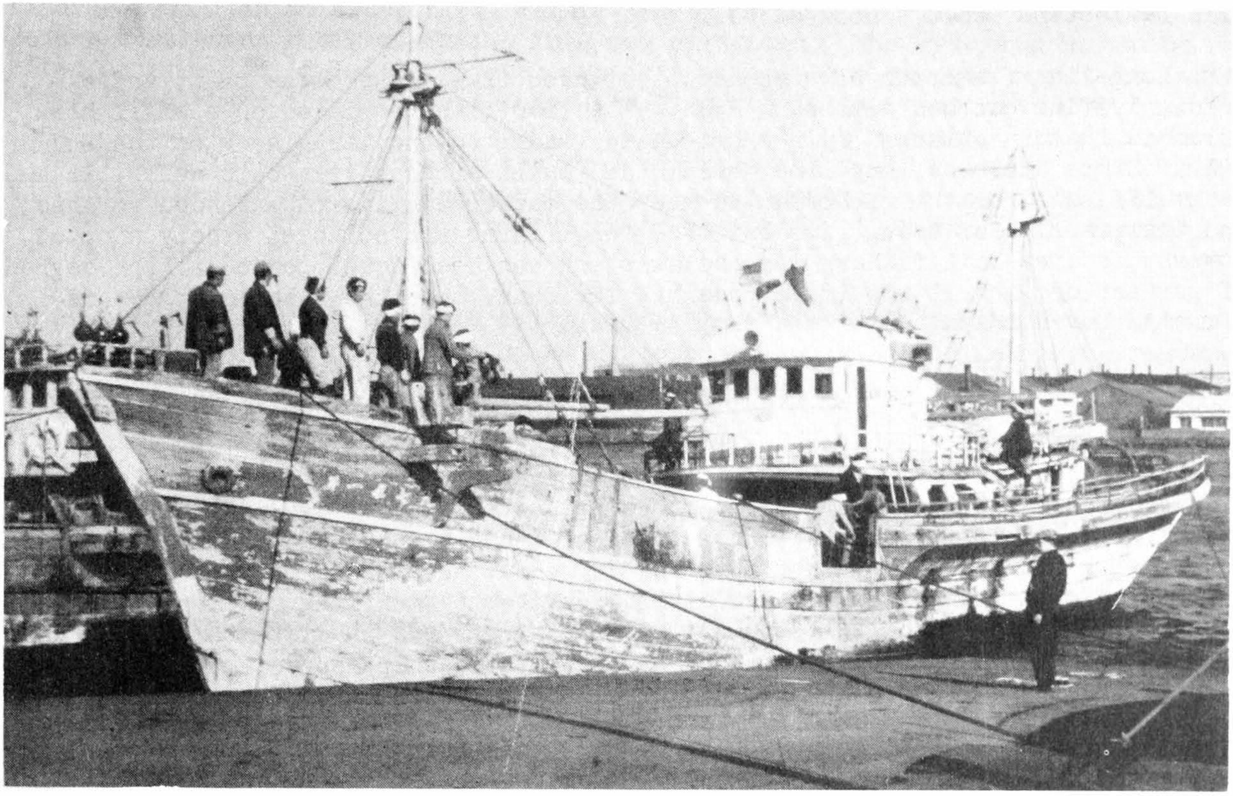

FIGURE 10 - COMBINATION POLE-AND-LINE SKIPJACK AND LONG-LINE TUNA VESSEL. WOODEN TYPE OF 95 GROSS METRIC TONS. DURING THE SPRING, SUMMER, AND FALL, THIS VESSEL FISHES FOR SKIPJACK WITH LIVE BAIT; DURING THE WINTER, FOR OTHER TUNAS WITH THE LONG-LINE GEAR.

For ease of operation in setting or taking up the gear, a long-line vessel is built with a moderately low fore and afterdeck. Since the long line is set out over the aft rail, the afterdeck has sufficient level space for handling the baskets of gear. On the modern-type vessels, hauling in is done by heading into the line so that it comes aboard over either the starboard or port side of the bow, and a low main foredeck facilitates pulling in the gear and removing the fish from the branch lines. A line hauler is placed on the main deck forward of the pilot house near the side over which the line is hauled. Hatches to the cargo hold are on the main deck close to the line hauler. The fish are pulled aboard through an opening in the main-deck rail and bulwark immediately aft of the roller, which is set on the main-deck rail and over which the main line passes into the line hauler. When not in use, buoys, flagpoles, and baskets of line are secured on top of the deckhouse.

