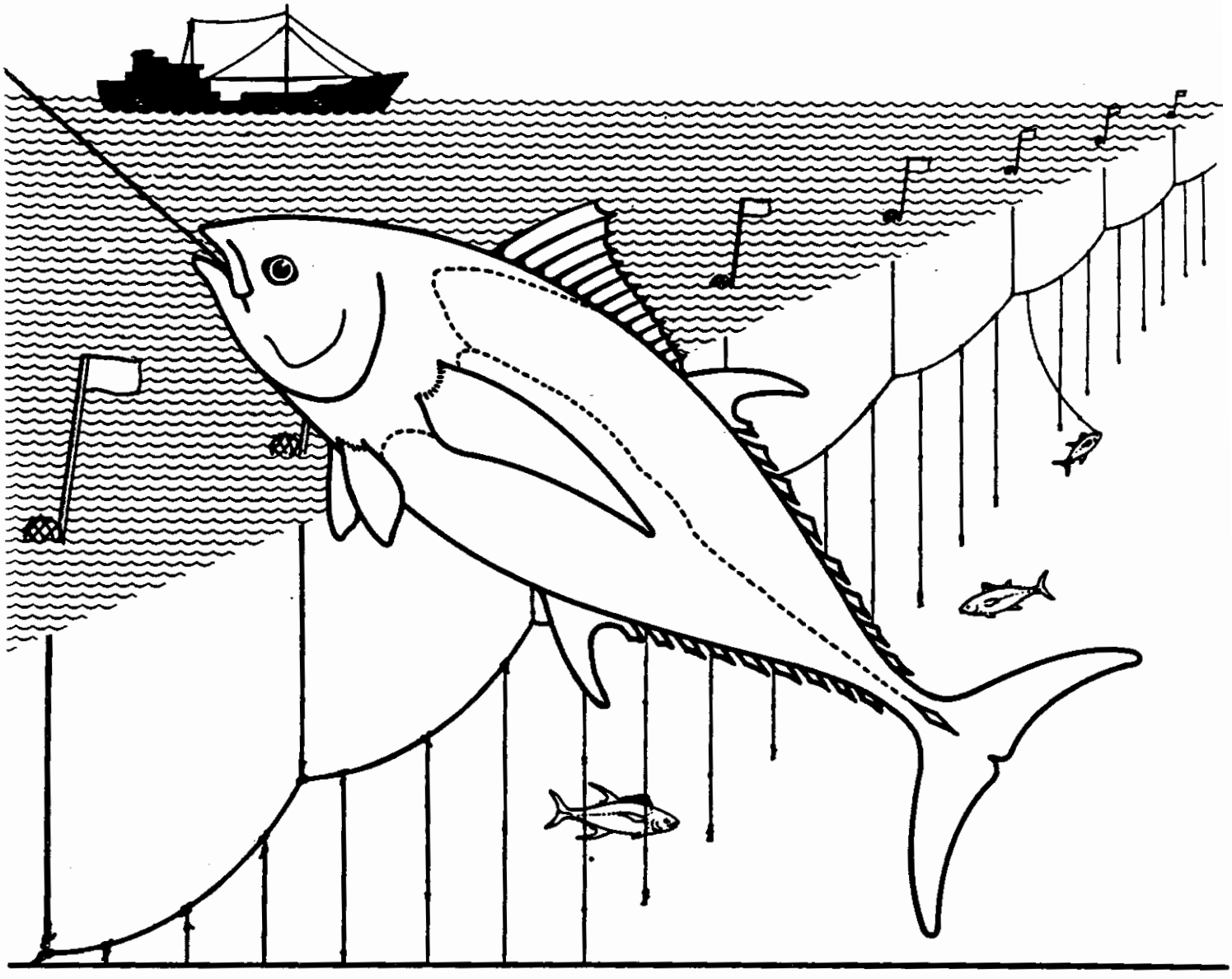
MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

TUNA FISHING



LABORATORY LEAFLET (NEW SERIES) **No. 14**

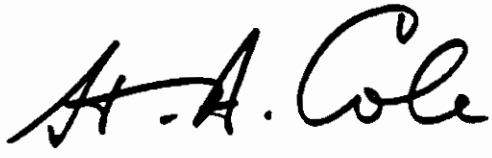
FISHERIES LABORATORY

LOWESTOFT

SUFFOLK

OCTOBER 1966

Tuna constitute the major fishery resource of the open oceans. This summary of existing information by Peter Johnson provides an account of the present state of the tuna fisheries of the Atlantic and of the methods of fishing employed. It has often been suggested that United Kingdom vessels might participate in this fishery; it is hoped that this leaflet will assist in reaching a reasoned appreciation of the prospects.



H. A. Cole

Director of Fishery Research

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Laboratory Leaflet (New Series) No. 14

Tuna fishing

PART I: TUNA FISHERIES - GENERAL

Introduction

There has been a steady increase in the total world catch of tuna over the period 1948-64 (Figure 1). In 1964 the catch amounted to 1 310 000 metric tons*, three and a half times that of 1948, and although tuna at present make up only 3 per cent by weight of the total marine catch it is a very important fishery as far as a few countries are concerned, notably Japan and the U.S.A. These two countries between them contribute nearly 60 per cent by weight of the total catch, and of the Japanese landings nearly 50 per cent are exported canned or frozen.

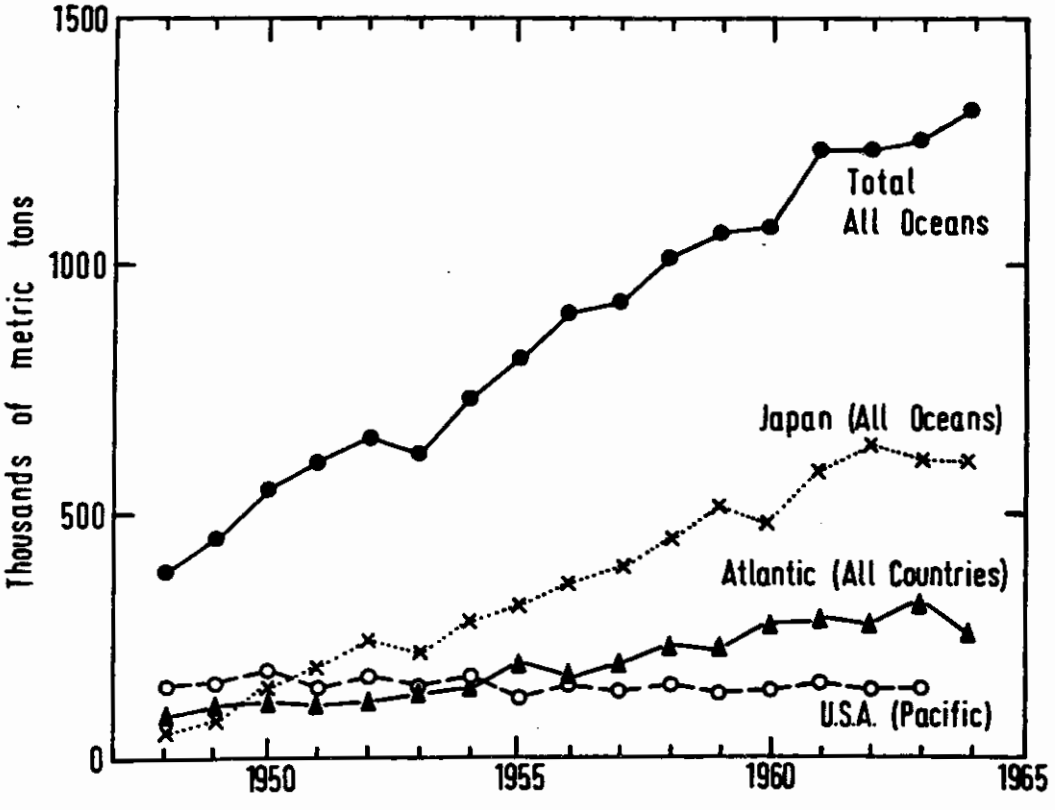


Figure 1 The total world tuna catch since 1948

*A metric ton is 2 205 lb, i.e. a little less than the English ton of 2 240 lb.

