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DEPARTMENT OF
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# Some Aspects of Tuna and its Potential in the Oceanic Waters off Western Australia

BY

J. P. ROBINS

PERTH
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Department of Fisheries and Wildlife
108 Adelaide Terrace
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*SUMMARY*

*In this report an endeavour has been made to describe very briefly the growth of the tuna fishery in Australia, world production, utilisation, price and future demand, tuna species descriptions, species occurrence around the Australian coast and the results of two aerial surveys for tuna off the west and north-west coasts of Western Australia.*

## I INTRODUCTION

Commercial catching, and production of canned tuna in Australia began at Narooma on the south coast of New South Wales on an experimental basis in early 1938. Canning commenced in an old boatshed which was later replaced by a cannery built in 1940. However, World War II interfered with further development and it was not until late 1949 that a more sustained effort was initiated and this resulted in a catch of about 350 tons of southern bluefin tuna, *Thunnus maccoyii*, which was landed at N.S.W. ports. Prior and subsequent to World War II, officers of Fisheries Division, C.S.I.R.O. (notably Dr D.L. Serventy), investigated the available tuna stocks in the near coastal waters of Australia.

To date the fishery on southern bluefin tuna has developed in the waters off New South Wales and South Australia with a small development in waters off southern Western Australia.

The maximum tonnage of bluefin taken in one season in Australian waters by Australian fishermen has been approximately 12,704 tonnes (in 1972) and the catch has fluctuated between 6-9,000 tonnes for the last five years. (Fig. 1)

The fishery is based on juvenile southern bluefin tuna ranging in age from 2 - 5 years with the 3 and 4 year groups dominating the catch.

Small quantities of other species, namely striped tuna (skipjack) yellowfin, albacore and northern bluefin tuna have been taken commercially from time to time, but to date these form an insignificant part of the total catch.

However, the proper perspective of the occurrence of the tuna group as a whole is missed by some people who are interested in the commercial possibilities of the tuna industry in Australia and especially Western Australia.

The most important thing to be understood is that the species of tuna of greatest commercial value do not normally frequent inshore waters but form a truly pelagic and oceanic group of fish which are known to make wide migrations, and it is during these migrations that some parts of the population (juvenile mainly) enter the coastal fishery. Most of the world catch is taken in the open waters of the main oceans.

## II WORLD TUNA PRODUCTION

World production of tuna and tuna-like fishes in 1963 was 1,265, 000 tonnes. Production has increased over the years to 1,707,000 tonnes in 1972. i.e. an average increase of approximately 44,000 tonnes annually. (Figs. 2(a), 2(b))

Most of the increase in production has come from yellowfin and skipjack (striped tuna) which are being taken by surface fishing techniques (pole-and-line and purse seine net) rather than by longline which captures the deep-swimming and generally adult portions of the tuna populations. The adult portions of those tuna stocks vulnerable to the longline technique now appear to be fully exploited; thus it seems that most of the future increase in tuna production will depend on further exploitation using the surface fishing techniques.

The Japanese, South Korean and Taiwanese fishing fleets produce practically all of the longline-caught tuna. All other countries producing tuna, including those just mentioned, use the surface fishing techniques (Tables 1(a), 1(b)) Figure 3 shows the production by gear type, and Figure 4 shows the breakdown of longline-caught fish by major producers. In Figure 3 it appears that longline fishing production has stabilized at around 400,000 tonnes per year.

## III UTILISATION, PRICE AND FUTURE DEMAND

The United States of America, Japan and Western Europe are the major world markets for tuna.

The American preference is for canned albacore and, because of its white-coloured flesh and bland flavour fetches the highest price. Skipjack, which has a darker coloured flesh, stronger flavour, and smaller size (resulting in a lower recovery rate after processing), fetches a lower price. Yellowfin and bluefin on the U.S. market lie between these two products in acceptability and price.

The Japanese domestic usage of tuna is mainly in the raw (used for "sashemi"), smoked and dried forms, and there is a relatively small consumption of canned tuna although in recent years there are indications that canned tuna is becoming more popular in Japan.

The European market is orientated almost completely to canned tuna and with the exception of France and Spain who have their own tuna fishing fleets and canneries and Italy with its own canneries to produce canned products from imported raw tuna, all tuna is imported in the canned form.

On a liveweight basis, the utilisation of tuna in 1972, by major markets was: U.S.A. 651,000 tonnes, Japan 365,000 tonnes and Western Europe 240,000 tonnes.

Price trends of raw frozen tuna in the major world tuna markets (U.S.A., Japan and Western Europe) show a close relationship because tuna is a commodity which has relatively free access to these major markets.

Figure 5 shows the yearly average price of selected species in the U.S.A. and Japan; for comparison the average price paid to Australian fishermen by Australian processors for southern bluefin tuna in Eastern Australia is shown. The Australian price has been adjusted to the rates of exchange ruling in each year and is expressed in U.S. dollars.

The projected market growth by major area is as follows:

Demand in ,000 tonnes liveweight

| Market | 1974 | 1977 |
|---|---|---|
| U.S.A. | 710 | 750 |
| Japan | 370 | 390 |
| Europe | 270 | 300 |
| Others | 100 | 110 |
| | 1450 | 1550 |

As mentioned previously, the potential for increased tuna production will depend on further development in the surface fisheries - mainly for skipjack and yellowfin and perhaps northern bluefin to a limited extent.

It has been estimated that the aggregate potential of the surface fishery in the Indian Ocean could reach 300,000 tonnes per year. (Ref. I.O.F.C./Dev/74/40, FAO Rome, 1974)

The increasing prices being paid for tuna in recent years have stimulated the construction of large numbers of tuna fishing vessels, (mainly purse seiners and livebait vessels) in countries such as the U.S.A., Japan, France and Spain, and new fishing areas are being developed in the South West Pacific, off South-east and South-west Africa and off Argentina. Further development is most likely to take place in the southern and western Pacific and the Indian Ocean.

## IV SPECIES DESCRIPTION

The mackerels and tuna belong to the family Scombridae in which there are numerous genera and species. The main distinguishing characteristics of this family are -

1. Finlets present behind the second dorsal and anal fins.
2. Caudal fin deeply forked.
3. At least two small keels on each side of the caudal peduncle, a larger keel in between these keels in many species.

The tunas are easily recognised as members of this family and in the tuna the scales are small or minute, the body is plump and spindle-shaped and is perfectly streamlined with the first dorsal fin fitting into a slot and the pectoral and pelvic fins fitting into shallow grooves.

The following twelve species of tuna (Plate 1) are represented in Australian waters and are not listed in order of present commercial importance:

| | |
|---|---|
| Southern bluefin tuna | *Thunnus maccoyii* |
| Northern bluefin tuna | *Thunnus tonggol* |
| Yellowfin tuna | *Thunnus albacares* |
| Striped tuna (Skipjack tuna) | *Katsuwonus pelamis* |
| Albacore tuna | *Thunnus alalunga* |
| Australian bonito | *Sarda australis* |
| Oriental bonito | *Sarda orientalis* |
| Mackerel tuna (Little tuna) | *Euthynnus affinis* |
| Frigate mackerel | *Auxis thazard* |
| Leaping bonito | *Cybiosarda elegans* |
| Dogtooth tuna | *Gymnosarda unicolor* |
| Bigeye tuna | *Thunnus obesus* |
| Falla's tuna | *Allothunnus fallai* |

## IDENTIFICATION

Southern bluefin tuna *Thunnus maccoyii* (Plate 1a)

Colour: Back, blue-black; sides and belly, silvery grey; finlets, mainly yellow and edged with black; caudal keel, yellow in adults. * Pectoral fins short and do not extend to origin of second dorsal. Gill raker count on first gill arch 9-13 (upper) plus 21-25 (lower), most usual 11/22-23 mean total 33-34 gill rakers, swimbladder present. Range in size to over 300 lb. (136 kg). Surface commercial catch composed of 5-50 lb. fish (2-23 kg).

Northern bluefin tuna *Thunnus tonggol* (Plate 1b)

Colour: Back, blue-black; sides and belly, silvery grey. Very similar to southern bluefin; the main external difference is its more slender form (hence called longtailed tuna in India and west coast of America). The slenderness is due to the greater distance between second dorsal fin and tail.

* Without comparative specimens the definite distinctions between southern and northern bluefin rests on -

(a) Its gill raker count on the first arch - the mean count is 5-6 (upper), 15-17 (lower); the range is from 19 to 28.

(b) No striations on ventral surface of liver.

(c) No swimbladder.

Range in weight up to about 27 kg.

Yellowfin tuna *Thunnus albacares* (Plate 1c)

Colour: Back, blue black; sides, slightly golden and belly, silvery grey. In small fish before death, thin non-persistent perpendicular white bands appear on the sides. This feature is sometimes noted in small southern bluefin tuna. * Pectoral fins extend to and slightly beyond origin of second dorsal. No striations on liver. Finlets, yellow with black edges. Swimbladder present. Gill raker count on first arch range 26-35. With age, length of second dorsal and anal fins greatly elongate. Weight range to 250 lb. (113 kg.)

Skipjack or striped tuna *Katsuwonus pelamis* (Plate 1d)

Colour: Back, purplish blue; sides and belly, silvery, * with

4-6 conspicuous longitudinal dark stripes which in live specimens may appear as discontinuous lines of dark blotches. * Body naked of scales except for a corselet in the anterior region of body and along the distinct lateral line. Weight range up to 30 lb. (14 kg), but commercial catch mainly between 7 and 14 lb.

Albacore tuna *Thunnus alalunga* (Plate 1e)

Colour: Back, metallic dark blue; sides and belly, silvery grey. * Pectoral fins extremely long extending beyond second dorsal and anal fins. * Caudal fin possesses narrow but distinct white posterior border. Gill raker count 26-32. Weight range to 60 lb. Main commercial catch composed of individuals below 25 lb.

Australian bonito *Sarda australis* (Plate 1f)

Colour: Back, dark green with mackerel-like sheen; sides and belly, silvery grey with numerous unbroken longitudinal dark stripes. Gill rakers 19-21. Is the least plump of all tunas and ranges in weight up to 10 lb.

Oriental bonito *Sarda orientalis* (Plate 1g)

Colour: Light apple green on dorsal surfaces becoming steel blue on death; sides and belly silvery grey with dark longitudinal stripes on upper half of body. Gill rakes 8-13. Range in weight up to 9 lb.

Mackerel tuna or Eastern little tuna *Euthynnus affinis* (Plate 1h)

Back, greenish black (after death) or dark green in life with wavy mackerel-like longitudinal stripes extending from posterior 2/3rds of first dorsal fin to caudal peduncle; sides and belly silvery grey with *a group of black spots (generally about 5 in number) below the pectoral fins; spots sometimes absent. Body naked of scales except for a corselet and along lateral line. Range in weight up to 22 lb. most common 8-15 lb.

Frigate Mackerel or Leadenall *Auxis thazard* (Plate 1i)

Colour: Back, lead coloured with mackerel-like pattern of stripes; sides and belly, silvery grey, shiny lead-coloured after death. *Wide gap between first and second dorsal fins. Weight range to 3 lb.

Leaping bonito *Cybiosarda elegans* (Plate 1j)

Colour: Back, greenish blue with broken longitudinal stripes; sides and belly silvery grey with several unbroken longitudinal stripes. * First dorsal fin tall and parti-coloured black and white. Gill rakers 12-15. Range in weight up to 3 lb.

Dogtooth tuna *Gymnosarda unicolor* (Plate 1k)

Colour: Dark bluish above, grey-white on belly. Fins, blackish or grey and the tips of the dorsal and anal, whitish. Dorsal finlets, blue in life and anal finlets, yellow. * Easily distinguished by its strong peglike teeth. Gill rakers 12-13. Characteristic wavy lateral line. May attain 176 lb. in weight.

Bigeye tuna *Thunnus obesus* (Plate 1l)

Colour: Back, metallic dark blue; lower sides and belly, whitish, a lateral iridescent blue band runs along sides. First dorsal fin deep yellow, second dorsal and anal fins, light yellow; finlets, bright yellow, edged with black. Pectoral fins moderately long in large specimens (over 110 cm fork length) but very long in small specimens (distinguished from albacore at this size by lack of white posterior margin of tail). Ventral surface of liver striated, swimbladder present. Gill rakers 23-31 on first arch. Range in weight to over 300 lb.

Falla's tuna *Allothunnus fallai*

Not described.

## V AUSTRALIAN DISTRIBUTION

It has been mentioned that the tunas are a wide-ranging migratory group of fish and it is only during the seasonal migrations that sections of the populations enter coastal fisheries, where they are exploited by various fishing methods, namely trolling, live-bait and poling and purse seining. Longlining is normally carried out in more oceanic areas, and this method generally catches the more adolescent and sexually mature part of the populations. Most longlined tuna are caught by Japanese, Korean and Taiwanese fishermen.

Purse seining and pole and line fishing is also used to capture tuna in the more oceanic areas.

For ease in description of distributions (surface schooling tuna) certain, but arbitrary, geographical areas are specified (Fig. 6) and tuna of immediate or presumed importance in the areas are briefly discussed -

1. Queensland (East Coast) and New South Wales north of Sydney.
2. South-east Australia from Sydney southwards to Tasmania including Bass Strait.
3. Southern Australia including western Victoria to Head of the Great Australian Bight.
4. Head of Bight to Shark Bay.
5. Shark Bay to Cape York.

AREA 1

This area contains northern bluefin, striped tuna, yellowfin tuna, mackerel tuna, dogtooth tuna, frigate mackerel and leaping bonito. Northern bluefin probably occur in greatest abundance in inshore waters. Yellowfin tuna and striped tuna further offshore. Despite several short surveys by boat and plane in Queensland waters, little is known of the resources in this region. Striped tuna are more prevalent on the northern N.S.W. coast from August onwards as they migrate southwards to East Coast Tasmanian waters where they mainly concentrate in the period March to May after which they then appear to retreat northwards. Few are found off the southern part of N.S.W. after June. No commercial pole and line fishing of any significance occurs in Area I. Fishing season presumed to be late winter, spring and early summer.

AREA 2

The tuna species occurring in this area are southern bluefin, striped tuna, yellowfin, albacore, small bigeye tuna occasionally, Australian bonito, mackerel tuna, frigate mackerel, leaping bonito, and Falla's tuna (not described) at the southern extremity of the area.
Fishing season: The fishing emphasis is on Southern bluefin tuna and the season generally extends from August to January in N.S.W .waters. Loosely schooled bluefin commence moving north along the lower half of the New South Wales coast in July and August and commence a southward movement thereafter. Bluefin occur in Tasmanian waters in best commercial quantities between November and June peaking in late summer and autumn. This species is taken mainly by pole and line, although purse seining is recently producing good quantities. Some are taken by trolling. Tonnage taken ranges from 2,300-6,400 tonnes.

Striped tuna: This species ranges mainly from St. Helens on the east Tasmanian coast (although in some seasons have ranged as far south as 40 miles south of Tasman Island) northwards along the East Australian coast and the concentrations are seasonally distributed throughout this area. In late winter and early spring this species occurs in greatest abundance from Coffs Harbour to Sydney (i.e. in Area 1); from Sydney to Bass Strait in late spring and early summer; from East Tasmania to southern New South Wales in late summer and early autumn, and from the central to north coast of N.S.W. in early winter. Small quantities have been taken by pole and line and also by purse seine.

Northern bluefin tuna: Is distributed as far south as Eden in southern New South Wales, and usually occurs there in the autumn months. It has been caught from time to time with beach seines when close to beaches.

Albacore: Is distributed from Sydney to Tasmania and in the same season as southern bluefin tuna. It is taken by trolling and has from time to time been pole and lined. It is taken mainly along the 100 fathom line.

Yellowfin tuna: Occurs fairly rarely in surface schools in this area. Its southernmost occurrence has been noted off the mid east Tasmanian coast in Autumn. Has been poled from time to time off the N.S.W. coast and a modified longline technique has been used to capture it off the southern New South Wales coast during the late summer months.

Australian bonito: Occurs along the New South Wales coast but rarely further south although it occurs as far west as Port Phillip Bay. Occurrence mainly in the summer and autumn months. Not of commercial significance to date.