BAIT FOR LONG-LINE FISHING

Obtaining adequate bait for long-line operations does not offer the serious difficulties often encountered in the live-bait skipjack fishery. Sardine, anchovy, mackerel, saury, flying fish, cuttlefish, or squid are among the more important of the baits used. Firm, fresh bait is preferred, since it will stay on the hook longest without tearing out. A round-bodied fish is said to be more desirable than a somewhat flattened form, for the latter tends to fall over on its side in the water and does not appear as lifelike as the rounded form. On long voyages, the bait is either frozen or salted. The hooks are generally baited by putting the barbed point through the eyes of the fish. Cuttlefish and squid are placed on the hook by putting the barbed point through the fleshy posterior region and then doubling this point back again through the flesh so that the bait will be fastened to the hook securely.

Long-line fishermen have occasionally used live mackerel as bait, and exceedingly fine catches have been made. The live fish is placed on a small hook, which is in turn attached by a short chain leader to the large hook on the branch line. Since Japanese long-line vessels are built without live-bait wells, it has been difficult for the fishermen to keep the mackerel alive on extended voyages, and the practice of using live bait for long lining has not been widely adopted. However, a live-bait fishery for the skipjack has been developed to a high degree of perfection, and it should be possible for tuna long-line vessels to be constructed for handling bait in a similar manner.

METHODS OF LOCATING LONG-LINE FISHING GROUNDS

The success of the Japanese long-line fishery has been based largely on the ability to locate fishing grounds that are capable of yielding abundant quantities of fish. A period of exploration to locate productive grounds has been necessary since it is impossible to detect by ordinary methods the presence of the far-ranging tunas when they are swimming at subsurface levels in many different parts of a vast ocean. As commercial interests were unwilling to invest the money and effort necessary to locate promising fishing grounds in distant waters, Japanese national and prefectural fisheries organizations sponsored the exploratory phase needed to develop a sizable offshore long-line fishery. Their exploratory vessels compiled and disseminated to the industry a huge amount of data on the catch obtained during their fishing voyages. Moreover, these catch records were correlated with various oceanographic factors, such as water temperature, current drift, and depth of the ocean bed. Commercial vessels were thus given not only the general location of new fishing grounds but also the hydrographic conditions under which the best catches were likely to be made.

A number of the major developments in the Japanese long-line fishery can be attributed directly to exploratory fishing operations by the national and prefectural vessels. The location and eventual exploitation of the albacore grounds nearby Midway Island were almost entirely due to their efforts, and a sizable winter fishery for producing the exportable white-meat tuna was established. In the South Seas, major long-line explorations were under way during the greater part of the 1930 decade, and major fishing grounds, principally for the yellowfin tuna, were located near the equatorial belt of the southwest Pacific. Closer-to-home smaller-scale explorations witnessed the development of the Ryukyu region as a long-line fishing area.

On the basis of their exploratory work, Japanese investigators claim that the tunas caught by the long-line gear are primarily on a feeding migration and it is best to set the gear across the path of movement of the fish or near an obstacle in their path. The migrating tunas tend to follow the course of a current, and the long line can be set where a strong current exists and the tunas are known to be plentiful. However, areas where the tunas are available are more easily located by looking for barriers to movement. Barriers to movement may be an island, a reef, a submerged bank, or a difference in water temperature between two water masses.

Where reefs, banks, islands, or submerged shelves act as barriers to movement and change the direction of current flow, they are often inhabited by a diverse and plentiful assemblage of reef and bottom fish. The voracious tunas, finding such fish an attraction, remain nearby or move alongside these barriers before continuing their migration in a new direction. The Ryukyu area can be cited as a region in which the most productive long-line grounds have been found to be those where the migratory tunas are hindered in their movements by shallow banks, islands, or reefs which change the course of the current. Other productive grounds in the Ryukyu area are located where the shallow waters surrounding the island groups drop off sharply to great ocean depths, as they do to the east and south of the archipelago, for the tunas apparently find excellent feeding alongside these shelves.

Where temperature barriers exist, water currents of different temperatures are present and the colder mass of water acts as a wall into which the warm-water tunas hesitate to enter. The zone of contact between two currents is often irregular and there is much mixing between the cold and warm waters. Places of mixture between currents are considered excellent feeding localities, for the colder waters have a greater abundance of food than do the warmer waters. The migratory tunas, searching for food, can take advantage of the fact that an abundance of pelagic crustaceans and other animals, which comprise a large share of their diet, are swept from the colder waters which they normally inhabit into the warmer waters at the zone of mixture between currents. As they are feeding at these temperature barriers, the tunas can be taken in numbers large enough to make commercial operations feasible.