This increased tuna fishery has involved large-scale expansion in fleets, areas fished, and development and modernization of gear. The Japanese originally pioneered this fishery and have been largely responsible for its subsequent developments, especially in the field of long-lining operations on the open oceans. Up to 1957 most of the world tuna catch came from the Pacific and Indian Oceans, but in that year commercial exploitation by the Japanese commenced in the equatorial Atlantic region and has developed rapidly (Figure 2). In 1956 the total

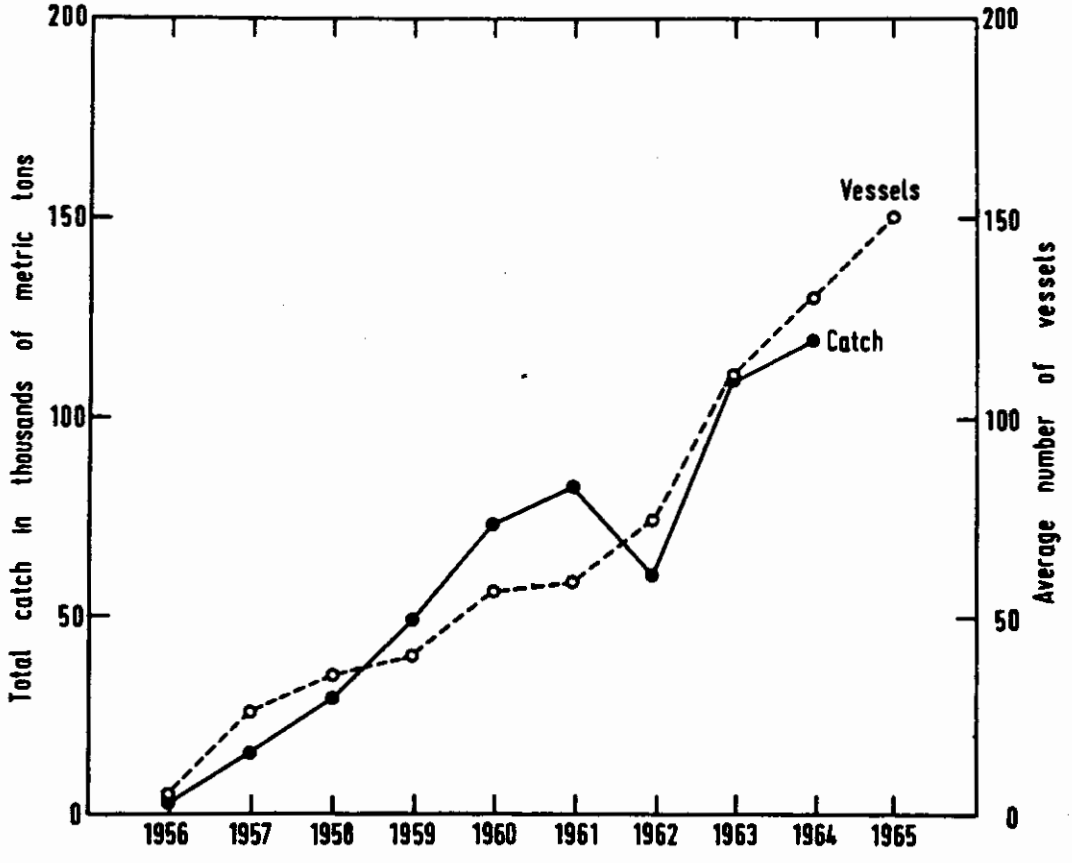


Figure 2 Japanese Atlantic tuna landings (all species) and effort (number of vessels)

Atlantic catch of the larger tuna (bluefin, bigeye, yellowfin and albacore) was only about 82 000 metric tons, but in 1963 it had reached nearly 250 000 metric tons, the increased Japanese effort accounting for most of this rise. The Atlantic now contributes about 20 per cent by weight of the total world catch of tuna and is exploited to nearly the same degree as are the Indian and Pacific Oceans.

Table 1 shows how the Japanese landings of the different species of tuna have varied, depending on their economic desirability; the most sought-after species is the yellowfin, which has therefore suffered most from the effects of fishing. A recent assessment of world tuna resources by the Japanese shows that by 1963 on their main Pacific

yellowfin grounds the stocks had declined to a half or even a quarter of their average level over the period 1952-62, and as fishing effort has continued at a high level since then the stocks may now be even further reduced. The albacore seems to be holding its own on the north Pacific grounds, but elsewhere a downward trend is evident; the Pacific Ocean bigeye catch is thought to have passed its peak yield, and similarly for the southern bluefin, although the bluefin tuna stocks immediately off Japan are thought to have increased since 1960. The present level of the skipjack resources is unknown, these being difficult to assess due to large-scale short-term fluctuations that tend to arise in this species.

Table 1 Japanese tuna landings from all oceans (thousands of metric tons)

	Albacore	Bigeye	Bluefin	Yellowfin	Frigate mackerel	Skipjack
1952	59.7	30.9	14.1	19.4	25.0	85.9
1953	52.0	29.2	17.6	35.9	15.6	72.7
1954	55.9	25.8	19.7	52.9	20.6	99.8
1955	48.4	42.1	23.1	67.7	23.4	99.6
1956	65.8	49.1	36.9	80.9	25.9	98.0
1957	77.7	60.3	34.2	99.5	20.4	97.5
1958	63.2	73.0	21.1	111.5	23.3	147.4
1959	68.2	74.2	51.1	126.4	19.9	166.7
1960	89.1	72.5	65.7	154.0	15.8	78.6
1961	87.8	113.8	70.1	148.1	18.2	144.5
1962	104.6	126.2	47.0	158.1	21.1	170.3
1963	115.5	129.7	63.0	130.9	48.3	112.9
1964	113.2	110.4	59.4	122.0	26.9	167.0

Tuna fishing methods

(i) The Japanese long-line

The long-line when laid consist basically of a continuous length of mainline, supported at intervals by floatlines attached to buffs or glass floats at the surface, from which are suspended branchlines and snoods to which the baited hooks are attached (Figure 3). The mainline, floatlines and branchlines are all made of a tarred synthetic twine ("Kuralon" or "Vinylon") of about $\frac{1}{4}$ inch diameter with a dry breaking strain of around 700 lb and runnage of 24.5 yards per lb. The "sekiyama" is an extension

of the branchline, consisting of a thin steel wire core, covered by tarred Kuralon twine, to which is attached the steel wire snood and hook, the breaking strain of this wire section being about half that of the mainline.

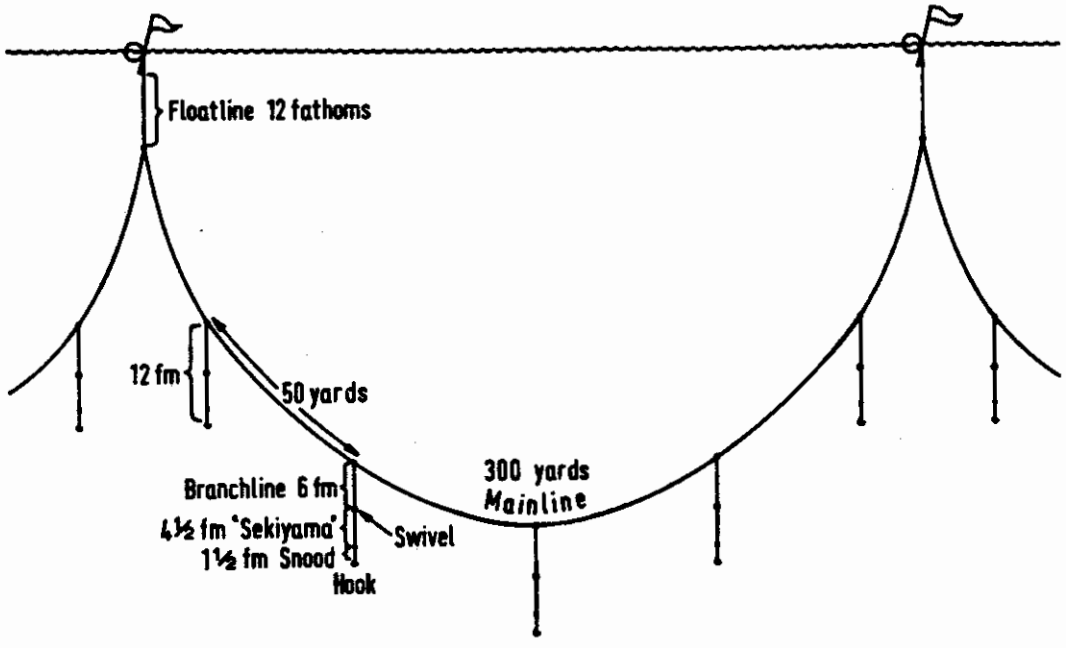


Figure 3 The basic layout and dimensions of one unit or "basket" of a Japanese long-line

The average liner (500 G.T.) will carry between 350-450 baskets of line, fishing between 1 500 and 2 000 hooks per setting. The overall length of this line thus ranges between 63 and 70 nautical miles, although the horizontal distance between terminal buoys when laid will depend on the amount of slack allowed, this being the main method of adjusting the effective fishing depth of the hooks. In practice the laid distance is usually 40-50 nautical miles, with an average of 1 800 hooks fishing, the hooks being spaced at about 50-yard intervals.

The principal bait fish employed is the Japanese saury (Cololabis saira), these being about 10 inches in length with an average weight of $\frac{1}{4}$ lb, which means that about $4\frac{3}{4}$ cwt of bait is required for each set of the line. These fish are kept deep-frozen in small wooden or cardboard boxes until required for use. Other bait species sometimes used are Sardinella, squid and mackerel.

The lines are shot from the stern of the vessel down a chute, about twelve crew members being actively involved, engaged in operations such as connecting the mainline units together, attaching bamboo poles to the glass buoys and their floatlines to the mainline, baiting the hooks, and casting the different components of the line in such a way as to ensure they do not tangle. Shooting takes place at a speed of 8-9 knots,

typically starting in the early morning between 0300 and 0500 hours, and being completed in 4-5 hours. The vessel then lays to for a few hours while the crew rest, and hauling operations usually commence between 1400 and 1500 hours, the vessel heading with the wind slightly on the starboard bow, at a speed of 4-5 knots.