Mackerel tuna: Occurs infrequently in this area and few range as far south as southern N.S.W.

Bigeye tuna: Occasional schools have been poled off the mid south coast of New South Wales during late summer. No significant quantities taken.

AREA 3

The main species in this area is southern bluefin with some striped tuna and albacore. The bluefin population is exploited mainly during the period January to May and tonnages taken range to 7,000 tons. The fishing area extends from about Streaky Bay to Kangaroo Island with concentration mainly south of Eyre Peninsula. Striped tuna occur at the same time as the bluefin but catches to date have been small.

## AREA 4

Species occurring here are southern bluefin, striped tuna, yellowfin, albacore, oriental bonito, mackerel tuna, frigate mackerel and leaping bonito. Only the first three species mentioned appear to have any real potential in this area. At present only southern bluefin tuna (mainly 2½ years old) are taken in a small area near Albany and production has ranged between 250-770 tonnes since 1969. Small quantities of striped tuna are also taken by pole and line and very occasionally some yellowfin tuna have been landed. Southern bluefin appear to occur along the south coast throughout the year with greatest concentrations occurring in inshore areas between March and July. A fishery for southern bluefin is now developing in the Esperance area where 2 and 3 year old fish are being caught, and the season here appears to be from November to April. No commercial fishing of any significance has been developed along the west coast between Cape Leeuwin and Shark Bay, although seasonally this area is visited by striped tuna and, to a lesser extent yellowfin tuna as well as being the area through which juvenile southern bluefin pass on their migration to south coastal waters.

## AREA 5

The surface and near surface waters of this vast area are dominated by the so-called tropical tunas - yellowfin, striped tuna, northern bluefin tuna, mackerel tuna and dogtooth tuna. Results from aerial surveys (December 1966 - February 1968 and August 1973 - September 1974) show that a good potential for tuna exists in this region throughout the year (see next section). This potential, although not fully confirmed by vessel operation, consists of striped tuna, northern bluefin tuna, yellowfin tuna and mackerel tuna.

The presence of large northern bluefin (up to 60 lb.) and yellowfin tuna (to 60 lb.) in Shark Bay has been known for many years but until the last couple of years the economics of fishing these species has not been considered worthwhile in this area mainly because of logistic problems and their effect on price. Incidental fishing by a few prawn fishermen using primitive fishing gear and minimum technique yielded approximately 60 tonnes of tuna, (northern bluefin and yellowfin) during 1974.

It is anticipated that more effort will be made on the stocks of tuna in and outside Shark Bay when the fishing boat harbour now under construction at Carnarvon is completed.

# VI AERIAL SURVEYS FOR TUNA OFF THE W.A. COAST

## A. GENERAL

Prior to late 1966, much anecdotal, but limited information for research was available on the relative abundance of the several species of tuna in the area surveyed.

The object of the surveys was to collect background information on distribution and relative abundance which could be used at a later date when research and industry were in a position to prosecute surveys by vessels with the intention of commencing commercial exploitation of the tuna stocks off the coast of Western Australia.

Two aerial surveys for tuna have been made since December 1966. The first survey period extended from December 1966 to February 1968 with the months of January and October omitted; the second survey covered the period August 1973 to September 1974, with the months October, February and April omitted.

## B. METHODS

### 1. AIRCRAFT AND SURVEY TACTICS

Two types of aircraft were used in these surveys. Both were chosen because of their characteristics which allow for good spotting (i.e. high wing) long endurance needed (because of the nature of the survey area), twin engines (safety), and of course conformed to D.C.A. flying regulations. A Cessna 337 was used for the first survey and an Aero Commander Shrike was used for the second. All spotting flights were made at an altitude of 1500 ft., and at a speed of 120 knots with variations in these procedures when close examination of schools of tuna was required, or when bad weather dictated change in operations.

The region surveyed extended from Fremantle to Wyndham (1968) and to Admiralty Gulf (1974), and for the purposes of survey and subsequent analysis of data collected, the region (Fig. 7) was divided into the following sub-areas:

| | |
|---|---|
| Fremantle to Carnarvon | (Area E) |
| Carnarvon to Onslow | (Area D) |
| Onslow to Port Hedland | (Area C) |
| Port Hedland to Broome | (Area B) |
| Broome to Wyndham (or Admiralty Gulf) | (Area A) |

On some occasions flights over some sections were cancelled due to adverse flying conditions.

The flight paths between these centres were designed to comply with D.C.A. regulations and to overfly topographical features with which tuna are known to be associated; such features are the 'edge' of the continental shelf, seamounts, emergent reefs, shallow banks and around headlands where 'upwelling', convergent and divergent currents, and current eddies are pronounced.

On most surveys the aircraft carried at least two spotters one of whom was responsible for logging all weather data, sightings of tuna schools, bait schools, turtles, whales, dolphins, bird flocks, current lines etc.

2. TUNA SIGHTINGS

Two criteria were used in an attempt to identify species of tuna sighted; these were -

(a) fish size

(b) school colour

Fish size was categorised into those greater than 40 lb. (large fish); 15-40 lb. (medium fish); less than 15 lb. (small fish).

These categories were used because of the known weights (size) which the following species attain, viz:

| | |
|---|---|
| Yellowfin | 250 lb., (180 cm) |
| Northern bluefin | 60 lb., (128 cm) |
| Striped tuna | 30 lb., (?85 cm) |
| Mackerel tuna | 22 lb., (?90 cm) |

Anecdotal information from fishermen and from vessel surveys in Nor'west Australia suggests that the weight range of the majority of mackerel tuna caught in those waters is from 8-12 pounds. The largest specimen caught by F.V. 'Western Star' during the 1973/74 survey was 14 lb. (74 cm).

Previous studies on northern bluefin tuna indicate that the large fish (25-60 lb.) of this species appear in the surface waters only at the southern end of their range of distribution (about 27°S with stragglers to 30°S).

Using this criterion it was assumed that all fish of a size estimated to be greater than 40 lb. were yellowfin tuna (except in the Shark Bay area) and the medium and small-sized fish could be any of the species listed above, although the probability is high, using the above criterion that the medium-sized fish were mainly yellowfin.

The other more subjective criterion used was that of school colour as determined from the aircraft. It is known that schools of yellowfin exhibit a tan colour over an ill-defined blue, striped tuna a deep blue and the school will occasionally "shine" as the fish, as a school, turn on their sides. The schools of larger mackerel tuna in these northern waters present a very dark blue or black appearance and the small fish exhibit a pale, almost silver colour. These schools do not "shine" as a school as do the striped tuna but the fish within the school appear to behave erratically showing many random flashes or "shines".

Observations on school colour were not made consistently and hence were not used in the analysis of data.

An estimate of school size (in tons) was made on all tuna schools sighted. The school size categories used were -

(a) small (less than 5 tonnes)

(b) medium (5-10 tonnes)

(c) large (greater than 10 tonnes)

The estimates of large school tonnages covered a range from 10 tonnes to a probable 250 tonnes.

Sighting data from both surveys were analysed separately and then combined for presentation in this report.

3. EFFECTIVE SEARCH TIME

Total searching time was modified to "effective searching time" by allowing for wind and sea conditions as they affected searching. (Fig. 8)

4. DATA TREATMENT

Because of the variations in the numbers of schools sighted from month to month it was decided to analyse the sets of basic data using the "weighted average" technique. This technique allows for smoothing out of irregularities so that trends are shown in the time series analysis. The "weighted average" technique generally produces a smoother curve than the simple "moving average" but still preserves the main features of the time series. (Ref "Mathematics of Statistics" Pt 1. 3rd Ed., 1974, by J.F. Kenney and E.S. Keeping).
Figures and tables presented in these results are shown as basic (non smoothed) and/or smoothed data.

## C. RESULTS

The results obtained may be given as answers to various questions which would be asked by a person who was interested in the potential of fishing for tuna off the west and north-west coast of Western Australia.

Such questions would be:

1. Where were the greatest concentrations of tuna?
2. At what period of the year?
3. What were the sizes of the tuna within the schools?
4. What were the sizes of the schools?
5. What was the species composition of the schools sighted?
6. What is the bait potential in the areas if tuna are to be caught by the livebait-and-pole method of fishing?
7. What were the seasonal movements of the population(s) along the coast?

*1. WHERE WERE THE GREATEST CONCENTRATIONS OF TUNA?*

The greatest number of schools sighted (Table 2) was in sub-area C, Onslow to Port Hedland, (1343 schools) followed then by sub-area A, north of Broome (935); sub-area B, Port Hedland to Broome, (605); sub-area D, Carnarvon to Onslow, (581) and sub-area E, Fremantle to Shark Bay (172).

Schools sighted per effective hour flown by sub-area over a 12 month period were 11.62(C); 7.45(A); 6.19(D); 5.47(B); 1.24(E) (Table 2). Area C is dominant when considering consistency of occurrence of schools. Using average number of schools sighted per effective hour flown (6.23) for the total region for the year, Area C is followed in order by Areas D, A, B and E. (Table 2, Figs. 9 & 10)

*2. AT WHAT TIME OF THE YEAR AND WHERE WERE THE GREATEST CONCENTRATIONS OF TUNA?* (Table 2 Figs. 9 & 10)

Tuna are available off the Western Australian coast throughout the year; the fish are in greatest abundance during the late autumn and winter months of May to August although as stated previously tuna are in fair to good abundance in Area C throughout the year; the tuna are in least abundance during the months of September and October.

A more detailed analysis of the data (Tables 3(a), 3(b) Fig. 11), relating to fish size within schools shows that there are differences, in seasonal abundance by area, between the small, medium and large-sized tuna. This information is important to a fisherman because it would allow for easier determination of fishing tactics.

3. *WHAT WERE THE SIZES OF THE FISH WITHIN THE SCHOOLS?* (Table 3, Figs. 12(a), 12(b)

In a total of 3,636 schools sighted, schools of small-sized fish totalled 1628 (45%) medium-sized fish 1851 (51%) and large-sized fish 157 (4%).

There were differences in fish size composition within schools by area and month; these differences are probably due to the varying migratory habits of the several species of tuna which occur throughout the area.

Sub-areas D and E, i.e. between Onslow and Fremantle were dominated by schools of small fish, roughly in the proportions of 60:38:2 (small:medium:large) whereas in A, B and C the proportions were 41:54:5 respective to fish size.

4. *WHAT WERE THE SIZES OF THE SCHOOLS?* (Table 4, Figs. 13(a), 13(b)

Regardless of fish size within schools sighted, small schools (i.e. less than 5 tons) totalled 2,464 (67.8%) medium sized schools (i.e. 5 to 10 tons) totalled 822 (22.6%) and large sized schools (greater than 10 tons) totalled 350 (9.6%).

5. *WHAT WAS THE SPECIES COMPOSITION OF SCHOOLS SIGHTED?*

This question cannot be answered with any precision at this stage. As mentioned previously the numbers of species in the area and the varying swimming behaviour and colour patterns exhibited by the schools sighted preclude an objective statement. However a subjective assessment, using data on the fish size composition of schools, is that the large fish were probably all yellowfin, the medium size fish were probably yellowfin and large striped tuna with perhaps some large mackerel tuna and the schools of small sized fish were composed of striped tuna, mackerel tuna, yellowfin and northern bluefin tuna.

6. *WHAT IS THE LIVEBAIT POTENTIAL IN THE AREAS SURVEYED IF TUNA ARE TO BE CAUGHT BY THE LIVEBAIT-AND-POLE METHOD OF FISHING?* (Tables 5(a), 5(b), Fig. 14)

Generally, most bait used for livebait fishing is captured in near-shore situations e.g. in bays and around islands. Many of the sightings made during the aerial survey occurred in offshore situations and it is inferred, except for Shark Bay and Exmouth Gulf, where sightings were made in relatively calm waters, that some proportion of the baitfish sighted offshore would probably move into more sheltered areas where capture could be more easily accomplished.

Knowledge of bait species distribution in the area surveyed is scanty except for Area E and the southern part of Area D where pilchard, *Sardinops neopilchardus*, appears to be the dominant species; another species of importance in the southern area is the scaly mackerel, *Amblygaster postera*. Both of these species are known as "mulies" in Western Australia.

Little is known of the populations of other likely baitfish for tuna fishing in the more northern areas but the species occurring there would probably include northern pilchard, *Amblygaster sirm*, fringe-scaled sardine *Sardinella dactylolepis*, Koningsberger's herring, *Harengula koningsbergeri*, blue sprat, *Spratelloides robustus*, and several species of tropical anchovy. It is anticipated that Koningsberger's herring will form the basis of the livebait for tuna fishing when this fishery develops in the northern areas.

Results from the aerial survey show that the most numerous sightings were made in sub-areas D and E.

In Area D, on a seasonal abundance occurrence basis, there is a good degree of correlation between tuna school sightings and bait school sightings. The cycles and degree of seasonal abundance in Areas D and E are quite similar.

Sightings of bird flocks and dolphins are shown in Table 5(b) to indicate the type of correlation existing between them and tuna in the various areas as shown in Table 3(b).

7. *WHAT WERE THE SEASONAL MOVEMENTS OF THE POPULATION(S) ALONG THE COAST?*

The results of the aerial surveys indicate that a tuna potential of a significant magnitude occurs in the region surveyed. The analyses of data show that the area between Onslow and Port Hedland (sub-area C) contained the greatest relative abundance of tuna over a 12 month period although at certain times of the year other areas contained greater apparent abundance than did sub-area C.

This observation indicates that seasonal migrations of the tuna species occur along the northwest and west coasts from one sub-area to another throughout the year, and at certain times of the year the longshore migrating populations are supplemented and diminished respectively by onshore- and offshore-migrating fish.

Because species composition, of the schools sighted from the air, cannot be made with any surety at this stage, a tentative hypothesis of these migrations is erected, and is based on the monthly proportions (relative to sightings/effective hour flown, Table 3a Fig. 15) of schools of (i) small-sized fish (<15 lb.), (ii) medium-sized fish (15-40 lb.) and, (iii) large-sized fish (>40 lb.), found in each sub-area.

(a) Migrations of schools of small-sized fish

| | |
|---|---|
| August to September | B to A very weak; B to C weak to moderate; D to C strong; D to E very weak |
| September to October | A to B to C moderate; D to C very strong; D to E weak to moderate |
| October to November | A to B to C, moderate; D to C moderate; D to E weak |
| November to December | A to B to C, moderate; E to D very weak |
| December to January | C to B weak to moderate; B to A weak; E to D very weak |
| January to February | C to B to A very strong; C to D weak; E to D weak |
| February to March | C to B to A moderate to strong; C to D strong; E to D weak |
| March to April | A to B moderate to strong; B to C to D moderate to strong to very strong; E stable |
| April to May | A to B moderate to strong; B to C slight to moderate; C to D strong; E to D very weak |
| May to June | A to B to C to D weak; E to D very weak; D to C weak |
| July to August | B to A moderate; D to C moderate to strong; D to E very weak |

(b) Migrations of schools of medium-sized fish (15-40 lb.)

| | |
|---|---|
| August to September | A to B moderate; C to B moderate to strong; C to D very weak; D to E very weak |

| | |
|---|---|
| September to October | A to B strong; B to C moderate, C to D weak to moderate; D to E moderate |
| October to November | A to B to C very strong; C to D weak; D to E moderate |
| November to December | A to B to C strong; D to E very weak |
| December to January | A to B moderate to strong; C to D strong; E to D very weak |
| January to February | A to B weak; C to B moderate; C to D very strong; E to D weak to moderate |
| February to March | A stable; B stable; C to D moderate; E to D weak |
| March to April | E to D weak to moderate; C to B to A weak |
| April to May | E to D weak; D to C very strong; C to B to A strong |
| May to June | E to D very weak; D to C to B to A very strong |
| June to July | E stable; D to C to B to A very strong |
| July to August | D to E very weak; D to C moderate; C to B to A moderate to strong |

(c) <u>Migrations of schools of large-sized fish</u> (>40 lb.)

| | |
|---|---|
| August to September | A to B weak; B to C weak; C to D moderate to strong; D to E moderate to strong |
| September to October | A to B to C to D, moderate to strong; D to E strong |
| October to November | E to D to C to B, moderate to strong; B to A moderate |
| November to December | B to A weak; B to C weak; E to D to C, strong |
| December to January | A to B to C very strong; E to D to C very weak |
| January to February | A to B very weak; B to C very strong; C to D weak; D to E weak to moderate |

| | |
|---|---|
| February to March | D to E weak to moderate; C to B to A very strong |
| March to April | E to D weak to moderate; D to C moderate; C to B to A very strong |
| April to May | E to D weak to moderate; D to C weak; C to B to A strong |
| May to June | E to D weak; A to B moderate to strong |
| June to July | A to B very strong; B to C moderate to strong; C to D very weak |
| July to August | A to B very strong; B to C weak to moderate; C to D to E very weak |

Examination of the presumptive migration directions from one sub-area to another (Figs. 16(a),(b),(c)) shows that there are contrary movements of the same sized fish in some months e.g. in small-sized fish migrations, during the period September to October, contrary movements are shown to occur from D to C, from D to E and from A and B to C.