A Japanese long-line vessel exploring a new region for tuna will set gear where it is able to find obstacles of the type mentioned above. The exploratory vessels look for localities:

1. Where the ocean bed drops off sharply to greater depths or where reefs or banks (either emergent or submerged) are present in an otherwise deep area. Hydrographic maps, which show the contours of the ocean bottom, are valuable aids in locating barriers of the submerged type. Echo sounders have recently come into wide use for exploring areas which are not well charted.

2. Where a strongly flowing current is present or where there are obstacles (reefs, islands, or banks) in the path of a current. In the tropics, the waters near coral banks are considered ideal places for exploratory fishing operations.

3. Where areas of convergence or divergence between two adjacent currents or masses of water are present. These are located by recording water temperatures at surface and below-surface levels.

All exploratory vessels, while moving about, have trolling lines out. The efficiency of catch with trolling jigs is low as compared to the long line. However, some investigators believe that when a few tunas are taken from near-surface levels, they signify the possibility of tunas at deeper levels. This has been found to be applicable along the coastal areas of Japan but does not hold true for the mid-Pacific albacore grounds and other off-shore areas.

After explorations have indicated an area to be suitable for further exploitation, Japanese commercial vessels, partly subsidized by government funds, continue the development of that area. Profitable trips to the newly-located fishing grounds eventually result in intensive exploitation by commercial vessels. The reports of exploratory vessels aid the commercial vessels in that, since the area has already been surveyed, the captain can proceed to the general locality which has been shown to be productive. There, the commercial fisherman follows much the same procedure used by an exploratory vessel, and determines the exact locality for setting out the line as follows:

1. From hydrographic charts, the fisherman can locate submerged banks or ocean bottom which fall away to great depths. The gear is then set out diagonally with the flow of the current (Figure 11) over or beside these barriers.

2. Fishermen often set long-line gear where a strong current is present, especially if an island or a reef is in the vicinity. Floating substances, such as logs and seaweed, serve to indicate the flow of the current. The gear is set out diagonally with the flow (Figure 11) and in a direction away from the island or reef, if any are nearby.

3. The line of contact between cold- and warm-water masses, if one is known to be present in the general vicinity, is located by recording surface-water temperatures. A sharp drop in temperature within a small area indicates a transition zone from warm to cold water, or vice versa, and the gear is set out along this line of contact (Figure 12).

OPERATION OF LONG-LINE GEAR

The long-line gear is almost always set out over deep water, where it would be impractical to anchor it. After remaining in the water for any length of time, the line will tend to adjust itself to current drift. Therefore, in setting out the gear some consideration must be given to the strength or direction of the current. Suppose an area is located that is thought suitable for a long-line operation and the current is flowing at a rapid pace. Theoretically, it would be most desirable to place the line across the current, but the force of the strong flow of water, if the flow is stronger at some points of the current, would put a bow in the line and possibly break it. Accordingly, the fishing vessel starts putting the line down from the strongest part of the current and works out diagonally (Figure 11) towards a weaker portion. Enough slack must be given the line to permit it to adjust to the different forces of the current and also allow the hooks to sink to their proper depth. Since the branch lines are not weighted, the hooks sink slowly, taking from one to one-and-a-half hours to reach their deepest fishing level. Not only does this slow settling permit the flagpoles and floats to adjust to current, but the baited hooks, as they descend, fish all levels of the water from the surface to the greatest depth for which the gear has been constructed. Slack is also necessary when a fish takes a hook; extra weight on a taut line may cause it to snap.