The line hauler, which may be hydraulically driven or run from its own diesel motor, is mounted on the fore well-deck and hauls the line in over a side-roller on the rail at speeds of up to 200-275 yards per minute. It also coils the mainline, and the completed sections ("skates") are transferred back to the stern area by a conveyor ramp system, ready for re-shooting. Depending on the catch, and troubles experienced with line breaks and snarls, hauling operations usually take 10-12 hours, the crew then having a few hours' break before shooting again. About fourteen crew members are involved in the hauling operations on deck, including a winch man, who has a very important role in controlling the speed of hauling so as to avoid undue tensions on the line. Some of the crew are responsible for breaking down the line and stowing its components for ferrying aft, and four men haul the fish inboard, killing them if necessary and removing hooks. Others are employed in gutting and gilling the fish for rapid transfer into either an iced hold or a low-temperature (-25°C) refrigerated compartment.

The usual working day for a crew member totals some eighteen hours, leaving only 4-5 hours for rest, and, as the duration of a trip may be 2-3 months, there is a considerable strain on personnel. Only younger men are able to stand up to this pressure, and by the age of forty most fishermen are finished for this type of work. Wages are not high enough to compensate fully for such arduous work and for such prolonged absences from the home ports (sometimes 14-18 months), and in recent years increasing difficulty has been experienced in finding crews.

The cost of the line, accessories and hauler amounts to about £5 000 (1965 price) and the gear has a life of about 2-2½ years (estimated at 350 operations).

The distant-water long-lining vessels range in size from about 250 gross tons, with thirty crew members, up to vessels of 1 500 gross tons with ninety crew, working two smaller catcher vessels. These are constructed of wood or aluminium, and are 19-20 gross tons and 45-55 feet long, with fish-hold capacities of 6-8 tons; each fishes about 250-300 units of line. Vessels of 1 000 gross tons or more usually carry these catcher boats on the fore-deck, whereas smaller vessels may tow one.

(ii) Pole and line

This method is used to exploit the juvenile stages of larger tuna such as bluefin and yellowfin, and the smaller species like albacore, skipjack, bonito and little tunny. The individual crew members fish with bamboo poles 15 to 20 feet long to which are attached lines a foot or so shorter, and barbless hooks. The hooks are baited either with live-bait (sardines) or with artificial lures such as coloured feathers. Shoals may be located visually when they are feeding near the surface, by the

presence of flocks of sea-birds, and by trolling lines (towed lures). When a promising shoal has been found it is attracted to the vessel by "chumming", that is by throwing live-bait overboard. The tuna are excited into greater feeding activity by hoses spraying water on to the surface, this presumably giving the impression of a shoal of small prey fish milling about near the surface as well as helping to conceal the shadows of vessel and crew which might otherwise scare away the fish.

The vessels engaged in this type of fishing vary in size and design, but all must carry a fairly large crew since angling time is usually limited and the maximum possible number of rods must be worked. Fishing takes place to leeward, this giving the lines greater range and tension, and the crew fish from special outboard platforms rigged along the bulwarks below deck level, a few feet above the water-line. The maximum size of fish than can be handled, unassisted, by a single angler is about 24 lb, but if larger types such as albacore are being fished two anglers work together, the lines from their two poles being joined to a single hook, and this combination can handle fish up to about 42 lb weight; any larger fish have to be brought in with a gaff hook.

One drawback to this method is that large quantities of live-bait must be readily obtainable, sardines being commonly used, and these small fish have to be purse-seined in coastal waters. The amount of live-bait needed to catch one ton of tuna varies between about 1 and 3 cwt, depending on the quantities used for "chumming" and the density of the tuna shoals. The bait is kept alive on board ship in special aerated tanks connected with a seawater circulating system, and these tanks can also serve as refrigerated compartments for the catch when emptied. Smaller vessels store their catch in ice and are limited to trips of relatively short duration, whereas larger ones have deep-freeze facilities for up to 150 tons and can remain at sea for up to one month.

This type of fishing is carried out mainly in Pacific waters by Japanese and American vessels, but has also become more important recently in the eastern tropical Atlantic and Bay of Biscay.

(iii) Purse-seining

This method of tuna fishing was first experimented with and later developed on the Pacific coast of the U.S.A. The introduction of synthetic twines (mainly nylon) and the hydraulically operated power block greatly accelerated development, and from 1958 onwards the original tuna cutters working pole and line gear began to change over in increasing numbers to the new and more efficient method, until at the present time most of the American west coast fleet are purse-seiners.

Although the actual dimensions and details of construction vary somewhat, a typical net operated by a 150 foot vessel is about 425 fathoms (850 yards) long and 42 fathoms deep (a 10:1 ratio of length to depth). It is constructed of monofilament nylon treated with a conditioning agent and has a stretched mesh size of $4\frac{1}{8}$ inches. Lengthwise the net is divided into four equal parts laced together by steel "zipper" rings

through which passes a nylon zipper rope, which provides a means of splitting the net into separate bags if the catch is very heavy. About 7 000 plastic floats are threaded along the nylon "corkline" in groups of eight, spaced 10 inches apart. The lower "leadline" is made up of a continuous length of 7/16 inch chain hung by every fourth link. Further bights of chain are attached at intervals, to which are linked the purse-ring bridles holding the 10-inch diameter purse-rings, through which passes the purse-line. This is made of $\frac{5}{8}$ inch stainless steel wire. The cost of such a net is around £17 000 (1965 price).

Purse-seiner vessels have the wheelhouse and accommodation well forward, with a good clear after-deck on which is mounted a turntable from which the net is shot. Heavy-duty masts and derricks are required for mounting the power block, for brailing, and for handling a powered launch, which is usually stowed on top of the net on the turntable. A special three- or four-drum purse-seine winch completes the deck equipment.

Fish are located mainly by visual signs, such as the presence of sea-birds, porpoises and whales and the splashes produced by feeding tuna, which can be seen up to five miles' distance. Most vessels carry a special "crows' nest" to hold a look-out, and recently experiments have been carried out using a towed hot-air balloon with an observer. At night tuna shoals can sometimes be detected by the use of a high-powered spotlight which stimulates the fish into increased activity, so producing phosphorescence in the water.

Setting operations

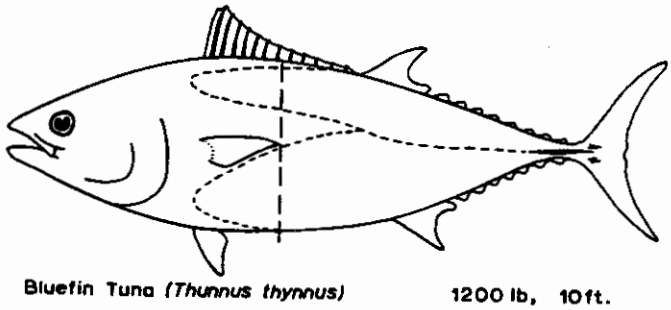
The powered skiff is launched from aft, taking one end of the net and purse-line with it. Once the skiff has been let go the drag pulls the net off the turntable, the speed at which it flakes out being controlled by a brake on the purse-line winch drum. The net is usually shot at nearly full speed, this being kept as constant as possible, since changes in the engine revolutions tend to disturb the fish. If the net becomes fully paid out before encirclement is completed, a gap is left through which fish could escape, and various methods are used to prevent this. The most effective are small explosive charges detonated underwater; others involve hammering on a steel plate fixed to the ship's rail or using underwater flashing lights.

Hauling operations

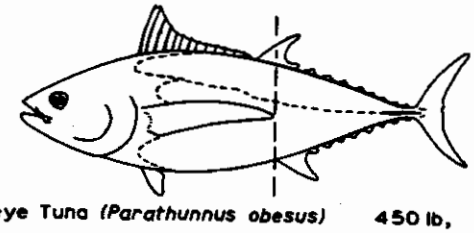
After the set is completed the skiff hands over its hauling line and net end, and patrols the open end of the net until it is closed. It then leaves the net and attaches a towing line to the vessel's starboard side to hold it square to the net and prevent it being pulled into the purse during hauling operations.

The purse-line is winched steadily in until the purse-rings are drawn together and begin to come out of the water. A hoisting line is then attached which hauls up the end of the net to the block, the purse-rings being raised and brought inboard. Next, the purse-line is

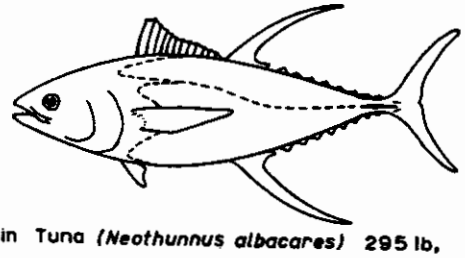
withdrawn from the rings and the net heaved up over the power block, while the purse-rings are released in sequence over the block and restrung with a line in the correct order for resetting. The net is then hauled in and stacked until the enclosed area is at a minimum, when the skiff comes alongside, picks up the corkline and forms a pocket of net into which the fish are driven by further hauling of the net. Finally, the fish are brailed from this pocket and dumped into chutes connected to fish storage tanks. The fish are refrigerated in a brine-immersion system, where they are eventually reduced to a dry-storage temperature of about -12°C.