No explanation can be offered, as yet, for these apparent contrary movements but they may be related to species behaviour differences which in turn may be related to the seemingly complex current systems operating off the coast of Western Australia (Fig. 17(a),17(b)). The 25°C, 22°C and 20°C isotherms are superimposed on the monthly charts to indicate the seasonal change in surface temperatures.

A diagram of generalised migrations of schools of different sized tuna along the north west coast of Western Australia is given in Figure 18. Compilation of this diagram ignores the presumptive weak migrations and is based mainly on the moderate to very strong movements indicated by changes in relative proportions of sightings between sub-areas in each month.

## VII DISCUSSION

The top-priced tuna on the world's markets are albacore, yellowfin, bluefin, bigeye and striped tuna (skipjack), in that order.

All of these species, as well as northern bluefin, occur in the waters off the Australian coast in varying degrees of abundance and it was one of the objectives of the aerial surveys to derive some estimate of the abundance of tuna which occur off the coast of Western Australia.

The index figure of relative abundance used in this report was that of "schools of fish sighted per effective hour flown".

A conservative estimate of the tonnage of tuna sighted on both surveys was 30,000 tonnes. This figure is calculated from the numbers of schools of different size which were sighted (Table 4). Weighting multipliers of 2.5 tonnes, 7.5 tonnes and 50 tonnes were used for small, medium and large-sized schools respectively.

Various extrapolations of this tonnage have been calculated in an attempt to estimate the possible size of the stocks of tuna in the area surveyed.

Using a weighting factor of 4 (total area within survey area:area searched = 4:1) a conservative figure of approximately 130,000 tonnes was derived for both the 1966/67 and 1973/74 surveys.

In 1966/67 the calculated tonnage sighted was 17,641 tonnes (1505 x 2.5 + 517 x 7.5 + 200 x 50) and in 1973/74 the tonnage sighted was 12,186 tonnes (959 x 2.5 + 305 x 7.5 + 150 x 50).

Although the number of schools sighted was less in 1973/74 (1414) than in 1966/67 (2222), the number of effective sighting hours was less (214.57 hours and 368.71 hours respectively) and the schools sighted per effective hour flown in 1973/74 were 6.60 compared with 6.0 in 1966/67.

The estimated tonnages from sightings are considered conservative for several reasons, one of which is that practically all surveying was carried out over continental shelf waters and it is known that the tuna populations extend much farther into oceanic waters.

It is also considered that both surface type fishing techniques (purse seining and livebait-and-poling) could be used to harvest commercially these stocks of tuna.

## VIII ACKNOWLEDGMENTS

I would like to thank Messrs K. Godfrey and P. Edsall for assistance in collection and collation of aerial survey data and to Mr P. Edsall for drafting the text figures. Thanks are also extended to the personnel of Boulden's Air Charters Company (1967 survey) and Executive Air West (1973/74 survey) for their co-operation and strong interest in the project.

TABLE 1(a)
WORLD PRODUCTION OF TUNAS BY COUNTRY
(Thousands of Metric Tons - Live-Weight Basis)

| COUNTRY | YEAR | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 |
| Japan | 566 | 594 | 566 | 628 | 549 | 542 | 525 | 508 | 502 | 555 |
| U.S.A | 161 | 159 | 171 | 154 | 196 | 189 | 208 | 230 | 239 | 243 |
| Taiwan | 12 | 13 | 25 | 43 | 59 | 100 | 110 | 103 | 110 | 110+ |
| South Korea | 1 | 2 | 8 | 25 | 34 | 57 | 99 | 102 | 100 | 103 |
| France | 46 | 49 | 42 | 51 | 51 | 62* | 51* | 50* | 60* | 69* |
| Spain | 40 | 30 | 39 | 33 | 39 | 56 | 58 | 63 | 72 | 66 |
| Ecuador | 13 | 10 | 15 | 12 | 20 | 18 | 20 | 17 | 23 | 23 |
| Peru | 28 | 17 | 12 | 12 | 17 | 10 | 16 | 16 | 12 | 4 |
| Ryukyu Islands | 10 | 13 | 14 | 15 | 16 | 19 | 15 | 20 | 31 | NA# |
| Australia | 5 | 8 | 7 | 8 | 6 | 7 | 9 | 8 | 7 | 10 |
| Others | 61 | 44 | 37 | 42 | 62 | 78 | 42 | 35 | 41 | 98 |
| Total | 943 | 939 | 936 | 1,023 | 1,049 | 1,138 | 1,153 | 1,152 | 1,197 | 1.281 |

+ Estimate

* Includes France, Ivory Coast and Senegal

# Included in Japan landings

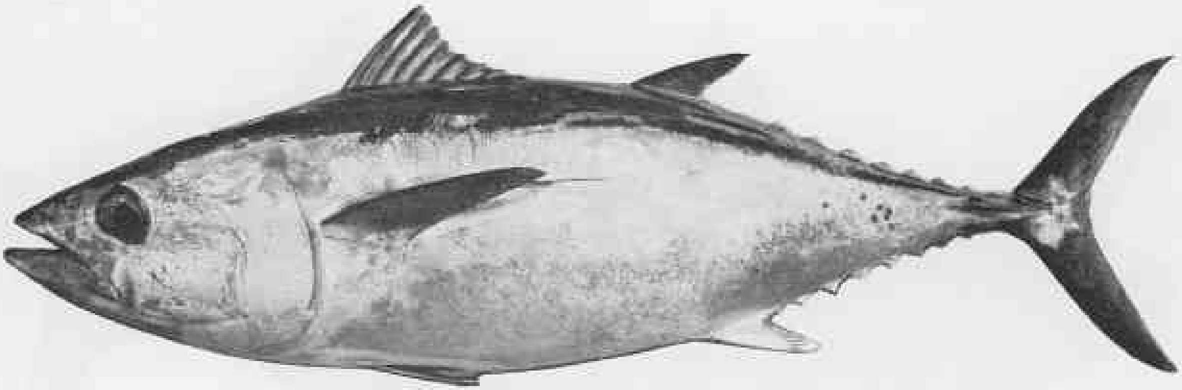
Source: IOFC/DEV/74/40, F.A.O. ROME. 1974

TABLE 1(b)
WORLD PRODUCTION OF TUNA BY GEAR
(Thousands of Metric Tons - Live-Weight Basis)

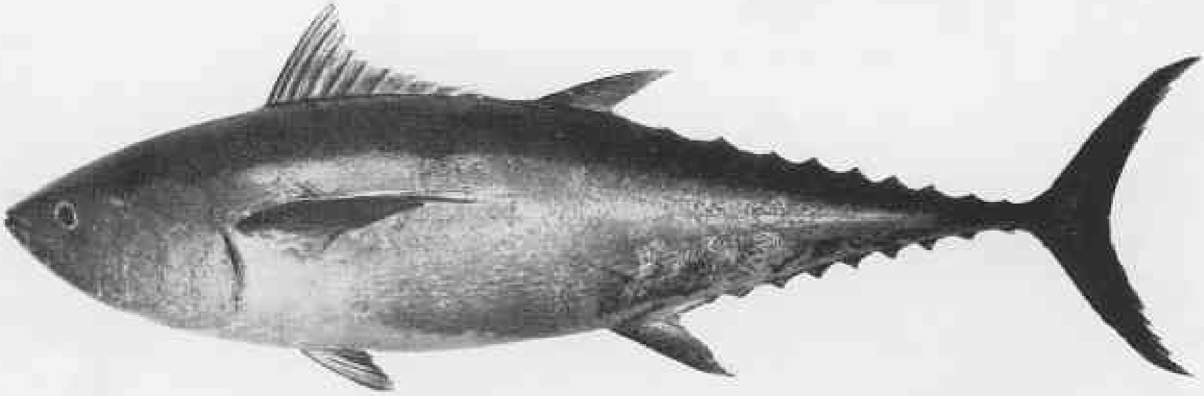
| | YEAR | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 |
| **LONGLINE** | | | | | | | | | | |
| Japan | 402 | 372 | 359 | 345 | 303 | 300 | 276 | 242 | 210 | 191 |
| South Korea | 1 | 2 | 8 | 25 | 34 | 57 | 99 | 102 | 100 | 103 |
| Taiwan | 12 | 13 | 12 | 26 | 38 | 78 | 86 | 89 | 89 | 89 |
| Total | 415 | 387 | 379 | 396 | 375 | 435 | 461 | 433 | 399 | 383 |
| **SURFACE** | | | | | | | | | | |
| All Countries | 528 | 552 | 557 | 627 | 674 | 703 | 692 | 719 | 798 | 898 |
| **TOTAL** | | | | | | | | | | |
| World | 943 | 939 | 936 | 1,023 | 1 049 | 1,138 | 1,153 | 1,152 | 1,197 | 1,281 |

Source: IOFC/DEV/74/40, F.A.O. ROME 1974

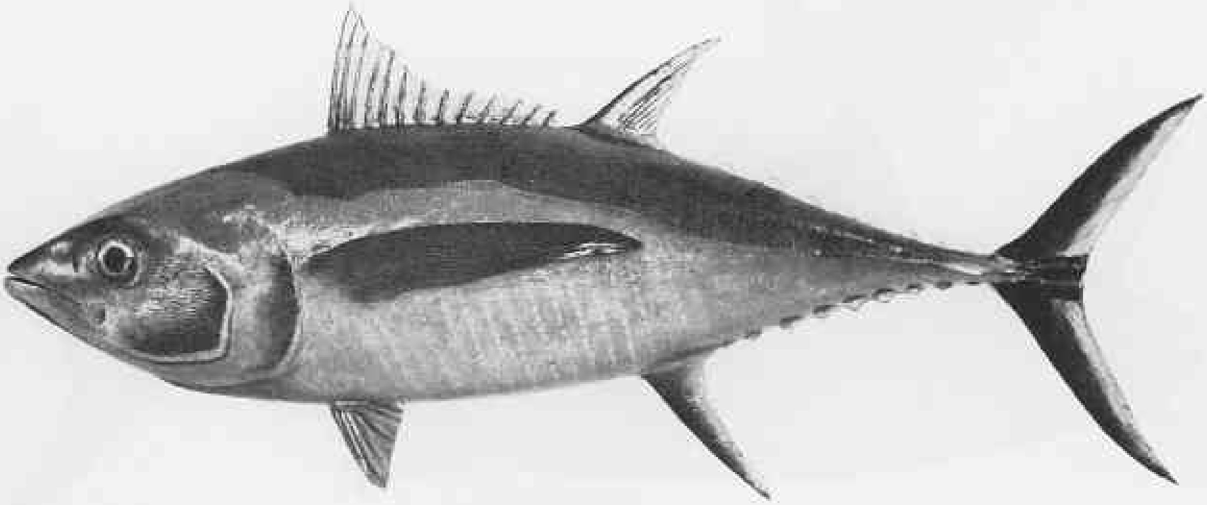
## PLATE 1



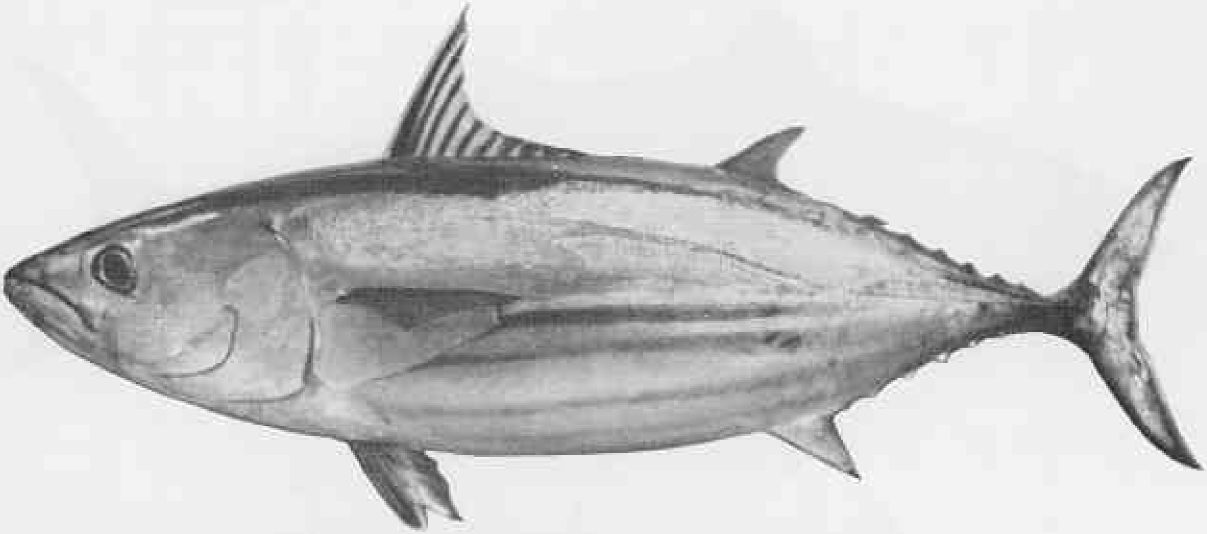
(a) Southern bluefin tuna *Thunnus maccoyii*



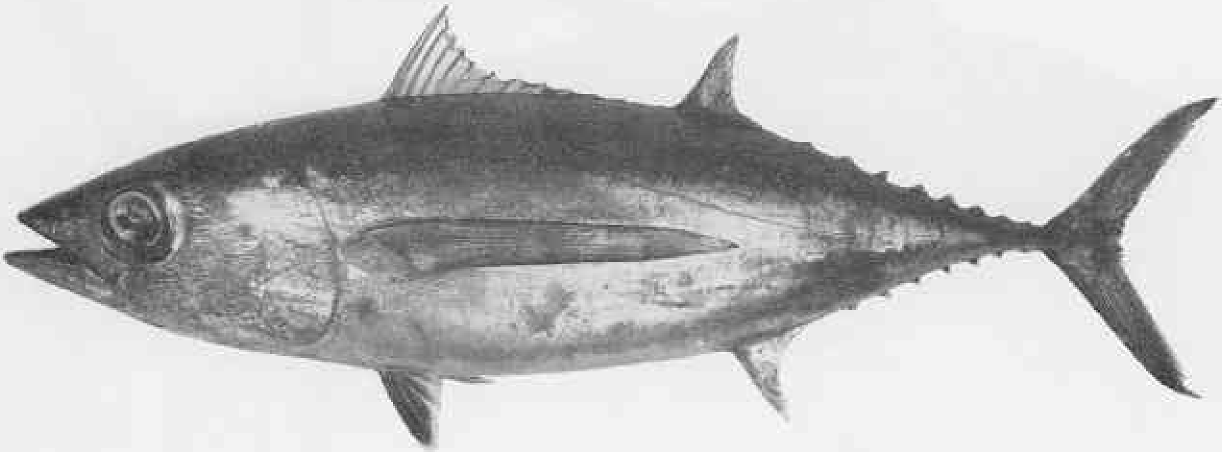
(b) Northern bluefin tuna *Thunnus tonggol*