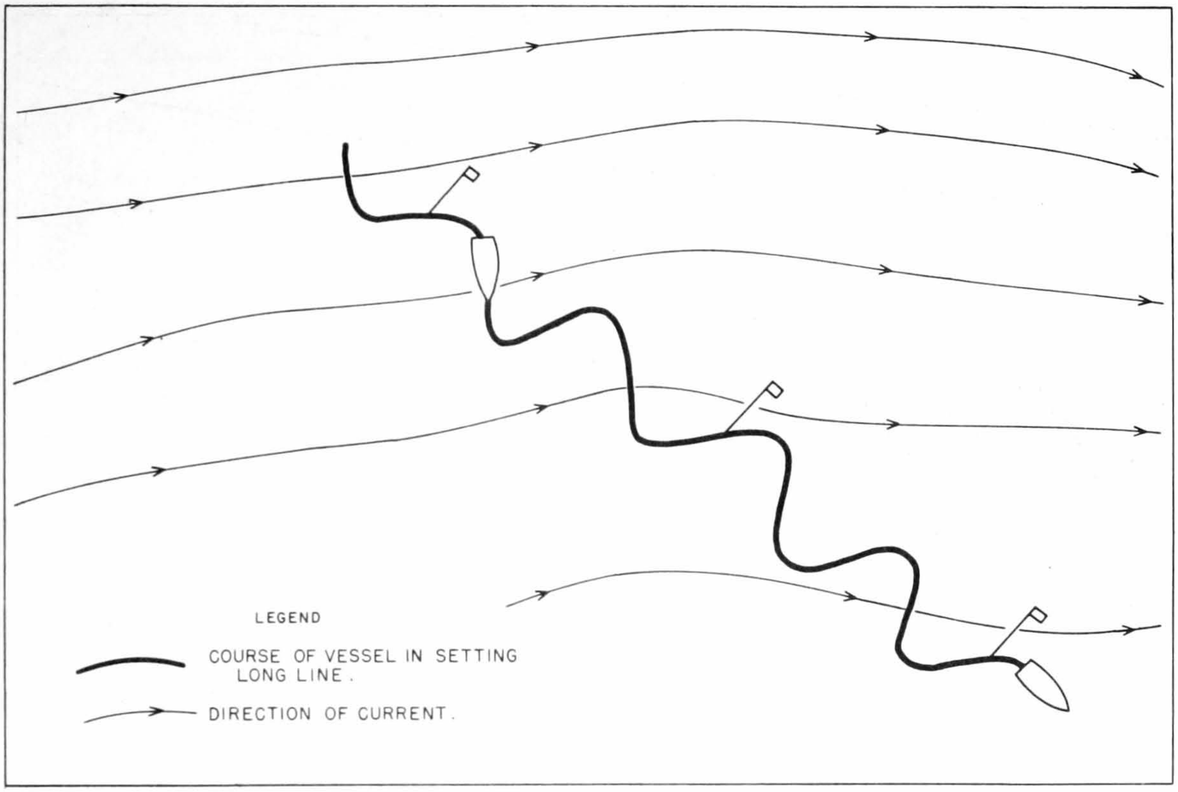

FIGURE 11 - COURSE OF VESSEL IN SETTING LONG LINE WHERE STRONG CURRENT EXISTS. THE LINE IS SET OUT DIAGONALLY TO THE FLOW OF THE CURRENT. CHANGING THE DIRECTION OF THE VESSEL ABOUT EVERY 200 YARDS PUTS SLACK INTO THE LINE AND PERMITS THE LINE TO ADJUST ITSELF TO WEAK AND STRONG CURRENT DRIFTS. SLACK MAY ALSO BE OBTAINED BY RUNNING A DIRECT COURSE (ALSO DIAGONAL TO THE FLOW OF THE CURRENT), BUT THE SPEED IS REDUCED TO TWO-THIRDS THAT USED WHEN A ZIGZAG COURSE IS FOLLOWED.

Slack in setting the long line is obtained by either of the following methods:

1. The vessel follows a zigzag course and changes direction about every 200 yards (Figures 11 and 12). This is the most commonly used method. The speed of the vessel, while the line is being put overboard, is largely determined by the experience of the crew. If the fishermen are exceptionally well-trained and experienced in the handling of the gear, the vessel can be run at full speed. On most of the modern type long-line vessels this is about eight or nine knots.

2. The speed of the vessel is reduced to two-thirds of its normal full speed ahead, and the line is set out with the vessel following a straight course. The gear is placed overboard as quickly as when a zigzag course is followed.

The gear is set out over the stern rail of the vessel (Figure 13). Before the operation begins, baskets of long line are assembled on the after deck. Floats, flagpoles, and bait are placed nearby. The coils of line comprising a single basket have already been arranged so that the beginning of the line and the first float line are at the top, a coil of main line follows, then a branch line (line, "sekiyama," leader, and hook also arranged in a coil), then another coil of main line, a branch line, and so on to the end of the basket of gear. The line is thus ready for quick and routine handling.