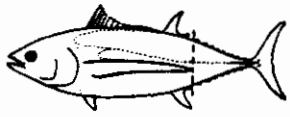
Bluefin Tuna *(Thunnus thynnus)* 1200 lb, 10ft.



Bigeye Tuna *(Parathunnus obesus)* 450 lb, 6ft.



Yellowfin Tuna *(Neothunnus albacares)* 295 lb, 5ft 6in.



Albacore
(Germo alalunga) 55 lb, 3ft 6in.

Atlantic Little Tunny
(Euthynnus alletteratus) 20lb, 3ft.

Skipjack
(Katsuwonus pelamis) 15 lb, 2ft 6in.

Atlantic Bonito
(Sarda sarda) 15 lb, 2ft 6in.

Frigate Mackerel
(Auxis thazard) 9 lb, 2ft.

Figure 4 The relative sizes of the eight species of tuna found in the Atlantic

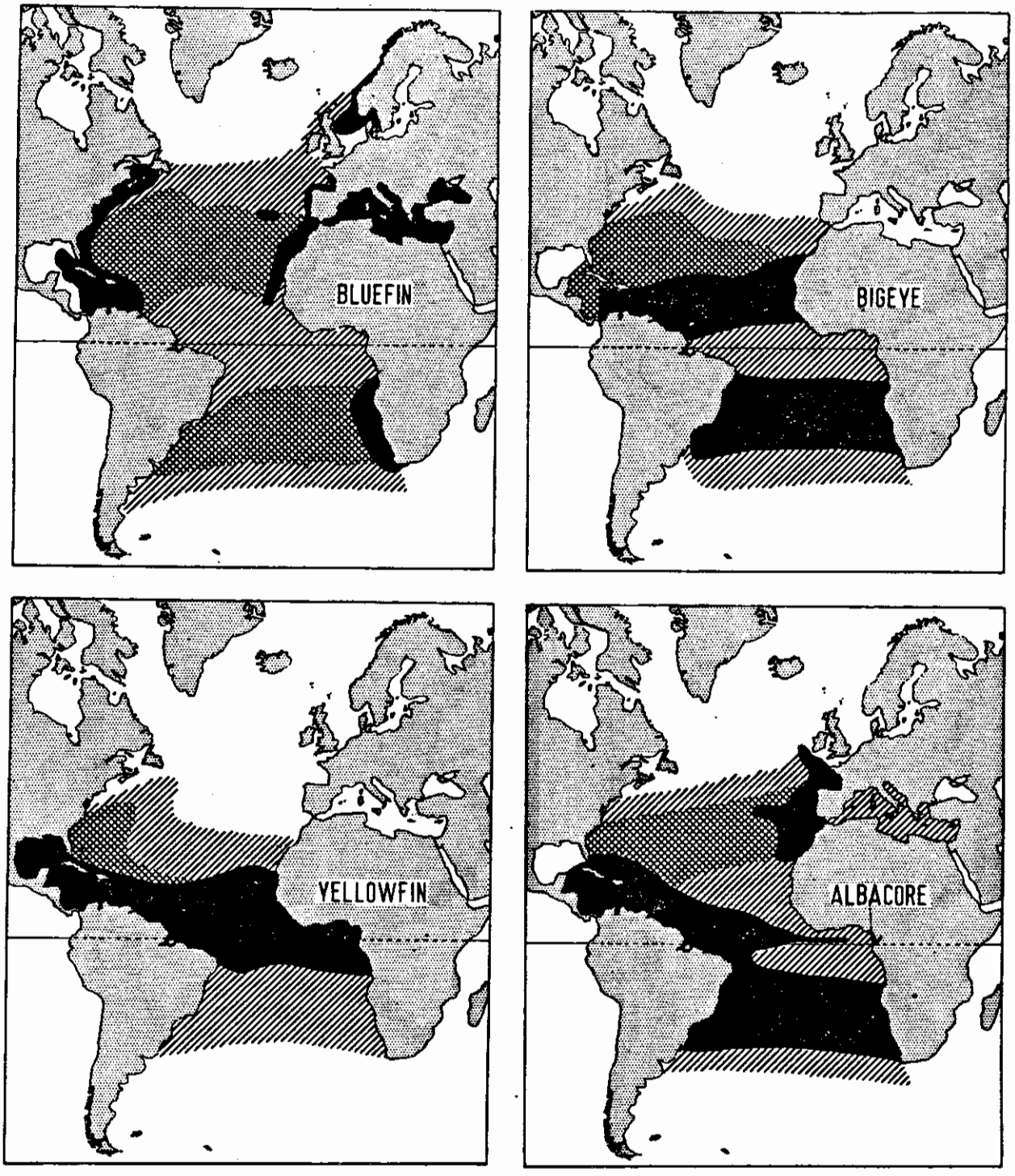


Figure 5 The distributions of the eight species of tuna found in the Atlantic

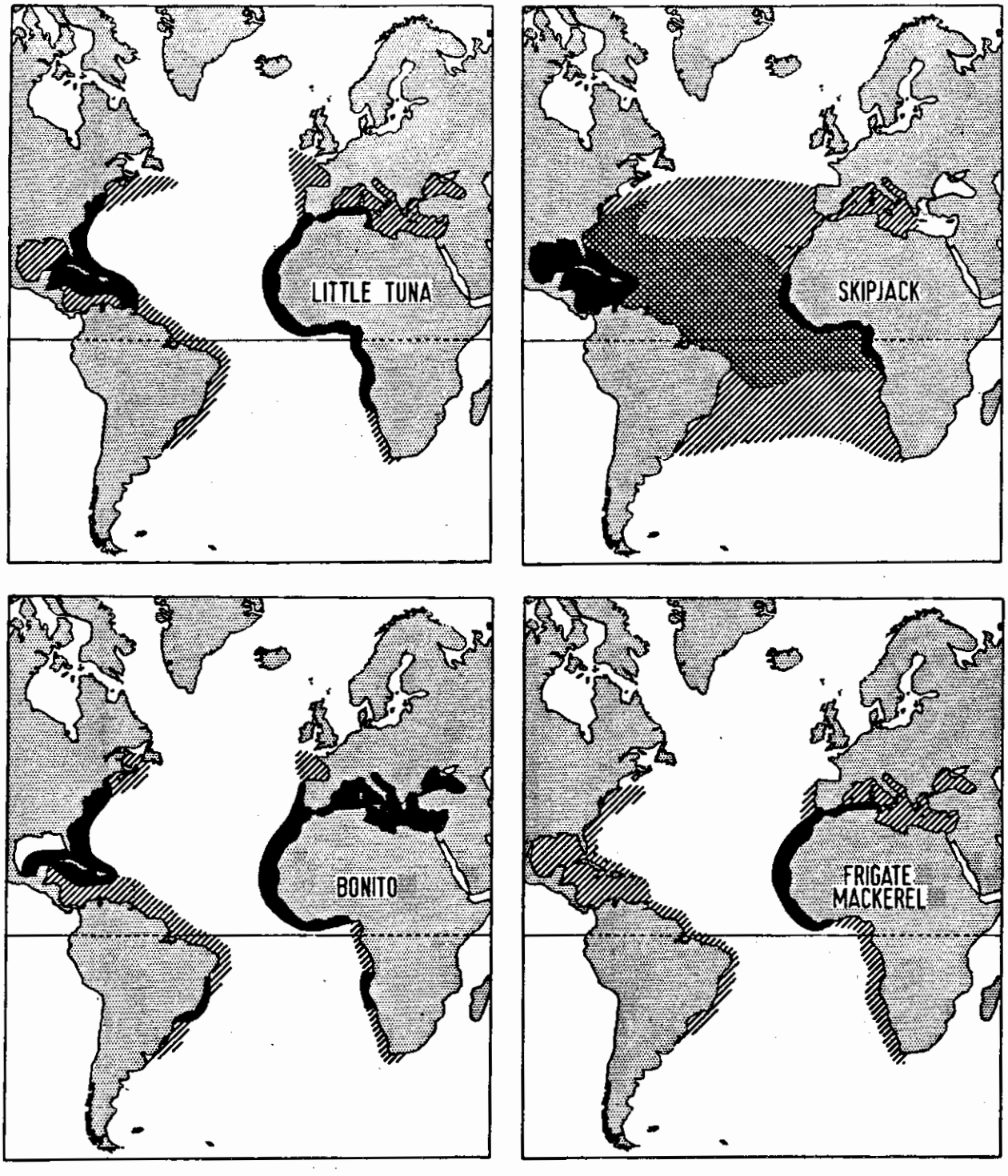


Figure 5 (contd.)