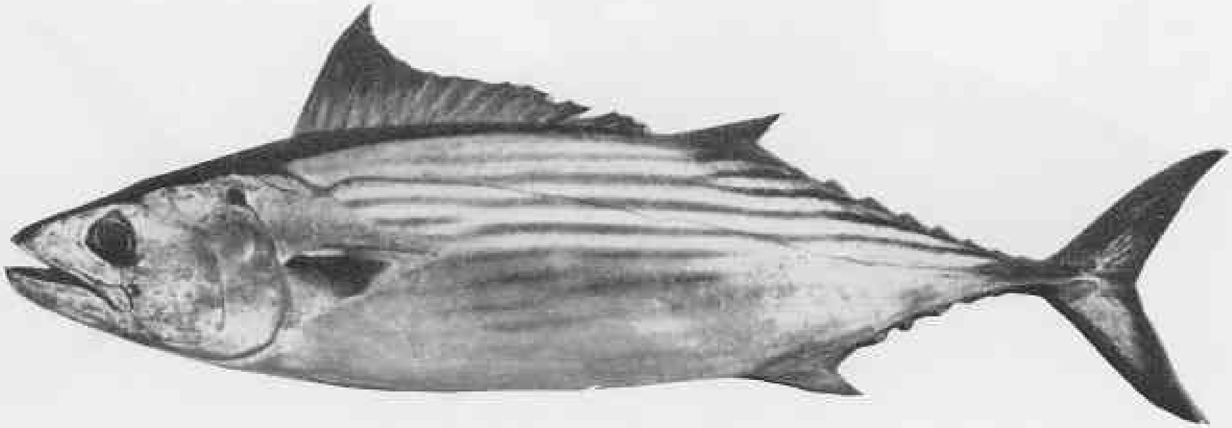
(c) Yellowfin tuna *Thunnus albacares*



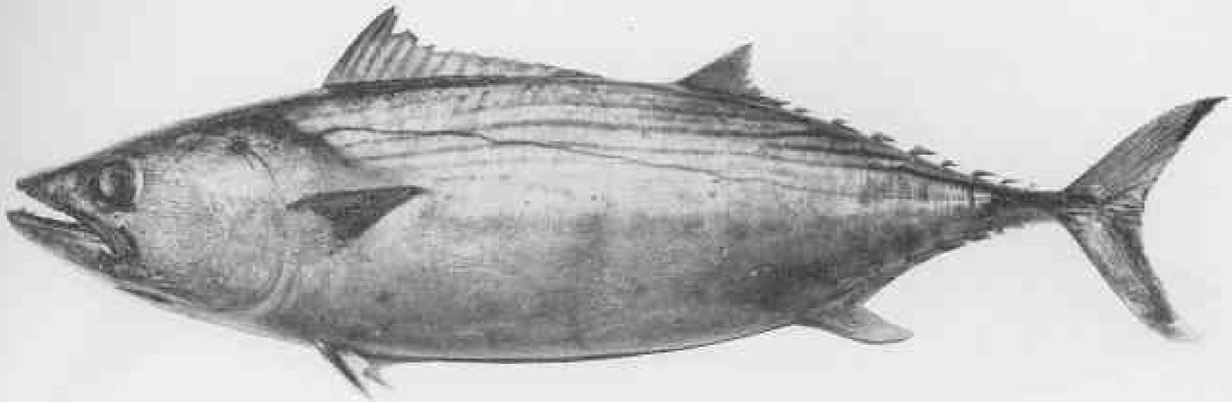
(d) Striped tuna (Skipjack tuna) *Katsuwonus pelamis*



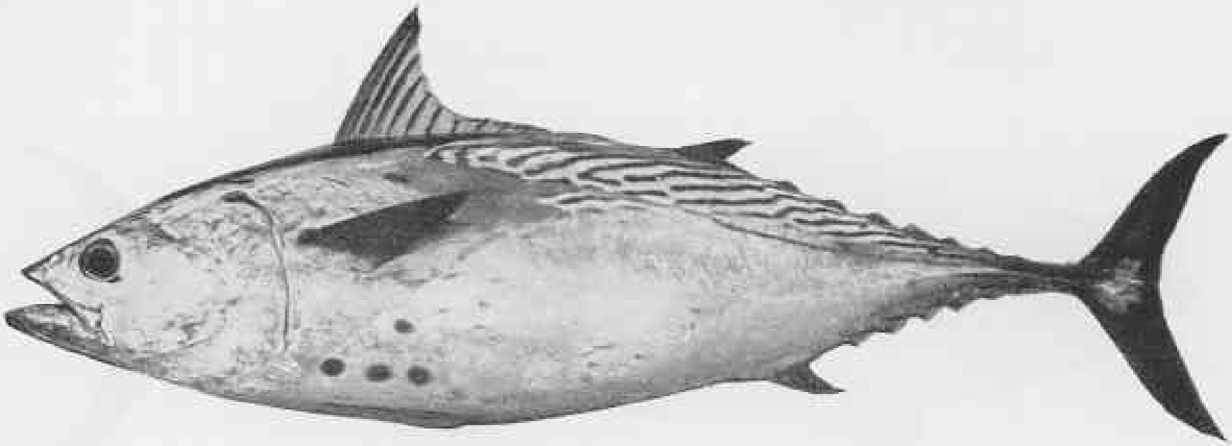
(e) Albacore tuna *Thunnus alalunga*



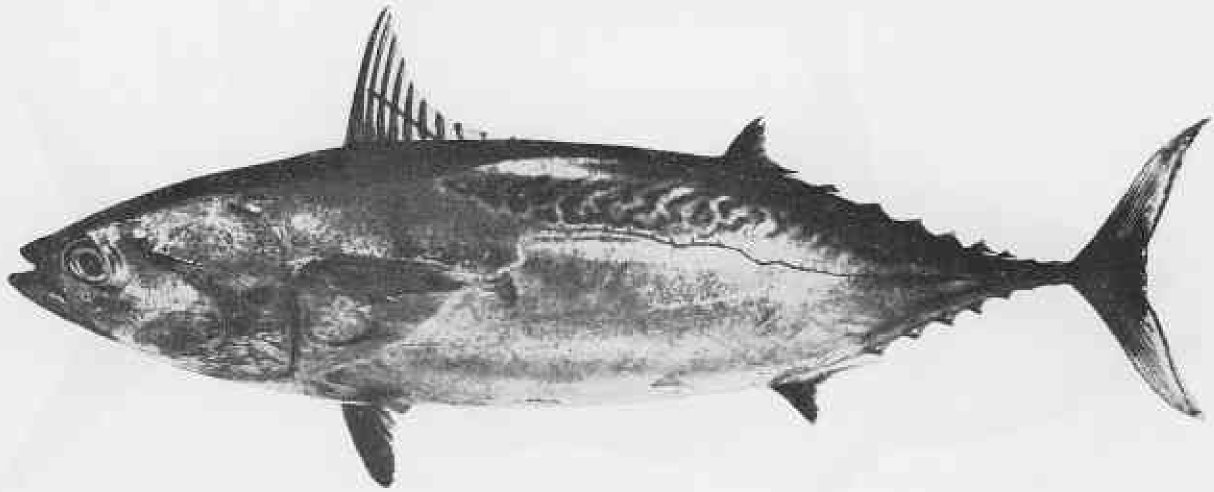
(f) Australian bonito *Sarda australis*



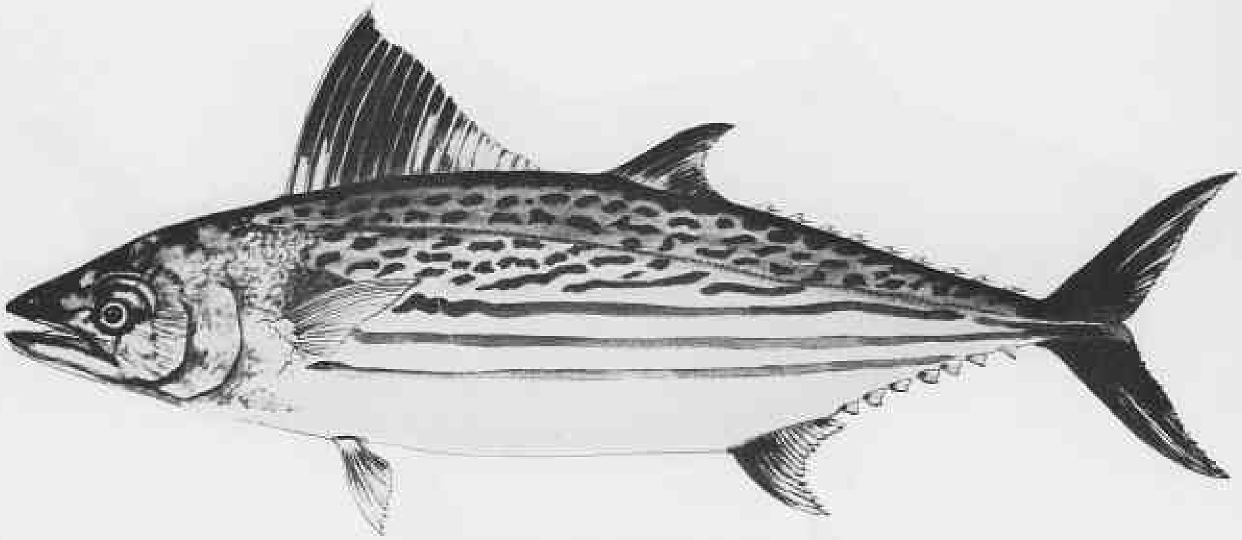
(g) Oriental bonito *Sarda orientalis*



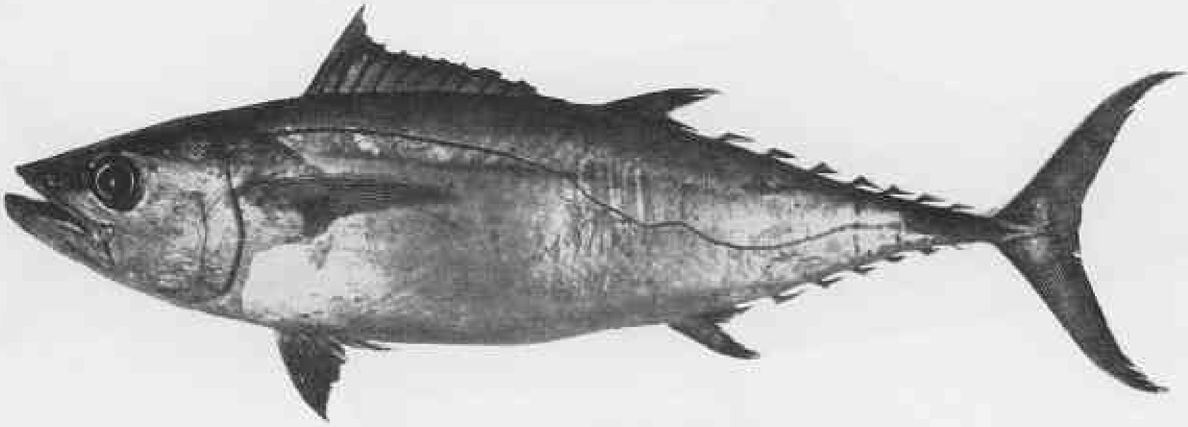
(h) Mackerel tuna (Little tuna) *Euthynnus affinis*



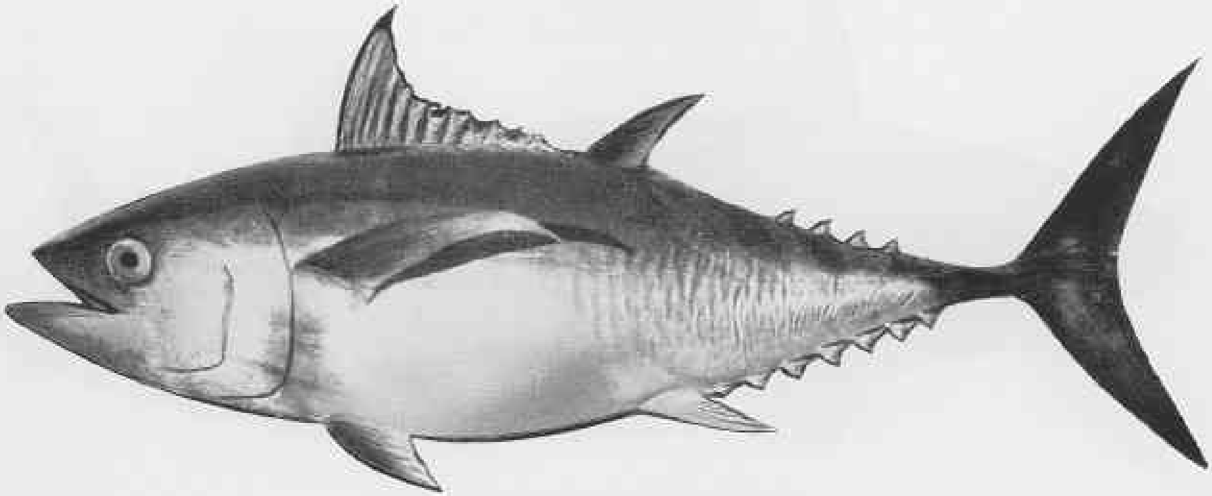
(i) Frigate mackerel *Auxis thazard*



(j) Leaping bonito *Cybiosarda elegans*



(k) Dogtooth tuna *Gymnosarda unicolor*



(l) Bigeye tuna *Thunnus obesus*

TABLE 2
NUMBER OF SCHOOLS SIGHTED PER EFFECTIVE HOUR FLOWN
BY AREA AND MONTH
(1966/67 and 1973/74; basic data)

| | NUMBERS OF SCHOOLS | | | | | | EFFECTIVE HOURS FLOWN | | | | | | SCHOOLS/EFFECTIVE HOURS FLOWN | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AREA | | | | | | AREA | | | | | | AREA | | | | | |
| MONTH | A | B | C | D | E | TOTAL | A | B | C | D | E | TOTAL | A | B | C | D | E | TOTAL |
| AUG | 136 | 112 | 98 | 147 | 16 | 509 | 11.30 | 16.27 | 14.52 | 14.10 | 18.05 | 74.24 | 12.03 | 6.88 | 6.75 | 10.43 | 0.89 | 6.86 |
| SEP | 7 | 33 | 47 | 6 | 3 | 96 | 14.70 | 14.39 | 12.39 | 14.03 | 13.65 | 69.16 | 0.48 | 2.29 | 3.79 | 0.43 | 0.22 | 1.39 |
| OCT | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| NOV | 63 | 41 | 64 | 17 | 13 | 198 | 8.42 | 12.47 | 11.27 | 10.02 | 15.00 | 57.18 | 7.48 | 3.29 | 5.68 | 2.14 | 0.87 | 3.46 |
| DEC | 56 | 34 | 357 | 18 | 86 | 551 | 13.58 | 7.67 | 5.92 | 8.43 | 18.12 | 53.72 | 4.12 | 4.43 | 60.30 | 2.14 | 4.75 | 10.26 |
| JAN | - | - | 12 | 3 | 2 | 17 | - | - | 3.90 | 4.13 | 8.52 | 16.55 | - | - | 3.08 | 0.73 | 0.23 | 1.03 |
| FEB | 1 | 37 | 58 | 12 | 17 | 125 | 6.67 | 7.25 | 7.93 | 7.08 | 10.05 | 38.98 | 0.15 | 5.10 | 7.31 | 1.69 | 1.69 | 3.21 |
| MAR | 125 | 102 | 225 | 118 | 20 | 590 | 12.67 | 16.49 | 15.35 | 9.79 | 9.22 | 63.52 | 9.87 | 6.19 | 14.66 | 12.08 | 2.17 | 9.29 |
| APR | 28 | 15 | 2 | 51 | 0 | 96 | 11.58 | 7.88 | 8.42 | 4.15 | 8.27 | 40.30 | 2.42 | 1.90 | 0.24 | 12.29 | 0 | 2.38 |
| MAY | 90 | 115 | 54 | 96 | 11 | 366 | 20.38 | 12.96 | 13.40 | 10.13 | 12.82 | 69.69 | 4.42 | 8.87 | 4.03 | 9.48 | 0.86 | 5.25 |
| JUN | 111 | 40 | 297 | 107 | 2 | 557 | 8.03 | 6.78 | 9.93 | 7.57 | 13.35 | 45.66 | 13.82 | 5.90 | 29.91 | 14.13 | 0.15 | 12.20 |
| JUL | 318 | 76 | 129 | 6 | 2 | 531 | 17.92 | 8.45 | 12.13 | 4.48 | 11.30 | 54.28 | 17.75 | 8.99 | 10.63 | 1.34 | 0.18 | 9.78 |
| TOTAL | 935 | 605 | 1343 | 581 | 172 | 3636 | 125.52 | 110.61 | 115.16 | 93.91 | 138.35 | 583.28 | 7.45 | 5.47 | 11.62 | 6.19 | 1.24 | 6.23 |