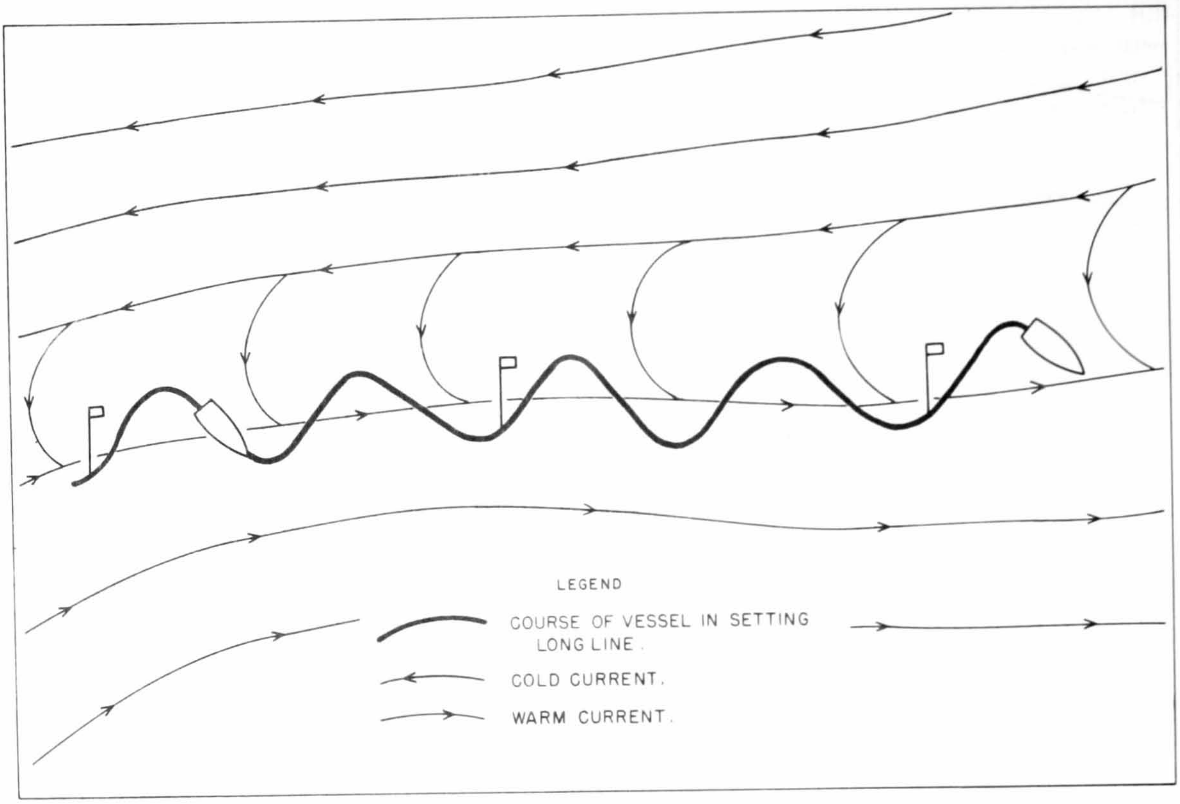

FIGURE 12 - COURSE OF VESSEL IN SETTING LONG LINE WHERE TWO CURRENTS FLOW IN DIRECTIONS OPPOSITE TO EACH OTHER. THE LINE OF CONTACT BETWEEN TWO CURRENTS IS DETERMINED BY RECORDING SURFACE-WATER TEMPERATURES. A SHARP DROP OR RISE IN TEMPERATURE INDICATES A CONTACT AREA, AND THE CAPTAIN ATTEMPTS TO SET THE LONG LINE ALONG THIS CONTACT ZONE. THE ZIGZAG METHOD OF SETTING GEAR IS MOST COMMONLY USED, BUT THE VESSEL MAY FOLLOW A DIRECT COURSE. SLACK IS THEN OBTAINED BY REDUCING SPEED TO TWO-THIRDS THAT USED WHEN RUNNING A ZIGZAG COURSE.

The setting of the line begins with the assembling of a bamboo flagpole and buoy, and their attachment to the head of the float line (Figures 6-A-1 and 7-A-1). Float line, buoy, flagpole, and the section of main line that follows are cast overboard first. The bait handler picks up a branch line from the basket, puts the bait on the hook, and then casts this section of the gear overboard (Figure 13). The next part of the main line is cast overboard, then a branch line is baited and also thrown over. This is repeated until the next float line (if more than one float line per basket is used) is reached; then a buoy is attached (Figure 7-A-6). Attaching the buoys to the float lines and baiting the hooks continues until the end of a basket is reached. The head of the main line of a new basket is attached to the tail of the old basket (Figures 6-A-5 and 7-A-5) and the process of setting is repeated.

In temperate waters where sharks do not bother fish caught on the long line, the gear is set out in the late afternoon and taken up in the early morning. Not only is the efficiency of catch greater during the night than during the day, but, when the weather is warm, fishermen prefer to haul in gear during the morning hours before the heat of the sun makes working conditions difficult. In tropical waters where sharks are abundant and will mascerate a helpless or dead tuna on the long line, the captain sets gear in the early morning (about 3 or 4 a.m.) and takes up in the afternoon. The long line is patrolled continuously during the five to

FIGURE 13 - SETTING OUT THE LONG-LINE GEAR. BAITING OF BRANCH-LINE HOOKS AND SETTING OF GEAR TAKES PLACE OVER STERN RAIL OF LONG-LINE VESSEL. IN THIS INSTANCE, FRESH SQUID ARE BEING USED AS BAIT.