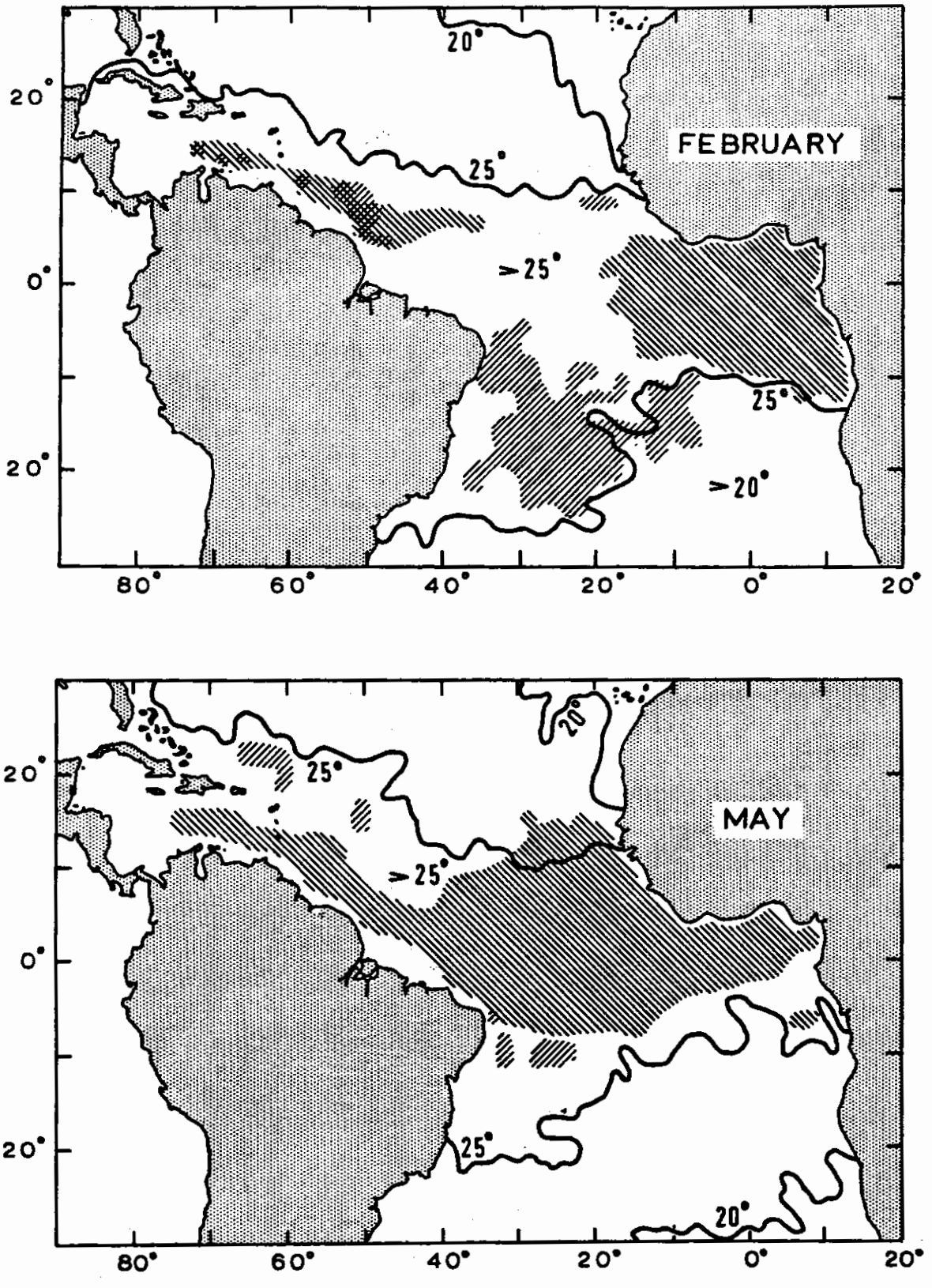


Figure 6 Outline of the main Atlantic fishing areas for yellowfin (in red) and albacore (in black), by seasons

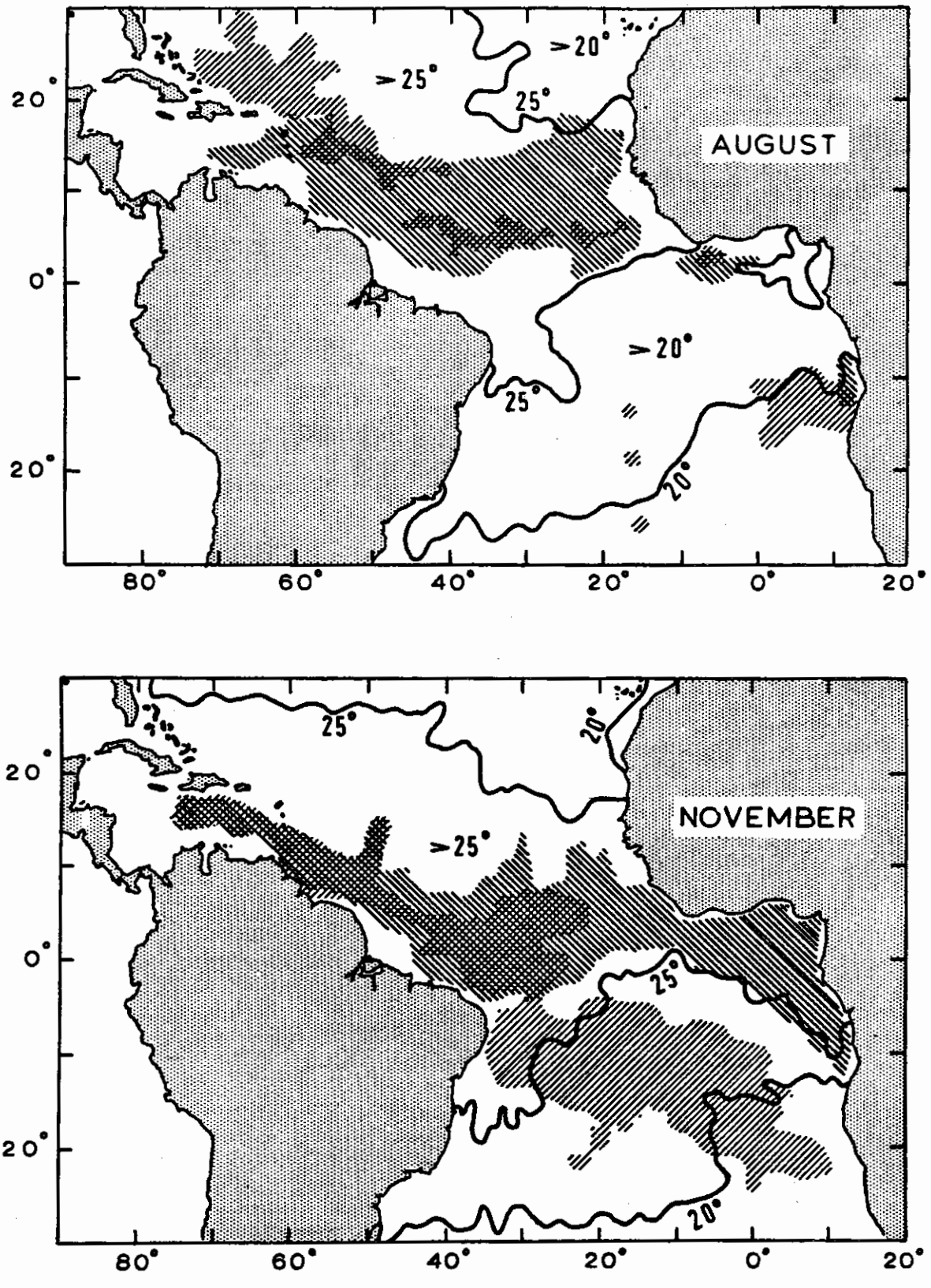


Figure 6 (contd.)

PART II: THE ATLANTIC TUNA FISHERIES

Introduction

Tuna are surface-living fish, usually associated with tropical and sub-tropical seas; for example, the yellowfin and skipjack are found mostly in waters where the surface temperature does not fall below 20°C throughout the year, although species such as the albacore and bluefin migrate into temperate waters during summer. The Atlantic region possesses a number of species of commercial importance, which may be grouped into two general size categories; the first include the larger fish such as bluefin, bigeye, yellowfin, and albacore (Figure 4). The second size category includes a group of species which rarely exceed 3 feet in length and 20 lb in weight, these being the Atlantic little tunny, the skipjack, the Atlantic bonito, and the frigate mackerel. Figure 5 shows the general distributions of these species in the Atlantic area. It will be noted that all the first size category and skipjack from the second group have transoceanic distributions, whereas the remainder are restricted to the vicinity of the continental shelves. The black areas on these charts represent regions where most of the present commercial exploitation takes place, the next density of shading represents regions where the temperature should be suitable for the species but fisheries have not yet developed, and the lightest shading shows areas where the fish are not common or are met with only during seasonal extensions of their range. Tuna are, however, very mobile and, even within the areas where they are most commonly found, they can be very unequally distributed throughout the year. Considerable seasonal movements (both north-south and east-west) take place, usually associated with feeding and spawning activities, which lead to localized areas of high density, often lasting only a short time in any given area.

Temperature requirements basically limit the distributions of these fish, the lower limits of tolerance being greatest for bluefin (about 12°C) and least for yellowfin (about 18°C). Yellowfin tend to be most abundant in waters where the surface temperature ranges between 25° and 27°C; in the eastern Atlantic their abundance is highest in the Gulf of Guinea-Angola region during the southern summer (January-March), after which there is a gradual shift to the north-west, with a zone of high density between the Cape Verde Islands and north-east Brazil over the period June-August. Figure 6 shows the distribution of yellowfin and albacore in four "key" months (February, May, August and November) when the fishing grounds are fairly well defined at their extreme northern, southern or intermediate positions.