TABLE 3(a)
NUMBER OF SCHOOLS SIGHTED BY AREA, MONTH AND SCHOOL SIZE
(1966/67 and 1973/74; basic data)
S = SMALL; M = MEDIUM; L = LARGE

| AREA | A | | | B | | | C | | | D | | | E | | | TOTAL | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | S | M | L | S | M | L | S | M | L | S | M | L | S | M | L | S | M | L | GRAND TOTAL |
| AUG | 75 | 58 | 3 | 74 | 34 | 4 | 43 | 52 | 3 | 139 | 8 | 0 | 15 | 1 | 0 | 346 | 153 | 10 | 509 |
| SEP | 3 | 4 | 0 | 4 | 26 | 3 | 44 | 3 | 0 | 6 | 0 | 0 | 2 | 0 | 1 | 59 | 33 | 4 | 96 |
| OCT | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| NOV | 30 | 33 | 0 | 32 | 7 | 2 | 56 | 8 | 0 | 14 | 2 | 1 | 9 | 4 | 0 | 141 | 54 | 3 | 198 |
| DEC | 39 | 14 | 3 | 29 | 0 | 5 | 237 | 119 | 1 | 18 | 0 | 0 | 55 | 30 | 1 | 378 | 163 | 10 | 551 |
| JAN | - | - | - | - | - | - | 8 | 4 | 0 | 3 | 0 | 0 | 2 | 0 | 0 | 13 | 4 | 0 | 17 |
| FEB | 0 | 1 | 0 | 17 | 15 | 5 | 30 | 18 | 10 | 5 | 5 | 2 | 3 | 14 | 0 | 55 | 53 | 17 | 125 |
| MAR | 101 | 20 | 4 | 30 | 69 | 3 | 68 | 142 | 15 | 11 | 106 | 1 | 7 | 9 | 4 | 217 | 346 | 27 | 590 |
| APR | 16 | 9 | 3 | 10 | 3 | 2 | 0 | 2 | 0 | 50 | 1 | 0 | 0 | 0 | 0 | 76 | 15 | 5 | 96 |
| MAY | 24 | 15 | 51 | 80 | 28 | 7 | 11 | 42 | 1 | 36 | 60 | 0 | 10 | 0 | 1 | 161 | 145 | 60 | 366 |
| JUN | 20 | 88 | 3 | 4 | 36 | 0 | 8 | 284 | 5 | 67 | 40 | 0 | 1 | 1 | 0 | 100 | 449 | 8 | 557 |
| JUL | 10 | 306 | 2 | 42 | 25 | 9 | 25 | 103 | 1 | 5 | 0 | 1 | 0 | 2 | 0 | 82 | 436 | 13 | 531 |
| Schools by size | 318 | 548 | 69 | 322 | 243 | 40 | 530 | 777 | 36 | 354 | 222 | 5 | 104 | 61 | 7 | 1628 | 1851 | 157 | 3636 |
| Schools by area | | 935 | | | 605 | | | 1343 | | | 581 | | | 172 | | | 3636 | | |
| % Within Area | 34.01 | 58.61 | 7.38 | 53.22 | 40.17 | 6.61 | 39.46 | 57.86 | 2.68 | 60.93 | 38.21 | 0.86 | 60.47 | 35.46 | 4.07 | | | | |
| % Between Areas | 8.74 | 15.07 | 1.90 | 8.86 | 6.68 | 1.10 | 14.57 | 21.37 | 0.99 | 9.74 | 6.11 | 0.14 | 2.86 | 1.68 | 0.19 | 44.77 | 50.91 | 4.32 | |

TABLE 3(b)
SCHOOL SIGHTINGS PER EFFECTIVE HOUR FLOWN
BY AREA, MONTH AND FISH SIZE
(Weighted Average)

| AREA | A | | | B | | | C | | | D | | | E | | | TOTAL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SIZE | | | SIZE | | | SIZE | | | SIZE | | | SIZE | | | SIZE | | |
| MONTH | S | M | L | S | M | L | S | M | L | S | M | L | S | M | L | S | M | L |
| AUG | 2.47 | 7.77 | 0.13 | 3.10 | 2.20 | 0.35 | 2.80 | 4.95 | 0.13 | 5.36 | 0.50 | 0.02 | 0.44 | 0.07 | 0.02 | 2.70 | 3.13 | 0.13 |
| SEP | 2.05 | 3.24 | 0.07 | 2.07 | 1.72 | 0.24 | 3.41 | 1.76 | 0.06 | 3.17 | 0.19 | 0.02 | 0.43 | 0.08 | 0.04 | 2.16 | 1.37 | 0.09 |
| OCT | 1.83 | 1.76 | 0.03 | 1.68 | 1.24 | 0.14 | 5.20 | 1.32 | 0.02 | 1.49 | 0.12 | 0.04 | 0.65 | 0.25 | 0.05 | 2.08 | 0.91 | 0.06 |
| NOV | 2.40 | 1.92 | 0.07 | 2.25 | 0.77 | 0.27 | 9.92 | 3.56 | 0.03 | 1.24 | 0.10 | 0.06 | 1.32 | 0.63 | 0.04 | 3.15 | 1.37 | 0.09 |
| DEC | 2.57 | 1.51 | 0.13 | 2.93 | 0.60 | 0.44 | 15.16 | 6.77 | 0.14 | 1.51 | 0.11 | 0.06 | 1.73 | 0.93 | 0.03 | 4.07 | 1.72 | 0.15 |
| JAN | 2.46 | 0.95 | 0.14 | 2.88 | 1.34 | 0.56 | 11.76 | 6.85 | 0.56 | 1.27 | 1.20 | 0.10 | 1.38 | 1.01 | 0.04 | 3.48 | 1.60 | 0.25 |
| FEB | 3.42 | 0.88 | 0.17 | 2.34 | 2.56 | 0.45 | 5.19 | 5.85 | 0.87 | 1.39 | 4.11 | 0.15 | 0.69 | 0.95 | 0.11 | 2.62 | 2.72 | 0.35 |
| MAR | 3.97 | 1.01 | 0.49 | 2.29 | 2.90 | 0.32 | 3.13 | 5.59 | 0.75 | 2.76 | 6.11 | 0.12 | 0.44 | 0.73 | 0.17 | 2.57 | 3.13 | 0.39 |
| APR | 2.85 | 1.31 | 1.11 | 2.96 | 2.55 | 0.35 | 1.93 | 5.73 | 0.43 | 4.69 | 5.99 | 0.05 | 0.45 | 0.32 | 0.12 | 2.48 | 2.97 | 0.48 |
| MAY | 1.73 | 3.48 | 1.45 | 3.77 | 2.59 | 0.48 | 1.05 | 9.04 | 0.22 | 5.65 | 5.16 | 0.02 | 0.39 | 0.07 | 0.06 | 2.23 | 3.98 | 0.53 |
| JUN | 1.55 | 8.02 | 1.05 | 3.96 | 3.09 | 0.56 | 1.27 | 12.66 | 0.22 | 6.01 | 4.00 | 0.03 | 0.30 | 0.07 | 0.02 | 2.23 | 5.77 | 0.42 |
| JUL | 2.12 | 11.09 | 0.40 | 3.81 | 2.84 | 0.50 | 2.08 | 10.22 | 0.20 | 6.44 | 1.83 | 0.03 | 0.32 | 0.09 | 0.02 | 2.63 | 5.51 | 0.23 |

TABLE 4
NUMBER OF SCHOOLS BY AREA AND MONTH AND SCHOOL SIZE
1966/67 and 1973/74 (basic data)
S = SMALL; M = MEDIUM; L = LARGE

| AREA | A | | | B | | | C | | | D | | | E | | | TOTAL | | | GRAND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | S | M | L | S | M | L | S | M | L | S | M | L | S | M | L | S | M | L | TOTAL |
| AUG | 100 | 26 | 10 | 74 | 27 | 11 | 66 | 25 | 7 | 126 | 9 | 12 | 16 | 0 | 0 | 382 | 87 | 40 | 509 |
| SEP | 5 | 2 | 0 | 22 | 6 | 5 | 32 | 10 | 5 | 1 | 4 | 1 | 3 | 0 | 0 | 63 | 22 | 11 | 96 |
| OCT | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| NOV | 60 | 3 | 0 | 38 | 2 | 1 | 41 | 21 | 2 | 15 | 1 | 1 | 12 | 1 | 0 | 166 | 28 | 4 | 198 |
| DEC | 55 | 0 | 1 | 22 | 11 | 1 | 253 | 43 | 61 | 18 | 0 | 0 | 71 | 13 | 2 | 419 | 67 | 65 | 551 |
| JAN | - | - | - | - | - | - | 10 | 2 | 0 | 3 | 0 | 0 | 2 | 0 | 0 | 15 | 2 | 0 | 17 |
| FEB | 1 | 0 | 0 | 11 | 26 | 0 | 32 | 18 | 8 | 5 | 6 | 1 | 12 | 5 | 0 | 61 | 52 | 9 | 125 |
| MAR | 82 | 31 | 12 | 62 | 38 | 2 | 137 | 66 | 22 | 59 | 35 | 24 | 18 | 2 | 0 | 358 | 172 | 60 | 590 |
| APR | 12 | 15 | 1 | 6 | 9 | 0 | 2 | 0 | 0 | 28 | 14 | 9 | 0 | 0 | 0 | 48 | 38 | 10 | 96 |
| MAY | 29 | 35 | 26 | 71 | 37 | 7 | 22 | 20 | 12 | 58 | 24 | 14 | 7 | 3 | 1 | 187 | 119 | 58 | 366 |
| JUN | 85 | 23 | 3 | 30 | 9 | 1 | 258 | 29 | 10 | 104 | 1 | 2 | 2 | 0 | 0 | 479 | 62 | 16 | 557 |
| JUL | 206 | 73 | 39 | 39 | 28 | 9 | 35 | 67 | 27 | 4 | 2 | 0 | 2 | 0 | 0 | 286 | 170 | 75 | 531 |
| | 635 | 208 | 92 | 375 | 193 | 37 | 888 | 301 | 154 | 421 | 96 | 64 | 145 | 24 | 3 | 2464 | 822 | 350 | 3636 |
| Area Total | 935 (25.71%) | | | 605 (16.64%) | | | 1343 (36.94%) | | | 581 (15.98%) | | | 172 (4.73%) | | | | 3636 | | |
| % Within | 67.91 | 22.25 | 9.84 | 61.98 | 31.90 | 6.12 | 66.12 | 22.41 | 11.47 | 72.46 | 16.52 | 11.02 | 84.30 | 13,95 | 1.74 | | | | |
| % Between | 17.46 | 5.72 | 2.52 | 10.31 | 5.31 | 1.02 | 24.42 | 8.28 | 4.24 | 11.58 | 2,64 | 1.76 | 3.99 | 0.66 | 0.08 | 67.77 | 22.61 | 9,62 | |

TABLE 5(a)
BAIT SCHOOLS, BIRD FLOCKS AND DOLPHINS SIGHTED
BY AREA AND MONTH
(1966/67 + 1973/74 - Basic Data)

| AREA | A | | | B | | | C | | | D | | | E | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | BAIT | BIRDS | DOL-PHINS | BAIT | BIRDS | DOL-PHINS | BAIT | BIRDS | DOL-PHINS | BAIT | BIRDS | DOL-PHINS | BAIT | BIRDS | DOL-PHINS |
| AUG | 15 | 31 | 246 | 35 | 60 | 369 | 33 | 75 | 273 | 82 | 24 | 56 | 111 | 39 | 31 |
| SEP | 7 | 45 | 148 | 14 | 31 | 91 | 57 | 67 | 59 | 13 | 63 | 32 | 7 | 18 | 1 |
| OCT | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| NOV | 11 | 69 | 114 | 25 | 23 | 9 | 25 | 18 | 0 | 7 | 15 | 0 | 6 | 4 | 1 |
| DEC | 4 | 24 | 277 | 16 | 19 | 66 | 0 | 29 | 34 | 20 | 4 | 4 | 55 | 31 | 80 |
| JAN | - | - | - | - | - | - | 0 | 24 | 0 | 1 | 5 | 0 | 7 | 10 | 5 |
| FEB | 0 | 10 | 1 | 3 | 16 | 12 | 208 | 12 | 10 | 75 | 7 | 57 | 0 | 17 | 20 |
| MAR | 34 | 85 | 58 | 5 | 91 | 22 | 4 | 122 | 43+ | 84 | 121 | 11 | 9 | 13 | 25 |
| APR | 24 | 21 | 32 | 2 | 17 | 12 | 2 | 10 | 0 | 14 | 12 | 0 | 0 | 2 | 0 |
| MAY | 8 | 49 | 49 | 0 | 33 | 57 | 3 | 41 | 0 | 468 | 262+ | 0 | 517 | 7 | 20 |
| JUN | 7 | 32 | 103 | 13 | 20 | 5 | 2 | 13 | 7 | 59+ | 48 | 250 | 250 | 55 | 79 |
| JUL | 55 | 163 | 522 | 32 | 139 | 85 | 36 | 42 | 36 | 19 | 13 | 9 | 31 | 21 | 6 |
| TOTALS | 165 | 529 | 1550 | 145 | 449 | 728 | 370 | 453 | 462 | 842 | 574 | 419 | 993 | 217 | 268 |

TABLE 5(b)
SIGHTINGS/EFFECTIVE HOUR FLOWN OF BAIT SCHOOLS, BIRD FLOCKS AND DOLPHINS, BY AREA AND MONTH
(Weighted Average)

| AREA | A | | | B | | | C | | | D | | | E | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | BAIT | BIRDS | DOL-PHINS | BAIT | BIRDS | DOL-PHINS | BAIT | BIRDS | DOL-PHINS | BAIT | BIRDS | DOL-PHINS | BAIT | BIRDS | DOL-PHINS |
| AUG | 1.62 | 5.08 | 15.56 | 2.04 | 5.20 | 14.22 | 2.97 | 4.55 | 9.92 | 3.87 | 3.01 | 4.30 | 4.56 | 1.93 | 1.25 |
| SEP | 0.99 | 4.15 | 14.71 | 1.60 | 3.09 | 10.27 | 3.44 | 4.58 | 7.87 | 2.32 | 3.24 | 2.39 | 2.32 | 1.40 | 0.59 |
| OCT | 0.78 | 4.57 | 12.62 | 1.55 | 2.16 | 5.36 | 3.27 | 3.75 | 3.86 | 1.26 | 3.01 | 1.46 | 1.10 | 0.95 | 0.53 |
| NOV | 0.73 | 4.49 | 14.78 | 1.75 | 2.04 | 2.84 | 2.40 | 3.12 | 2.01 | 1.10 | 2.07 | 0.68 | 1.24 | 0.91 | 1.39 |
| DEC | 0.50 | 3.08 | 16.10 | 1.99 | 2.16 | 4.44 | 3.02 | 3.42 | 2.10 | 1.88 | 1.19 | 0.76 | 1.72 | 1.19 | 2.31 |
| JAN | 0.45 | 2.35 | 13.59 | 1.74 | 2.67 | 4.33 | 8.16 | 4.25 | 2.08 | 4.49 | 1.98 | 2.40 | 1.48 | 1.43 | 2.43 |
| FEB | 1.11 | 1.29 | 8.31 | 0.83 | 3.65 | 2.55 | 9.11 | 5.01 | 1.92 | 7.46 | 5.09 | 3.53 | 0.76 | 1.02 | 2.03 |
| MAR | 1.73 | 3.90 | 4.28 | 0.33 | 4.05 | 1.81 | 4.96 | 5.06 | 1.71 | 11.28 | 9.08 | 2.50 | 3.85 | 1.14 | 1.71 |
| APR | 1.48 | 3.25 | 3.35 | 0.28 | 3.54 | 2.27 | 1.37 | 4.02 | 1.04 | 20.34 | 13.90 | 2.95 | 14.59 | 1.02 | 1.74 |
| MAY | 1.13 | 3.26 | 6.11 | 0.60 | 3.57 | 3.21 | 0.61 | 2.66 | 0.59 | 26.24 | 15.95 | 8.36 | 22.51 | 1.65 | 2.54 |
| JUN | 1.49 | 4.87 | 9.72 | 1.62 | 5.88 | 6.50 | 1.49 | 2.47 | 2.49 | 19.62 | 11.65 | 13.02 | 18.76 | 2.38 | 3.00 |
| JUL | 1.97 | 6.02 | 12.39 | 2.34 | 7.15 | 12.65 | 2.30 | 3.53 | 7.10 | 8.43 | 5.21 | 9.52 | 9.80 | 2.40 | 1.71 |