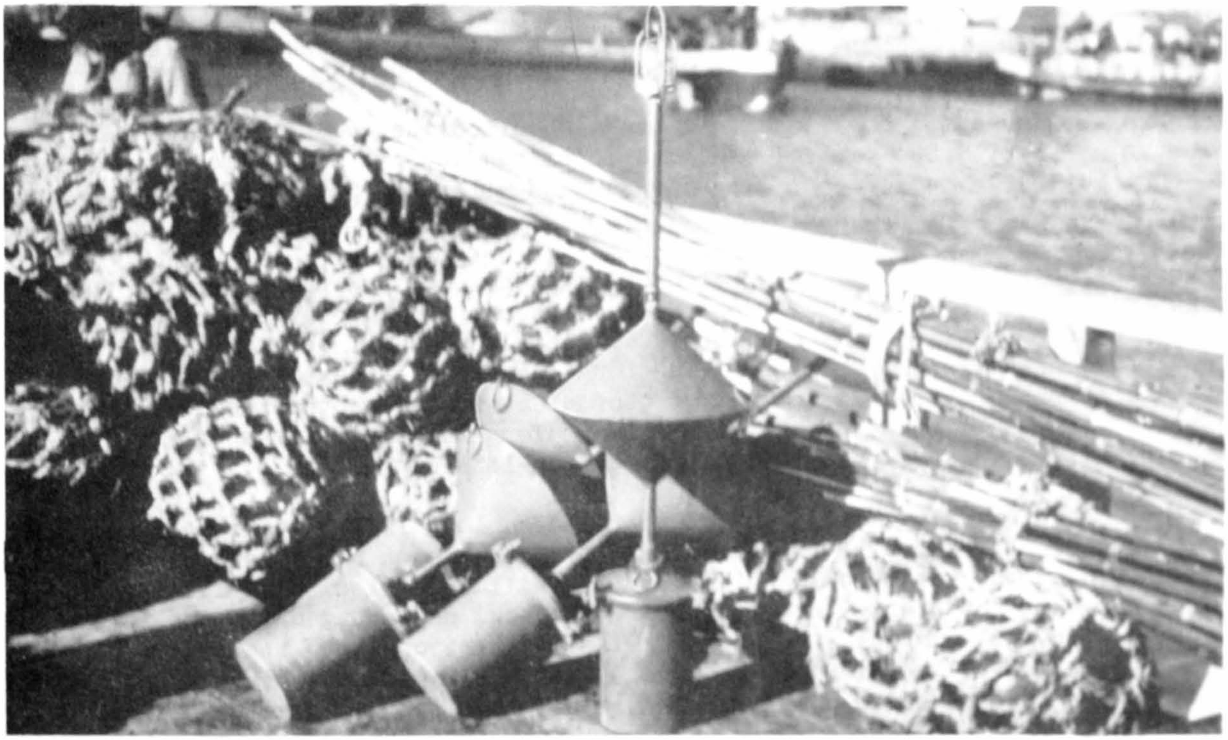

FIGURE 14 - LIGHT BUOYS USED BY LONG-LINE VESSELS. LIGHT BUOYS, IN PLACE OF GLASS, METAL, OR WOOD BUOYS, ARE PUT DOWN AT INTERVALS ALONG THE LINE TO INDICATE THE WHEREABOUTS OF THE GEAR DURING NIGHT OPERATIONS AND TO WARN OTHER VESSELS AGAINST SETTING OUT LINES IN THE SAME AREA.