Tuna are basically shoaling fish, although the numbers in a shoal tend to decrease the larger the fish become. Young bluefins, for example, may build up shoals containing many thousands of fish, whereas shoals of large adults would only exceptionally number a few hundred. Larger aggregations of adults may take place for spawning, although when these larger tuna are actively migrating to and from spawning and feeding grounds they travel in quite small groups. Aggregations may also build up at environmental boundaries such as marked horizontal temperature

gradients or "fronts", examples being along the edge of the Gulf Stream and in the Gulf of Guinea-Angola region, or where "pockets" of warmer water intrude into colder water areas. Tuna often aggregate in regions favourable for the production of prey species; these are typically along the continental shelves, or where oceanic currents meet or divide, or at counter-current boundaries, in the vicinity of islands or submerged sea mounts, and near continental headlands. Vertically the distribution of the fish is limited by the position of the thermocline (a zone of rapid change in temperature), which in tropical waters is typically from 38-55 fathoms below the surface, the temperature at this depth range showing a rapid drop of several degrees; usually with a surface temperature of 25°C the temperature falls from 18° to 15°C through the thermocline region.

Until 1957 the commercial exploitation of Atlantic tuna was mainly confined to the Black Sea, the Mediterranean, Iberian waters, the Bay of Biscay, the North Sea and the Norway coast, with a minor amount of fishing on the American continental shelf and in African equatorial waters between Senegal and Angola. Up to that time the total Atlantic catch never exceeded 100 000 tons per year. The Japanese long-lining effort in equatorial waters then began to build up and has since increased steadily; in 1963 this fleet alone took over 100 000 tons of the larger tuna (mainly albacore, bigeye and yellowfin). In more northern waters the main species fished are the bluefin, albacore and bonito. The relative importance of these species in the north-east Atlantic region can be judged from Table 2.

Table 2 Annual catches in the north-east Atlantic tuna fisheries (average for 1948-64)

	Metric tons
Albacore	
France and Spain	36 100
Bluefin	
West Mediterranean	3 900
Morocco Atlantic Coast	4 100
Spain and Portugal	12 400
Bay of Biscay	2 300
Norway-North Sea	6 100
Total	28 800
Bonito	
Eastern Mediterranean (mainly Turkey and Greece) (1953-63)	29 900
Spain, Portugal and Morocco	8 200
Frigate mackerel and little tuna	
Spain	3 400

The fisheries off the European and African coasts

(i) Bluefin

In the north-~~west~~ east Atlantic the bluefin tuna spawns mainly in the western part of the Mediterranean in May-July and at this time is caught by "madrague" nets along the southern coasts of Portugal and Spain, the North African coast from Morocco to Libya, and around Sicily and southern Italy. These nets consist of a long series of rectangular walls of netting, sometimes extending several miles out from the coast, which intercept and deflect shoals on their spawning migrations along the coast into a series of net chambers leading finally into a "death chamber". This has a no-return entrance flap and a bottom which can be raised to bring trapped fish near the surface for gaffing and removal. A well-sited madrague can catch up to 14 000 large tuna per season.

After spawning large numbers of bluefin leave the Mediterranean - the older and larger fish spawning earlier and leaving first towards the end of June - travelling via the Straits of Gibraltar into the Atlantic. A good proportion of them then head north, and it is thought that they follow the continental shelf to the west of Ireland and then swing east between the Faroes and Shetland, arriving off the Norway coast during July between latitude 62 and 63°N. These fish then travel north to the Lofoten Islands or even further in some years, some having been recorded as far as Murmansk. Some of these older fish (11-14 years old) also appear in the North Sea and Skagerrak during August. Medium-sized tuna (8-10 years old) arrive off Norway several weeks later and these tend to swing south into the Skagerrak, Kattegat and North Sea, where they arrive in late August and September in most years. The youngest fish (5-6 years old) arrive on the Norway coast about mid-September, replacing the medium-sized group in this region. An analysis of the timing between peak catches of different size-groups of tuna in the Spanish madragues and the arrival of similar size-groups on the Norwegian coast has shown a time-lag varying from under two weeks to five weeks, thus providing an estimate of the migration time between the two areas. It has been suggested that variations in migration time are related to weather conditions along the presumed migration route, southerly winds reducing, and northerly winds increasing, its duration. The tuna leave northern waters during October, when the surface water temperature in the North Sea drops below 12°C, and it is assumed that they then return south for the winter, as they turn up again in April-May heading back into the Mediterranean through the Straits of Gibraltar.

A similar movement of fish takes place off the North American continental shelf each year, where the main spawning grounds are situated in the Florida-Cuba-Bahamas region. These fish move as far north as Nova Scotia and Newfoundland in the summer months, but even more remarkable is the fact that some of them make a transatlantic crossing into European waters. Methods of tagging tuna with small dart- or harpoon-type tags have been in use for a number of years, and many of the larger tuna caught in the sport fishery off Florida have been tagged in this manner by co-operative fishermen. The first evidence for this transatlantic migration came in 1959, when in the Bay of Biscay French fishermen caught two

bluefins which had been tagged as young fish on the Massachusetts coast in 1954. Then in 1961 two bluefins tagged near the Bahamas in early June were recaught in late September and early October respectively on the Norwegian coast north-west of Bergen, having covered more than 4 000 miles in 118 days, thus averaging about 34 miles per day. These tuna were very lean, emaciated specimens of a type frequently turning up in Norwegian waters later in the season and known locally as "long-tailed bluefin".

Tagging has also provided evidence for the movements along the Norwegian coast, between Norway and Spain, and between the south Atlantic coast of Spain and Mediterranean waters.

The summer northwards movement of bluefin tuna seems to be a feeding migration, since during their three-month stay in northern waters they increase their body weight by an average of 10 per cent, feeding on herring, mackerel and sometimes even salmon.

The bluefin tuna has been a regular visitor to the North Sea at least since 1911, when they were first noted in numbers by herring fishermen; small fisheries from Sweden and Norway developed in the Skagerrak and Kattegat during the first world war. Bluefin were first reported off Tromso in 1921, and from 1922 onwards they were more frequently observed in the North Sea (mainly in deeper waters north of the Dogger Bank) until in the 1930s they became sufficiently numerous off the Yorkshire coast to give rise to a sport fishery based at Scarborough. The British record rod and line catch was made in 1933, when a specimen weighing 851 lb was captured off Whitby.

On the Norwegian coast up to 1948 tuna were caught principally by lines and hand harpoons, but only in small quantities of around 200 tons per annum. In the 1920s first experiments were made to construct purse-seines of sufficient strength and still manageable size to catch these fish, but it was not until the late 1940s that a design was perfected which led to a rapid increase in the Norwegian landings. Between 1946 and 1950 the average annual catch was only about 1 000 tons, whereas from 1951 to 1955 it rose to around 9 000 tons, with a record 11 400 tons in 1952. Subsequently, however, there has been a marked decline in the fishery, due mainly to a lack of recruitment since 1958 (the fish are usually 5-6 years old when they first appear in northern waters). The fishery takes place mainly within 4-8 miles from the coast, although fish have been observed at times up to 50 miles offshore. The usual length of fish in the catch ranges between about 5 and 9 feet, with weights of between 150 and 800 lb.

Other nations exploiting the bluefin in northern waters are Sweden, Denmark and Germany. The German fishery takes place mainly in the central North Sea on the Fladen ground and around the Dogger Bank; it lasts three months, commencing in August, reaching a peak in September, and ending in October. The average size of fish caught is between 7 and 9 feet, with weights of 400-800 lb. Compared with the Norwegian effort, this fishery is only a relatively small-scale affair averaging a few hundred tons per year; it has shown a comparable decline since 1959 and

there is evidence that the same stock is being exploited. The fishery is carried out by small cutters, mainly from Bremerhaven and Cuxhaven, fishing 5-6 baited hooks per boat, each hook being attached separately to a buff floating at the surface; the usual fishing depth of the hooks is 11-14 fathoms. Fresh herring, mackerel or whiting are used as bait, and in recent years "chumming" with bait, to attract tuna to the vessels, has become a common practice.

The French carry out a fishery in the Bay of Biscay between May and October for the younger bluefins (mainly 3- to 5-year-olds, which rarely appear in more northern waters). The principal methods of capture employed are either surface trolling, with 5-6 lines using baited hooks or artificial lures trailing from long poles on each side of the vessel (although this method has become less important in recent years), or pole and line fishing with live-bait, which has now become the most important method. The fish taken are mainly between 2 and 4 feet in length and 20-60 lb in weight. Trolling for even smaller bluefins takes place off the west coast of Portugal, mainly between September and November, these being between $1\frac{1}{2}$ and 3 feet in length and probably mainly 1- and 2-year-old fish.