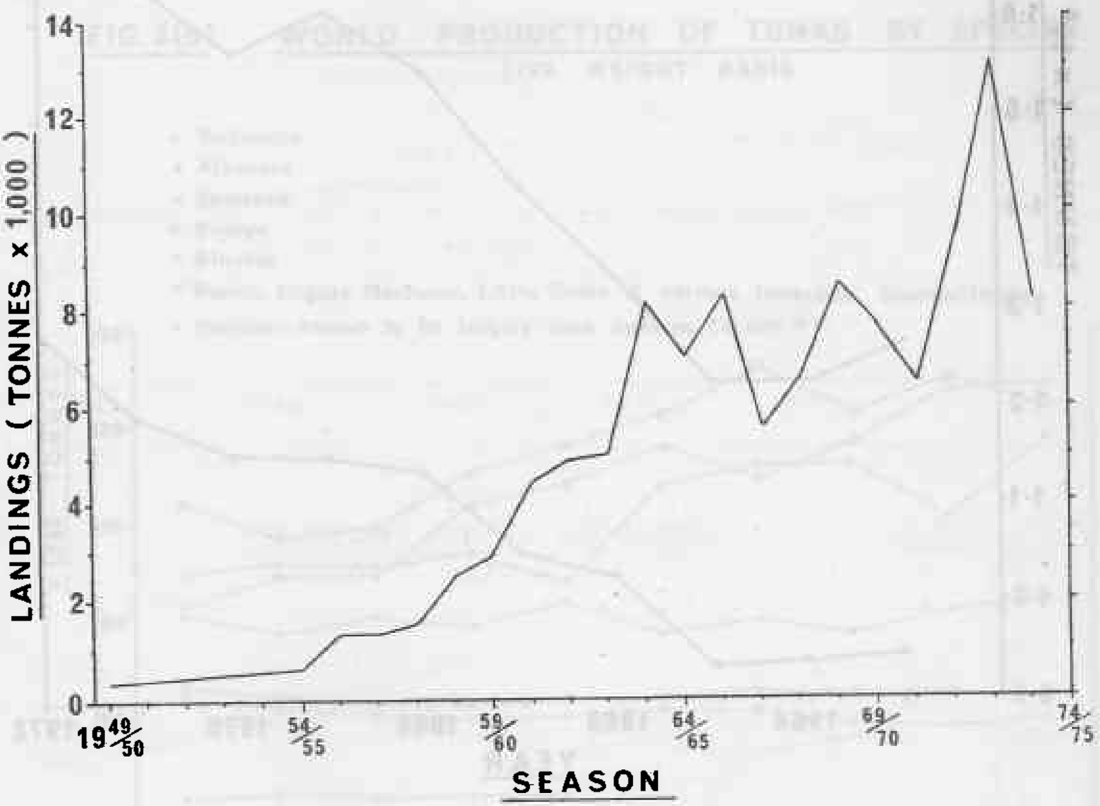



**FIG.1** **SOUTHERN BLUEFIN TUNA LANDINGS**
( N.S.W. & SOUTH AUST. COMBINED )

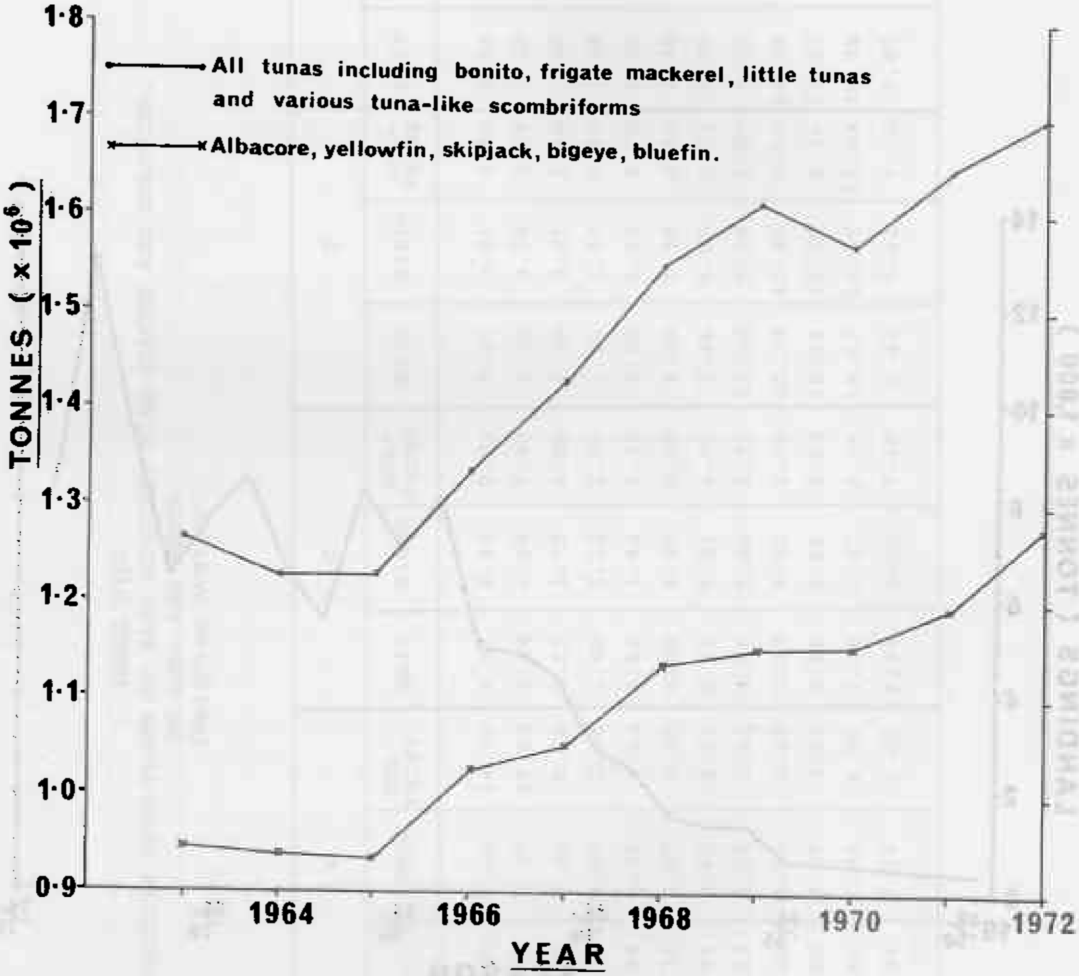



FIG. 2(a) WORLD PRODUCTION OF TUNAS

N.B. SOURCE OF DATA FOR FIGS. 2(a)–5 FROM IOFC/DEV/74/40. FAO. ROME, 1974.