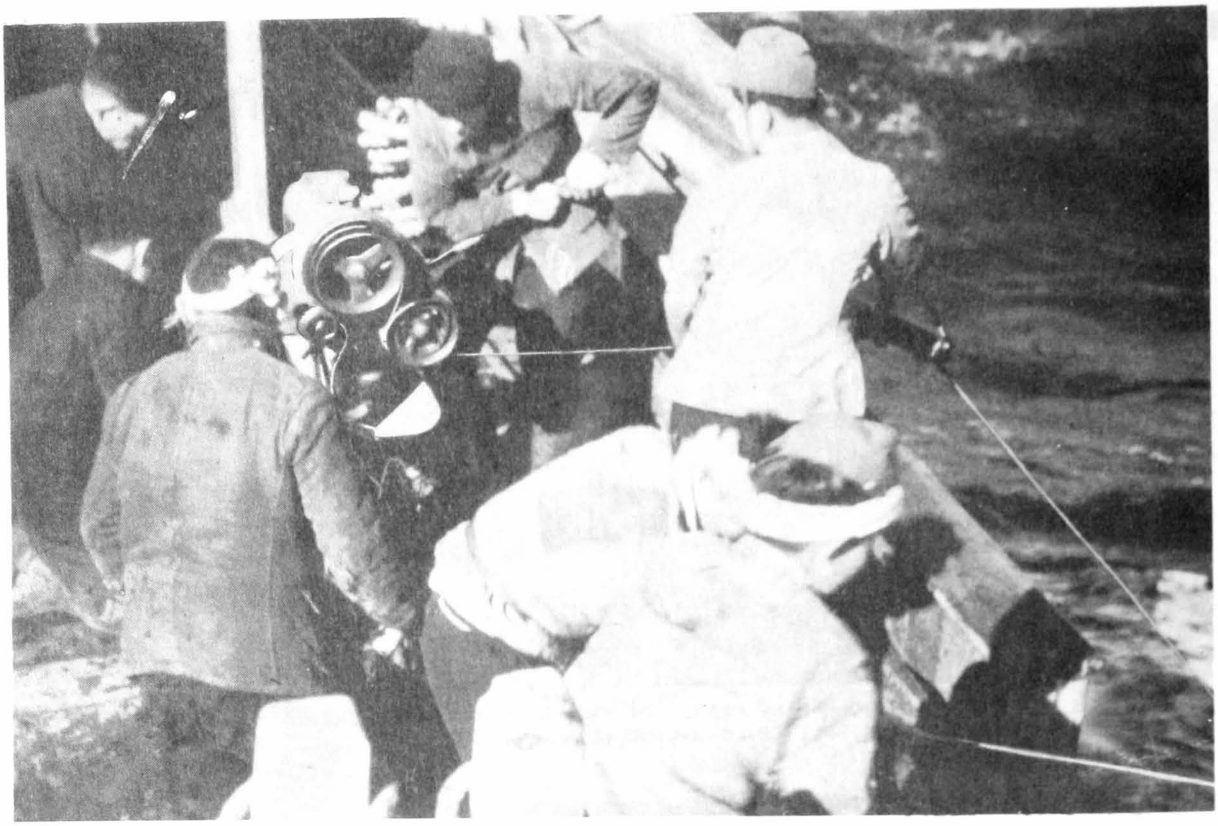

FIGURE 15 - HAULING IN LONG-LINE GEAR. THE MAIN LINE IS SEEN PASSING OVER THE ROLLER INTO THE HAULER. IN THE LOWER RIGHT CORNER, TWO FISHERMEN ARE PULLING IN A BRANCH LINE.

six hours between setting and taking-up and, should evidence indicate that a fish may be on the line, that part of the line is raised and the fish removed. During a 24-hour period, a vessel operating 200 baskets will take 2 to 3 hours to set the gear and 10 to 12 hours to haul in.

Light buoys (Figure 14) in place of flagpoles and glass buoys, may be put out at intervals along the line--generally at the beginning of the first basket, at every third basket, and at the end of the last basket. These lights not only serve to indicate the whereabouts of the long line to the fisherman, if the gear should be taken in when it is dark, but they also warn away other vessels that may put their long line out in the same area. Tangling of two sets of gear creates a wearisome task of untangling for two long-liners.

The most difficult task in the operation of a long line is taking in the gear. Which end of the line is hauled in first depends on the direction of wind and the side of the vessel over which the line will be hauled. The line hauler is set on either the starboard or port-forward deck, depending on the preference of the captain. To prevent tangling the line in the propeller, the vessel heads into the gear on the lee side of the line. As the line is brought aboard, it passes over a roller on the deck rail and is fed into the line hauler (Figure 15). The usual speed of the vessel is about three knots, but the actual speed depends on many factors--the experience of the crew, the water current, the direction of the wind, the running capacity of the line hauler, the number of fish caught, and the difficulty encountered in hauling aboard fish of the largest size. Hauling in is best accomplished if too much strain is not placed on the main line. Thus,