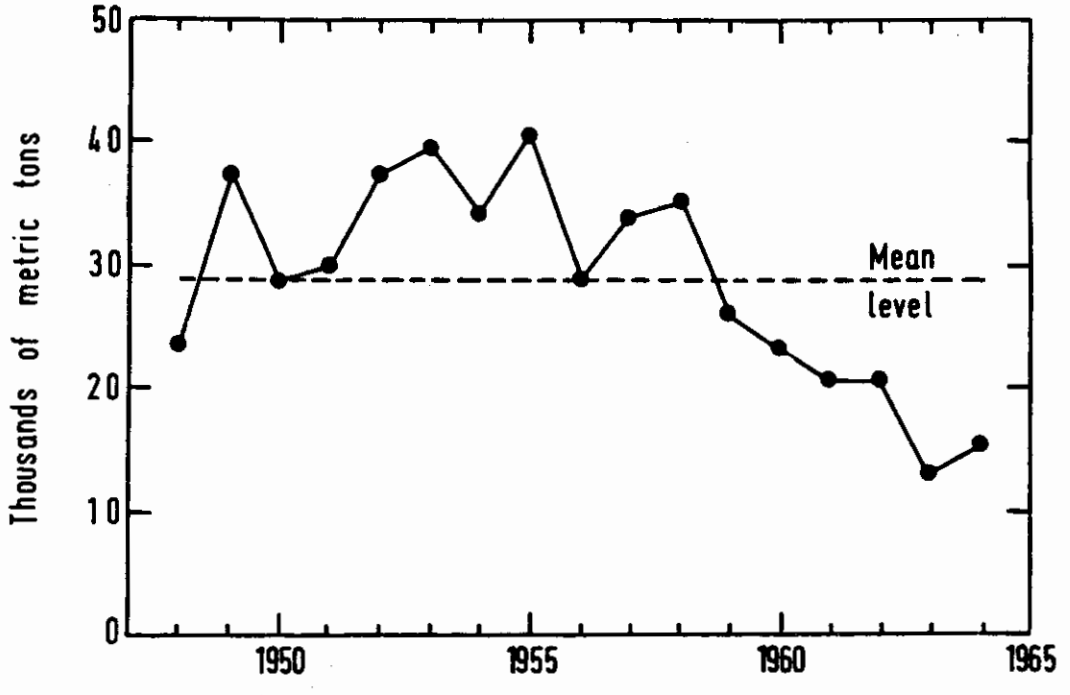


Figure 7 Total north-east Atlantic bluefin catches

Although the north-east Atlantic and Mediterranean catches of bluefin have shown an overall decline since 1958-59 (Figure 7), an opposite trend has taken place along the eastern seaboard of North America since 1961. This has been primarily due to the introduction of purse-seining on an increasing scale, with more long-lining for swordfish, which has brought in tuna as a by-catch. Prior to these recent developments the north-west Atlantic catch only averaged a few hundred tons per year, these fish being

captured by a variety of methods such as harpoon, shore-line traps, sport fishing and long-lines, whereas in 1964 the purse-seine fishery alone (U.S.A. and Canada) took about 4 450 tons of bluefin, the total catch by all gears rising to nearly 7 000 tons.

As mentioned above, tagging experiments suggest that the north-west and north-east Atlantic stocks are not entirely isolated, at least as far as west-east interchange is concerned. Also, comparison between the age-composition of the bluefin stocks on both sides of the North Atlantic shows certain similarities in the relative strengths of year-broods, e.g. the 1950 and 1952 broods were abundant on both sides of the Atlantic, and tagging results show that at least part of the 1952 brood split off and crossed the Atlantic. There is thus some evidence that the size of the European population may in some measure be influenced by the size of the American north-west Atlantic stock. However, the recent increase in bluefin landings along the Atlantic coast of North America cannot have contributed towards the decline in the European fisheries, since the American fishery (primarily by purse-seine) developed after a clear downward trend had become established in the north-east Atlantic catch (1959 onwards) and has exploited primarily younger fish.

(ii) Albacore

The other major fishery for tuna in North Atlantic waters is that carried out by French and Spanish vessels for the albacore. This species is typically an oceanic form, which is fished early in the year between the Azores, Madeira and the Canary Islands; the shoals then move north to arrive off the west coast of Portugal during May. The fishery becomes concentrated off Finisterre during June and in the deeper waters of the Bay of Biscay during July and August; the fish reach their maximum northwards extension in September, when fishing takes place off the south-west coast of Ireland. The shoals then begin to retreat south, until by November the fishery is again centred off Finisterre; Spanish vessels may continue fishing into the winter by following the fish further south.

Until 1960 the principal method of albacore fishing was by trolling lines, but since then an increasing number of boats have employed the pole and line method, fishing with live-bait. This method produced a catch-rate almost double that for trolling, and has now become the most important one.

The ships working this fishery are of several types; there are small wooden vessels which work in home waters all the year (trawling in the off-season), small tuna clippers which work home waters for albacore in the summer and African waters in the winter, and larger clippers (developed from these) which now work in African waters most of the year.

The total annual catch of albacore over the period 1950-64 has averaged about 38 000 tons (for France and Spain combined), varying between 35 000 and 45 000 tons with no really marked trends (Figure 8). The fish are mainly 2-4 years old, ranging in length between $1\frac{1}{2}$ and 3 feet and weighing 6-40 lb.

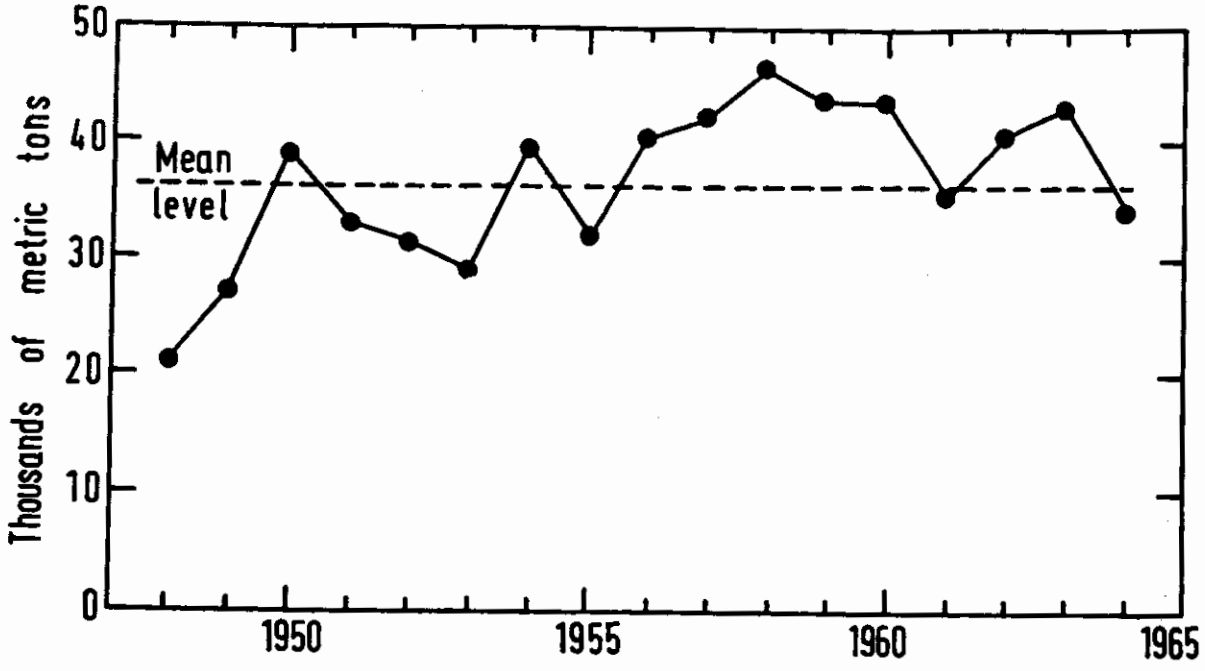


Figure 8 Total north-east Atlantic albacore catches

The Japanese long-line catch of albacore in the Atlantic area has risen considerably in recent years, the main grounds lying in the South Atlantic between the South American and African coasts between latitudes 10° and 30°S, and off the north-east coast of South America between Brazil and the Caribbean-Bahamas region.

(iii) Juvenile yellowfin and skipjack

The principal method of fishing for smaller tuna in West African waters is with pole and line, although some purse-seining is also carried out. The main species exploited are juvenile yellowfin (15-65 lb) and skipjack (3-10 lb) with occasionally small bigeye, little tunny, frigate mackerel and bonito appearing in the catches.

The fishery was pioneered in 1954-55 by French albacore vessels working from Dakar during their normal "off" season (November to March) in home waters. Since then fishing has expanded rapidly with bases developing at Conakry (Guinea), Freetown, Abidjan (Ivory Coast), Tema (Ghana) and Pointe Noire (Congo). Vessels from France, Spain, Japan and the U.S.A. and many of the African states now participate, and the total annual catch is at present about 25 000 tons, with the prospects of a further big increase in effort over the next few years.

The fishery shows seasonal shifts in area; north of the equator, in the region between Senegal and Ghana, the shoals are located in the Cape Verde region between May and September, after which the fish retreat towards the Gulf of Guinea during the northern winter, returning again in the following March-April. South of the equator the fishery reaches its southernmost limit off the Angola coast during the southern summer (December to March), and its northernmost limit off the Congo-Gabon coast between August and September. In this region it has been shown that the

tuna tend to concentrate in the vicinity of the 24-25°C surface isotherms which here mark the boundary between the warmer tropical water and cooler Benguela current water, the movements of the fish basically corresponding to the seasonal shifts in position of this boundary.