## FIG. 2(b) WORLD PRODUCTION OF TUNAS BY SPECIES

LIVE WEIGHT BASIS

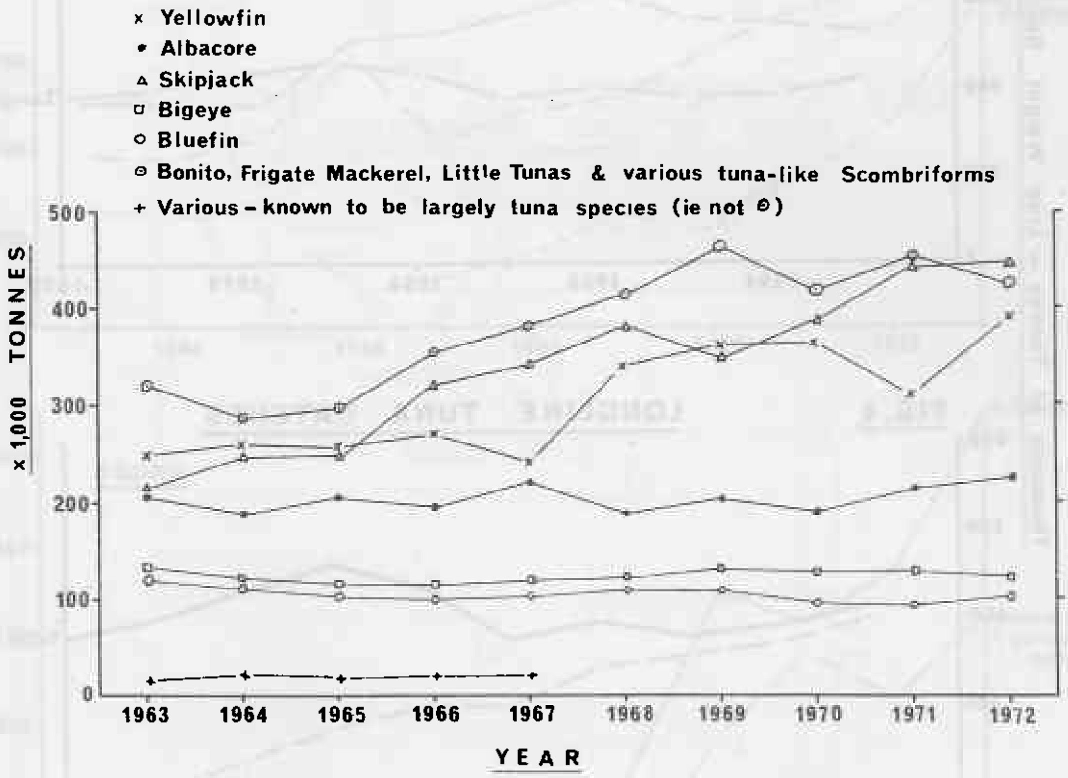


**FIG. 3** **WORLD TUNA CATCH BY GEAR**

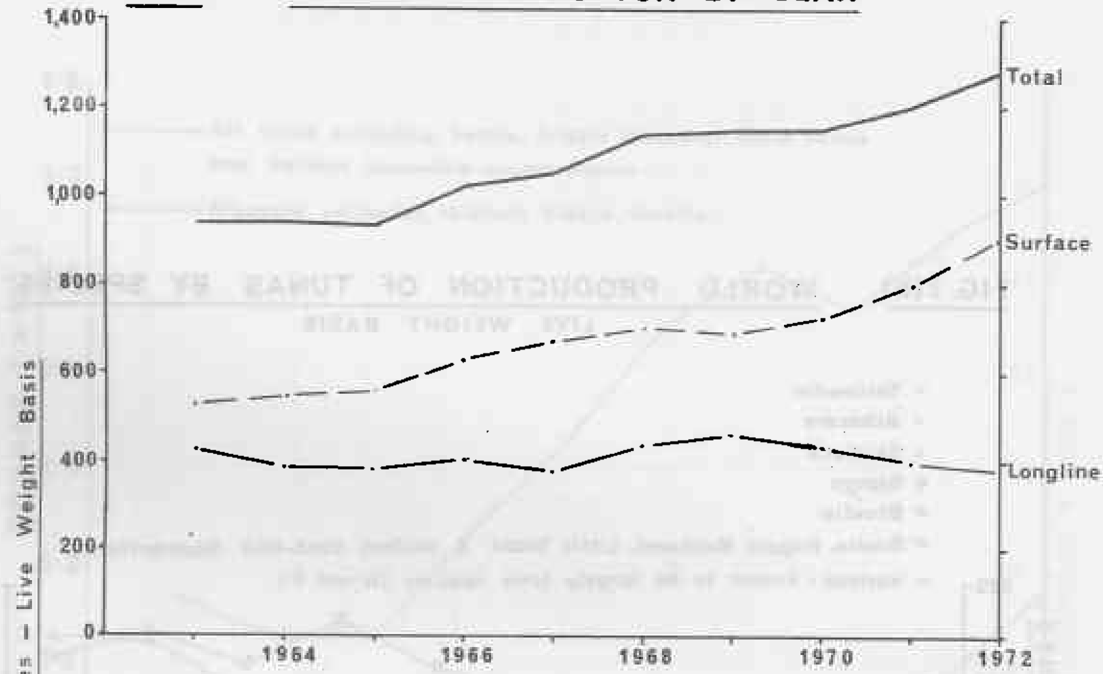



**FIG. 4** **LONGLINE TUNA CATCHES**

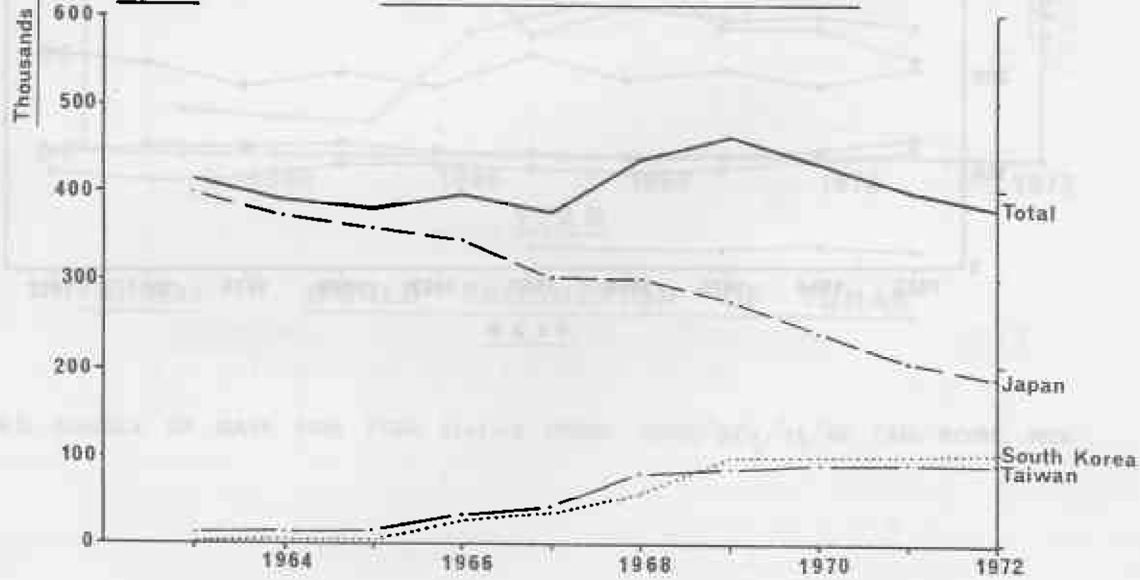
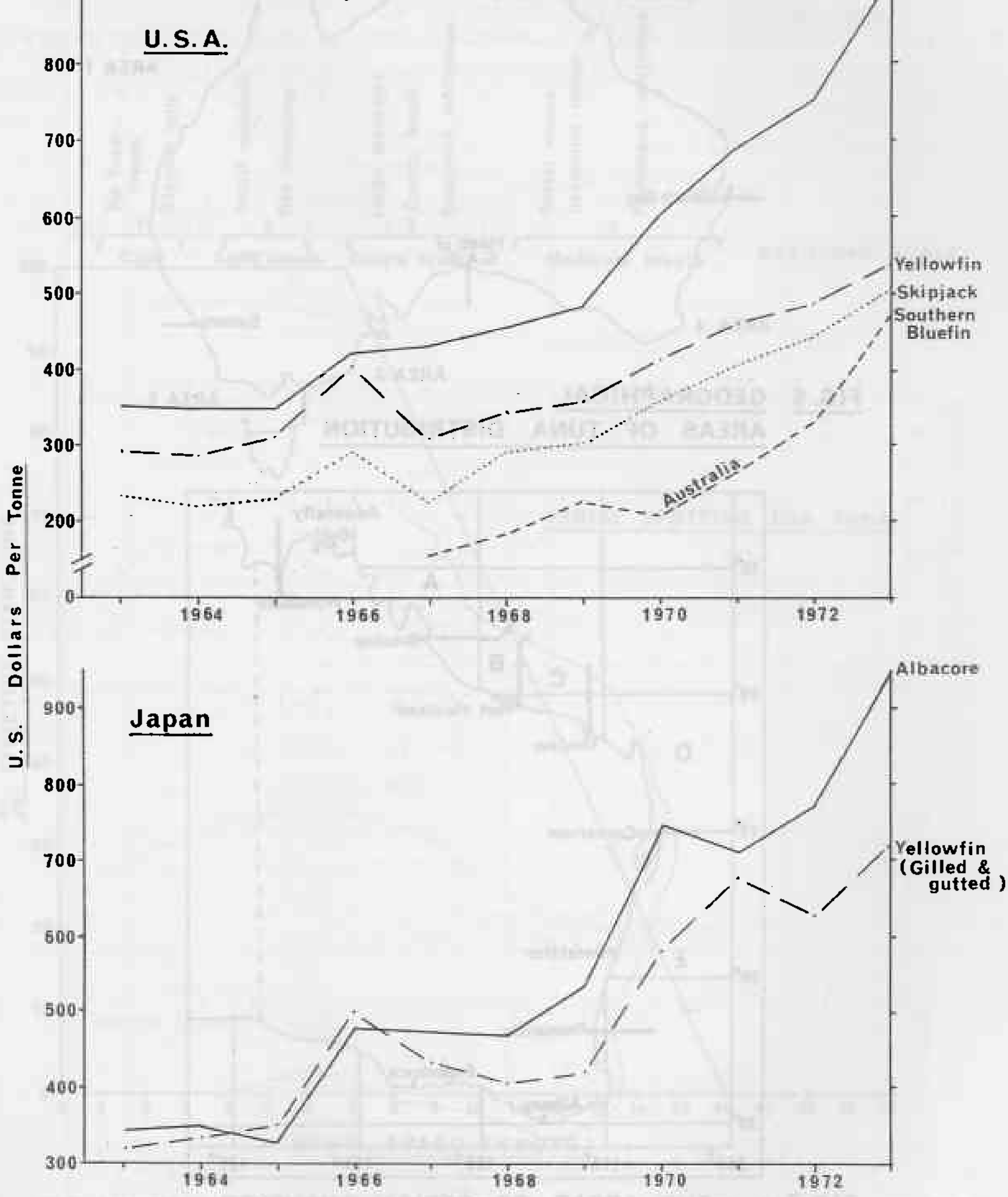


FIG. 5 TUNA PRICES (Yearly Averages For Selected Species)



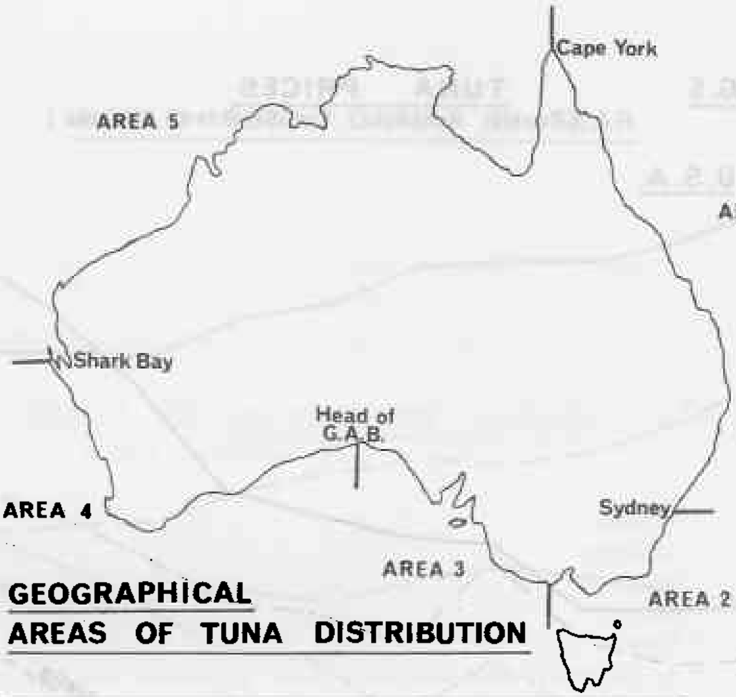



**FIG. 6** **GEOGRAPHICAL AREAS OF TUNA DISTRIBUTION**

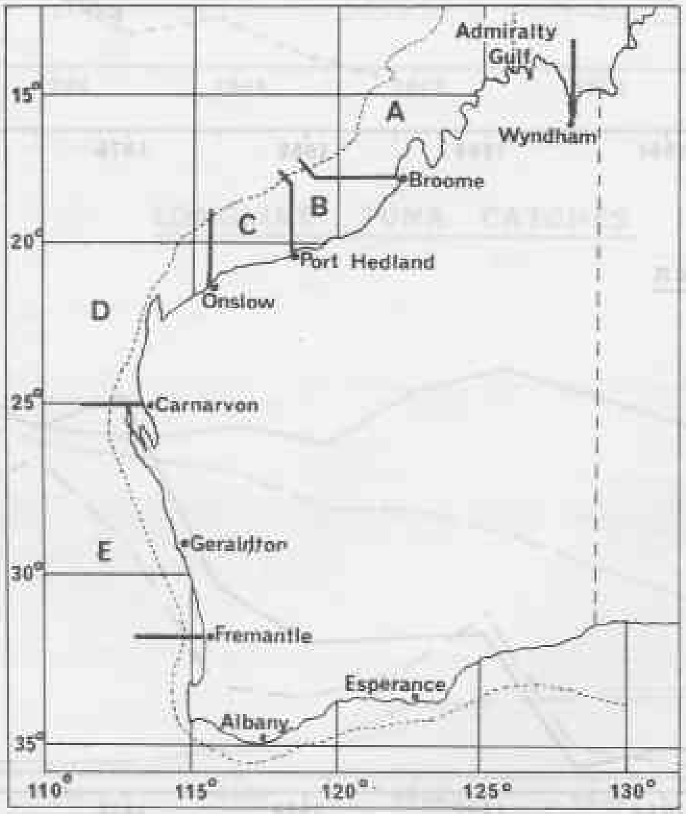



**FIG. 7** **SUB-AREAS OF REGION SURVEYED**

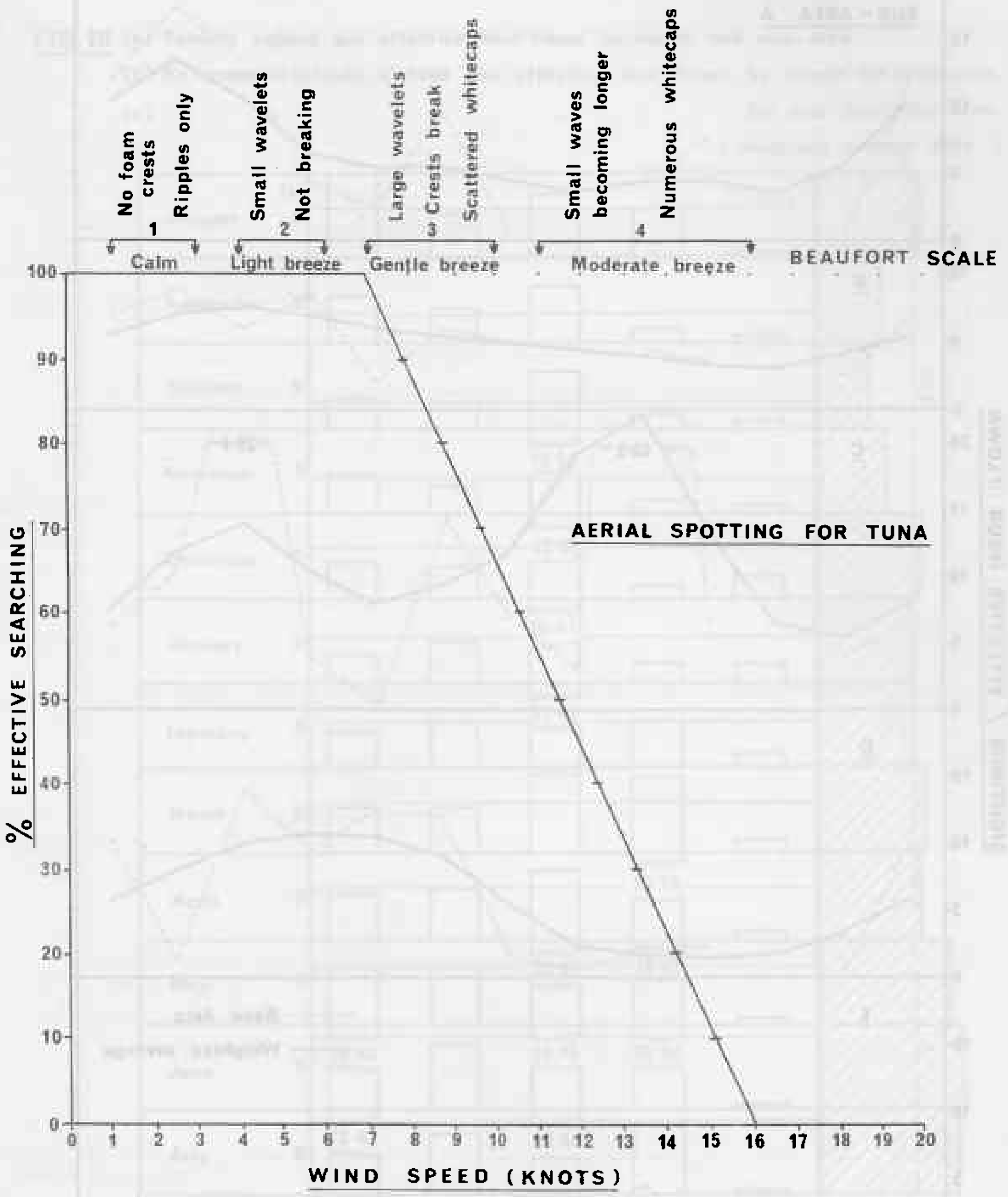



**FIG. 8 GRAPH FOR DETERMINATION OF EFFECTIVE SEARCHING TIME**

FIG. 9 TUNA SCHOOLS SIGHTED / E.H. / AREA / MONTH

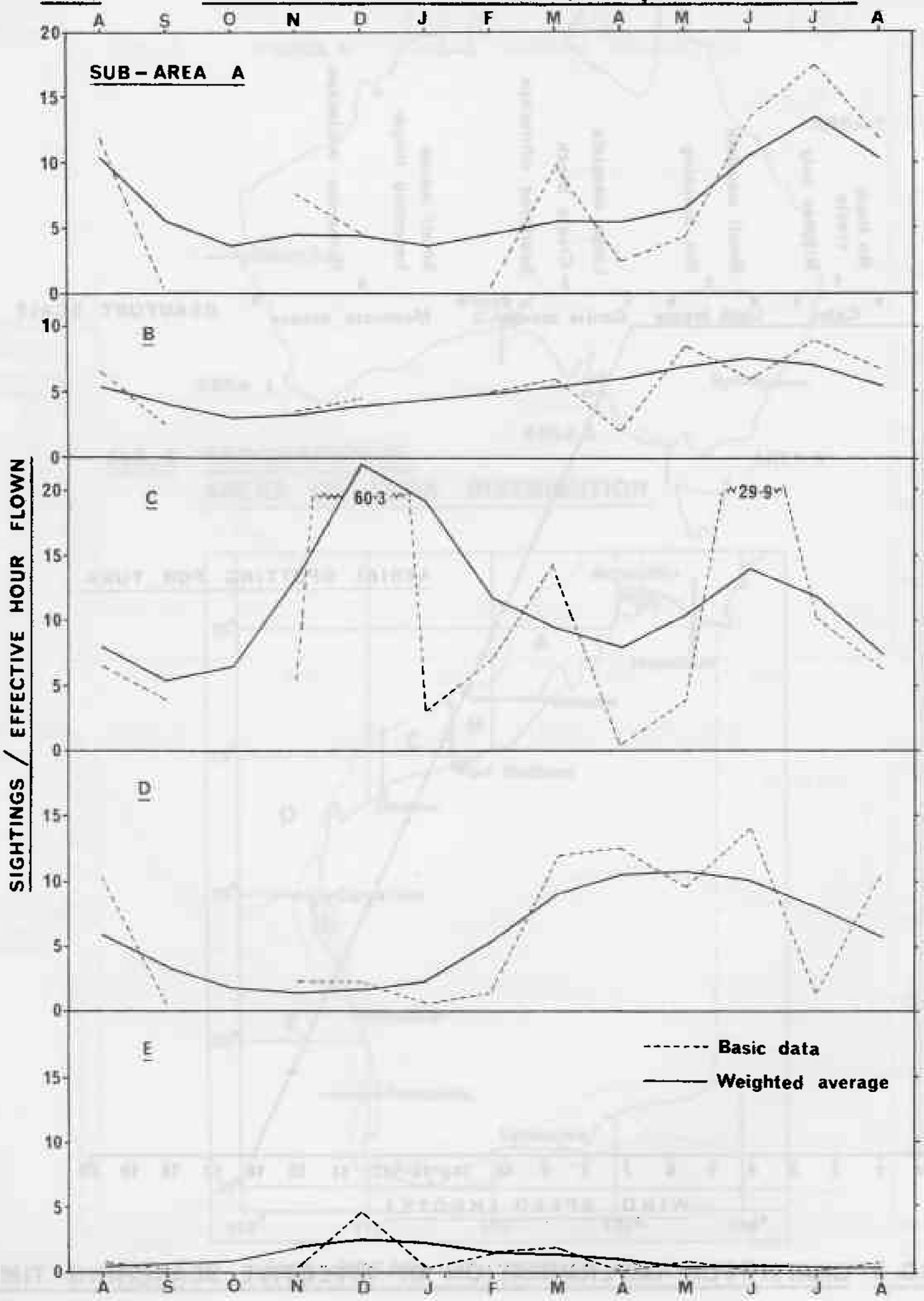


**FIG.10** (a) Schools sighted per effective hour flown by month and sub-area.
(b) Av. number of schools sighted per effective hour flown by month for total area.
(c) .. .. .. .. .. .. .. .. .. for year and total area.
( Weighted average data )