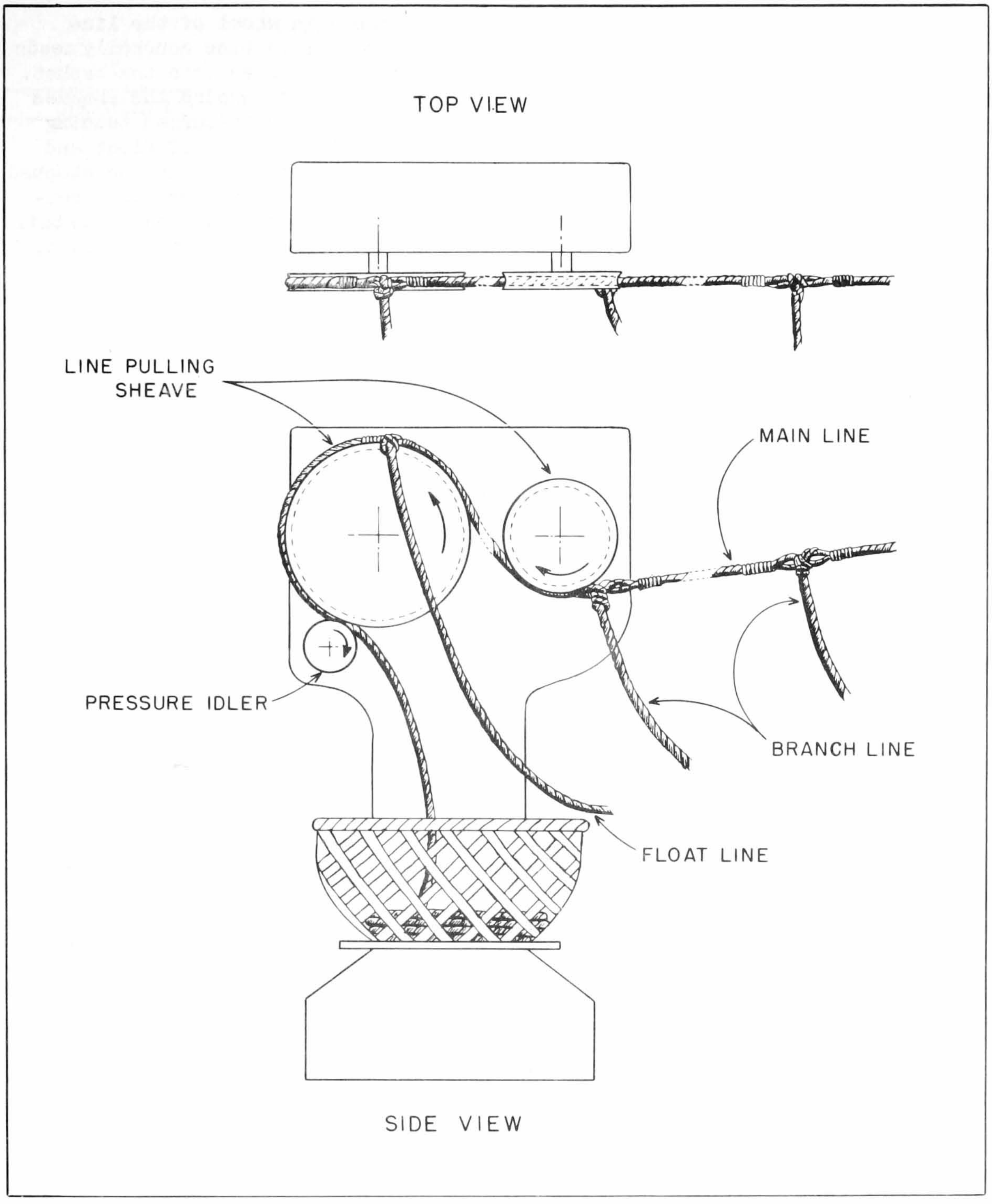

FIGURE 16 - LINE HAULER SHOWING ARRANGEMENT OF SHEAVES. THE KNOTS, ATTACHING FLOAT AND BRANCH LINES TO THE MAIN LINE, PASS AROUND THE SHEAVES WITHOUT BEING UNTIED.

during the hauling-in operation, if a consistent speed is maintained and the crew is experienced, there will be little danger of snapping the line.

As the main line comes aboard and passes over the main wheel of the line hauler, it drops into the basket placed underneath. The main line generally needs little attention at this point, for it tends to coil as it drops into the basket. The junctures of branch or float lines with the main line pass around the sheaves of the line hauler (Figure 16, see page 25). As they do, the fishermen tending the branch or float lines begin coiling them rapidly and the coils of float and branch (including hook) lines are placed in the basket. Hauling in may be stopped momentarily to untangle the line. Otherwise the taking in of the gear is a continuous operation with the crew disconnecting flagpoles, floats, and head and tail of each basket as they are reached. The remainder of the basket of gear (float, main, and branch lines) is recoiled ready for the next operation.

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