An analysis of vessels working from Pointe Noire in 1964 showed that on average about 20 per cent of the time at sea was spent bait-fishing, 30 per cent steaming and scouting, and 50 per cent actually fishing for tuna. The mean duration of a trip was about three weeks, with an average catch rate of 5-6 tons per day actually fished or 3 tons per day's absence, bringing in an average catch of 60 tons per trip.

Japanese tuna fishing in the Atlantic area

Development of the fishery

The first experimental long-lining in the equatorial Atlantic region was carried out by the Japanese in 1955-56; commercial exploitation commenced in 1956, when 4-5 vessels worked there and caught about 3 000 tons of mainly yellowfin tuna. Expansion of this type of fishing into the Atlantic area was prompted by several factors. Vessels based in Japan and landing there found that as the nearer grounds were becoming less productive so they were having to work further and further afield in the Pacific and Indian Oceans, which necessitated much longer voyages and meant that often 6-12 months elapsed between the fish being caught and becoming available for export. At that time about 40 per cent of the total Japanese tuna catch was exported (mostly to the U.S.A.), and the quality of the fish when landed was thus a prime consideration. These long voyages also resulted in greatly increased overheads, mainly due to increased fuel bills, which were then estimated to account for more than half of a vessel's expenses.

The new venture in the Atlantic aimed at reducing the time between capture and landing to 1-2 months, and at considerably reducing the overheads by basing the vessels at suitable ports reasonably near the fishing grounds. The fish were to be landed for direct export. It was also hoped to develop a European as well as an American market, and during 1957 Italy took 10 000 tons of the Japanese yellowfin catch from the Atlantic fishery, other countries such as Yugoslavia, France, Czechoslovakia, Spain, Greece and Israel taking increasing quantities in subsequent years, until in 1960 and 1961 the European market was taking over 40 000 tons per year, far exceeding the exports to America from this fishery.

The Atlantic fishery developed rapidly, with larger numbers of vessels participating each year and producing a total catch exceeding 100 000 tons in 1963. The catch has since been maintained around this level, but only through greatly increased effort (Figure 2). In the early days of the fishery the principal grounds worked extended in a rather narrow equatorial band, ranging mainly from about 10°N to 10°S, between the north-east Brazilian coast and the West African coast. Yellowfin tuna were the primary object of this fishery and this species made up about 90 per cent of the catch at that time. Landings were made

principally in Brazil for local markets (Recife), and in Panama, Cuba, Haiti and Trinidad for direct export to the U.S.A. Landings were also made directly in Italy (Venice) and Sicily (Trapani and Palermo). A typical plan of action for a 700-ton vessel in 1958 was first to make two 36-day trips to the Gulf of Guinea, landing 400 tons from each trip at Venice, then to make a third trip off north-east Brazil, landing 400 tons at Cristobal (Panama) for export to the U.S.A., and finally a voyage to the Caribbean-Guianas area, returning home with this catch of 400 tons to Japan, after a total absence of some thirteen months.

Effects of fishing

In 1958 there were already signs that fishing was having an effect on the equatorial yellowfin stocks. When the fishery commenced vessels were catching up to 15 tons per day, but by late 1957 the average catch rate had dropped to 7-9 tons per day, and in 1958 it fell still further to 5-7 tons per day. There was also a decline in the average size of yellowfin tuna caught, and in their hooking-rate (expressed as the numbers of fish caught per 100 hooks laid), over the period 1957 to 1962. In 1963 and 1964 the catch-rate levelled off to an average of about two fish per 100 hooks, this being equivalent to about 1½ tons per day (the economic minimum is about 3 tons per day). In 1958 the fishermen were of the opinion that these grounds might stand a further 5-6 years' exploitation at most, and the future prospects were not promising.

In 1959, when the catch rates had dropped even further, vessels began to probe into grounds further north and south of the area already fished, and in the South Atlantic, between about 10 and 20°S, good albacore grounds were located towards the end of 1959 and in 1960. The proportion of this species in the catch then began to rise steadily. Yellowfin are less common in this region and bigeye tuna became the next most predominant species. Problems then arose on the European market, this having been conditioned to taking mainly yellowfin, and at first most of the extra albacore and bigeye catch had to be disposed of on the American market or even shipped back to Japan.

Table 3 gives an indication of the relative species composition of the catch (percentage weight) between 1957 and 1963, and shows clearly the decline in the proportion of yellowfin tuna in the catches, and the compensatory increase in the proportions of bigeye and albacore.

Table 3 Percentage, by weight, of tuna species caught in the Japanese Atlantic fishery, 1957-63

	Yellowfin	Bigeye	Albacore	Bluefin
1957	90.5	3.1	5.9	0.5
1958	91.6	1.6	6.7	0.1
1959	89.2	3.0	7.3	0.5
1960	82.8	4.0	12.2	1.0
1961	68.4	14.4	15.4	1.8
1962	44.5	28.0	25.0	2.5
1963	42.0	15.9	33.2	8.9

In spite of the danger signs clearly evident by 1962, the yellowfin catch rate then being only about 68 per cent of that in 1959 and most operators at best only breaking even financially, a marked increase in effort continued over the next three years, with a peak number of about 154 vessels operating during 1965. This influx into the Atlantic area was mainly due to catch-rates becoming even lower on many of the grounds in the Pacific and Indian Oceans, and when stronger markets developed for bigeye and albacore the Atlantic still seemed a fairly attractive proposition, due to decreased overheads and direct export of the fish to Europe and the U.S.A. Over the last three years there have been further reductions in the catch-rates for all species of tuna, and the total catch has only been maintained by greatly increased effort. In the early years of the fishery the average duration of a trip was about 36 days, this producing about 400 tons of fish; recently trips have been of 90 days' duration or more, and these have sometimes resulted in financial loss.

A point has now been reached where a substantial reduction in the fleet is inevitable; in fact, after the albacore season finished in late August 1965, a large number of liners returned to Japan and it is reported that many of these have no immediate plans for a return to Atlantic waters unless better prospects arise. A research vessel has recently surveyed the remaining Atlantic tuna resources and was due to return to Japan in March 1966; presumably the immediate future of the Atlantic fishery will be considerably influenced by its findings.

The shortage of yellowfin tuna since 1961 has produced considerable price increases on the European market. Previously the price per metric ton was fairly stable at around £100-105, but during 1961 it rose to £120, in 1963 it was £140-145, and in 1965 it reached a record £176-179 at the end of the year. The other tuna species have shown comparable increases, bluefin and bigeye tuna reaching £140-160 per metric ton and albacore £137-144 in 1965. However, price increases have not offset the drastic decline in catch-rates, and even in 1960 it was reported that out of 1 800 Japanese tuna vessel operators at least half were experiencing financial difficulties.

CONCLUSIONS

General

At the present time the prospects for the larger tuna species in the Atlantic region are gloomy: the north-east Atlantic bluefin tuna stocks are now at a low ebb, the equatorial region yellowfin long-line fishery has become uneconomic, and the albacore stocks in the South Atlantic have recently shown a decline. The northern albacore fisheries have however been maintained at a fairly steady level, and in the north-west Atlantic there are better prospects for bluefin, skipjack and possibly yellowfin in the Gulf Stream region. Further expansion may be possible in fishing for juvenile yellowfin and skipjack in the equatorial Atlantic, with further development of similar "surface" tuna fisheries in certain regions of the Caribbean and along the South American coastline.

Yellowfin

The yellowfin long-line fishery has only been in existence for a few years, and so there are very few effort data from which the effects of fishing can be assessed. Crude estimates of fishing effort are available up to 1962, in terms of the number of voyages made or the total number of hooks laid per annum, but since 1959 a steadily increasing proportion of the total effort has been expended on the albacore, instead of on the yellowfin. It is clear, however, that the fishery for adult yellowfin is now at a barely economically exploitable level, and that any further increase in fishing on the juvenile stocks must adversely affect the adult fishery.

The decline in hooking-rate and in average size of fish in the catches does indicate that fishing has probably had a marked effect on the stocks and that it has reached and passed the level where a sustained yield might be expected. It is considered, however, that if fishing were reduced the stocks might recover fairly rapidly. The young fish first appear in the long-line fishery when they are between 2 and 3 years old, when they first show signs of becoming sexually mature and exceed a length of about $2\frac{1}{2}$ feet. It is thought that they can live to an age of 10 years, although fish older than 6 years are not commonly found, possibly because there is a high natural mortality.

Bluefin

The rapid decline in the north-east Atlantic bluefin fisheries since 1959 has been due to a real decrease in abundance of fish and not to changes in their distribution or behaviour, since it has been reflected in all the fisheries employing a variety of gears. It seems doubtful whether fishing has played a large role in this decline, because the effort tended to be fairly constant over the main period of the fishery and its reduction in the last four years has been brought about by the decrease in the stock. This decline can be mainly attributed to a succession of poor year-broods, with a resulting lack of recruitment in strength since 1958, and must be considered as due to "natural causes".