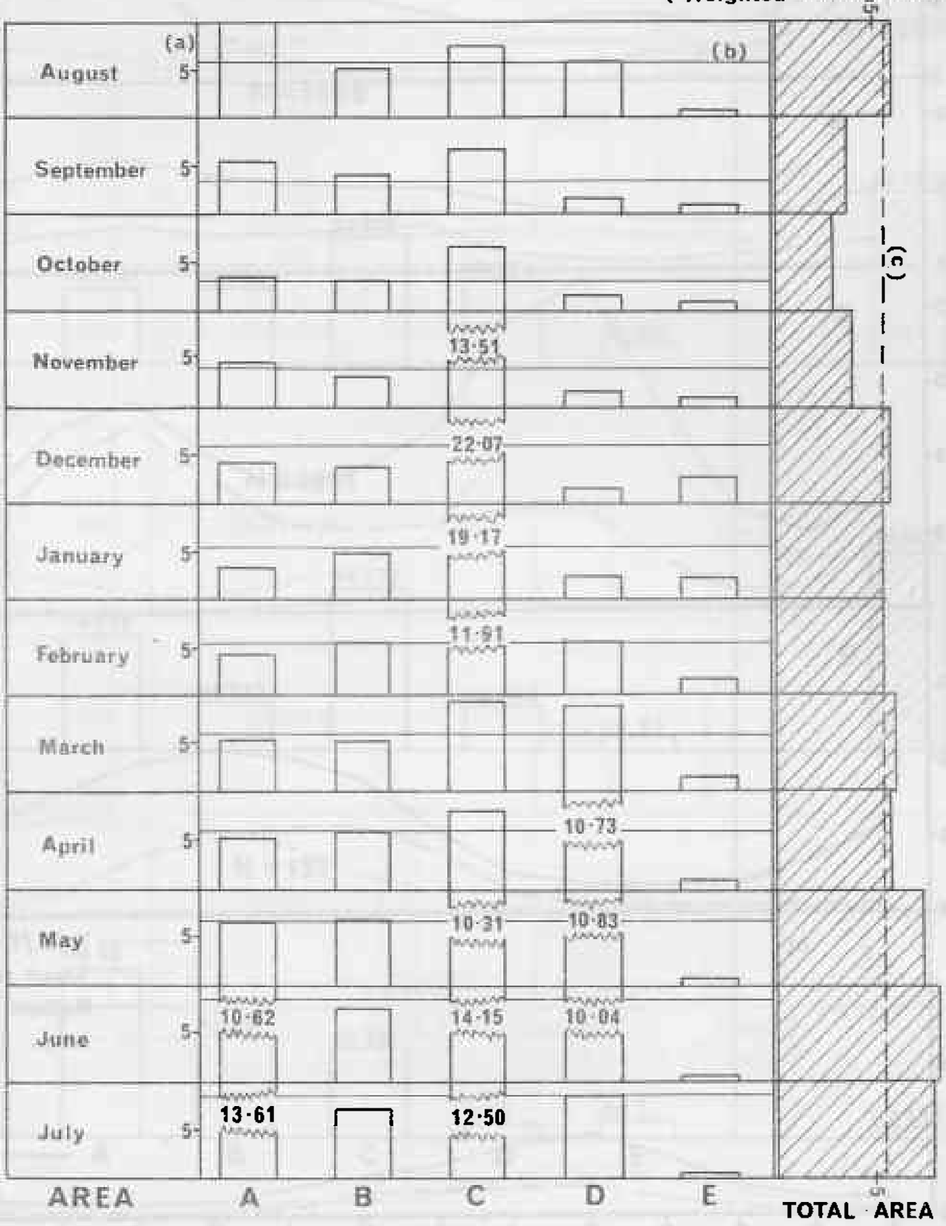


FIG.11 TUNA SCHOOLS SIGHTED / E.H./AREA/MONTH (Weighted Av.)

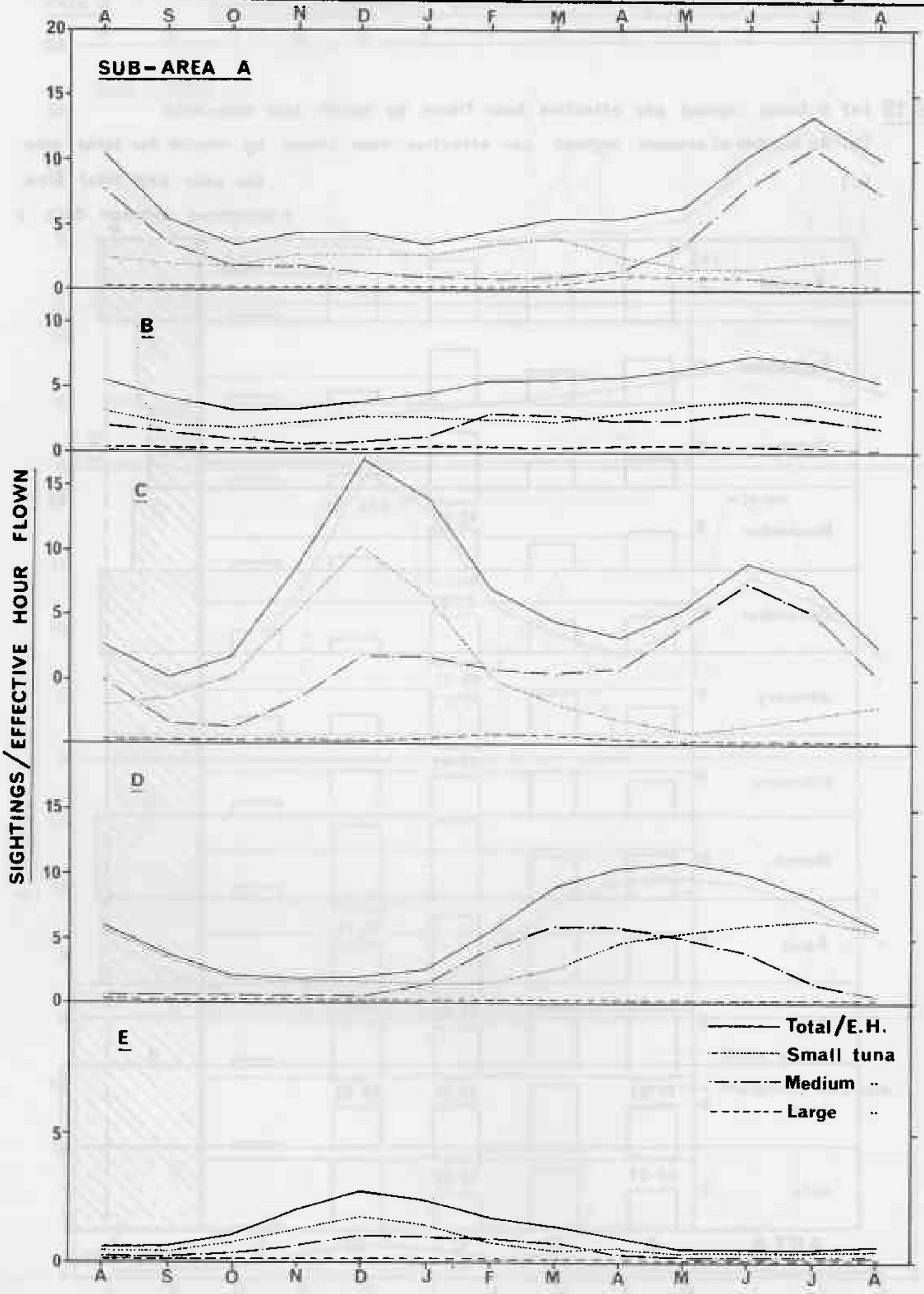


FIG. 12(a) Between sub-area proportions of different-sized tuna in schools. Between fish size proportions for total area.

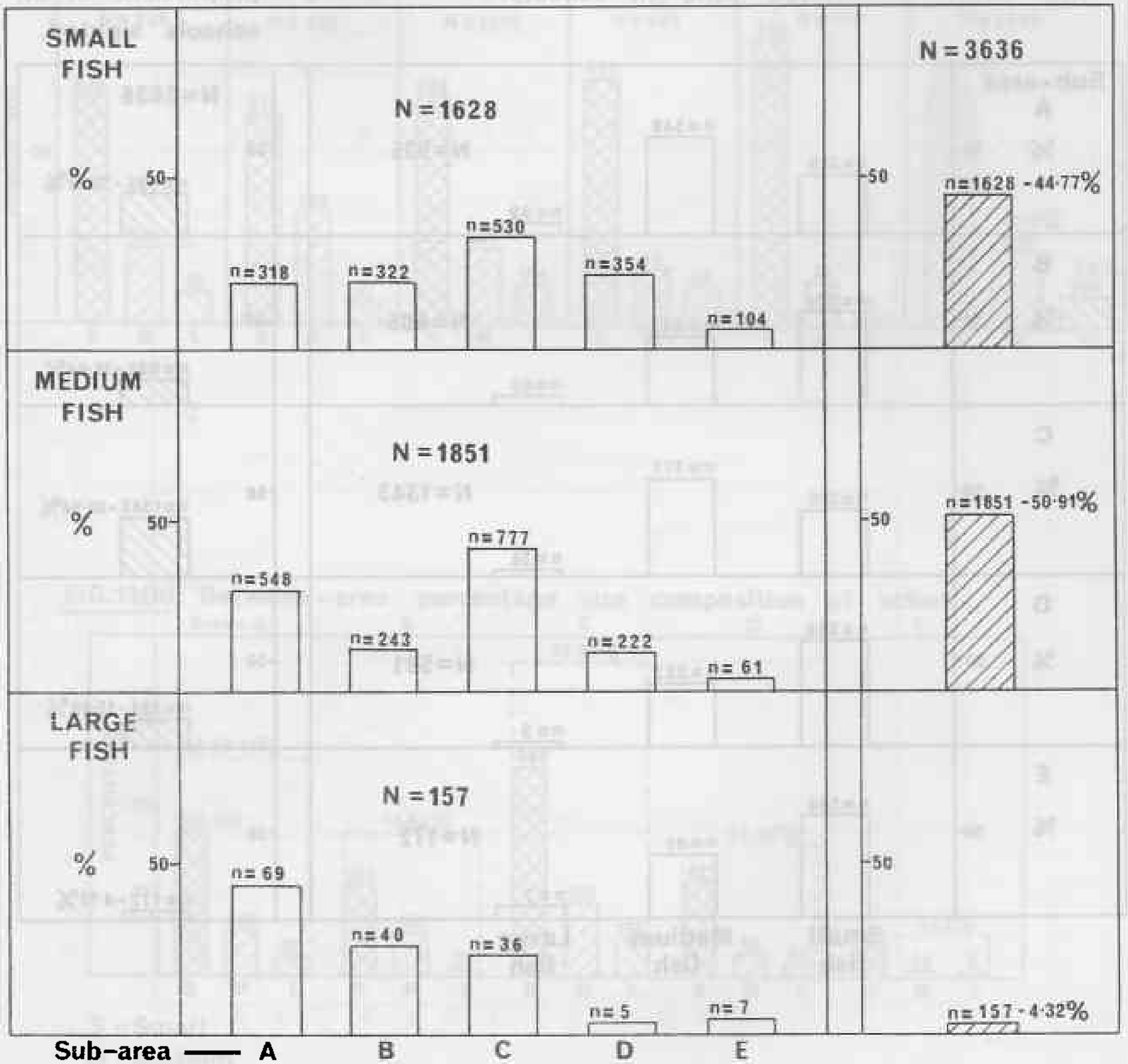


FIG. 12(b) Within sub-area proportions of different-sized tuna in schools. Between sub-area proportions of all schools sighted.

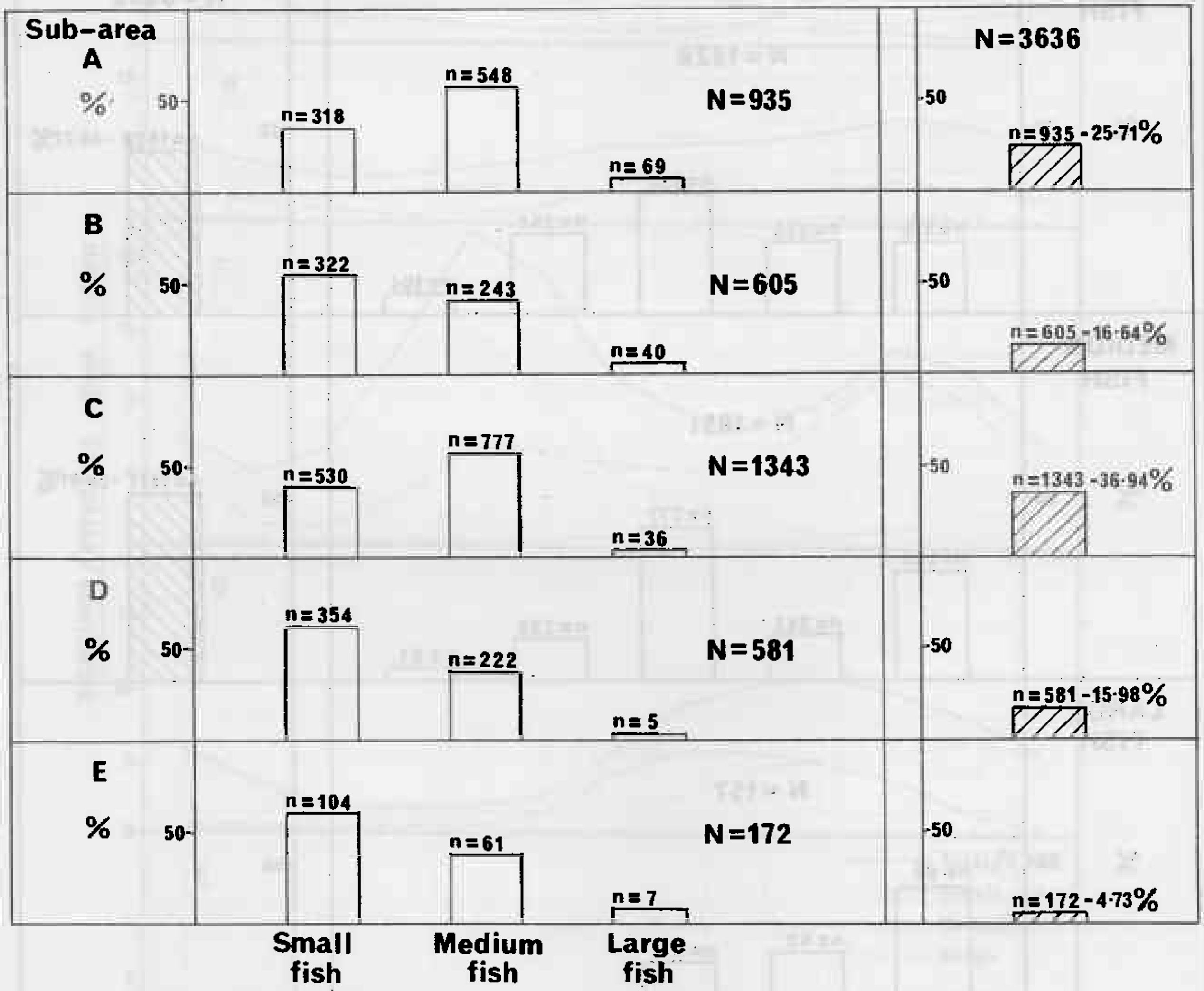


FIG.13(a) Within-area percentage size composition of schools.

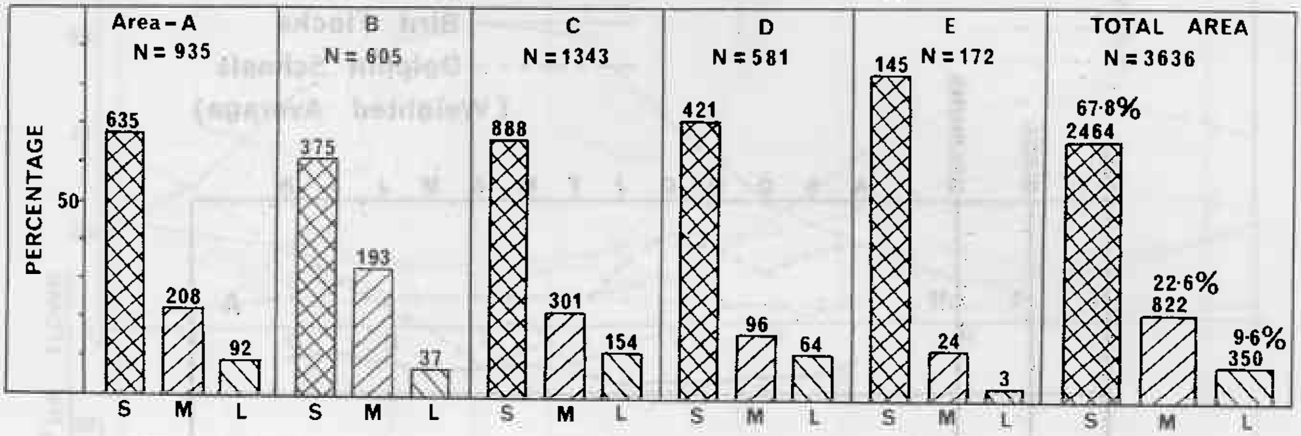
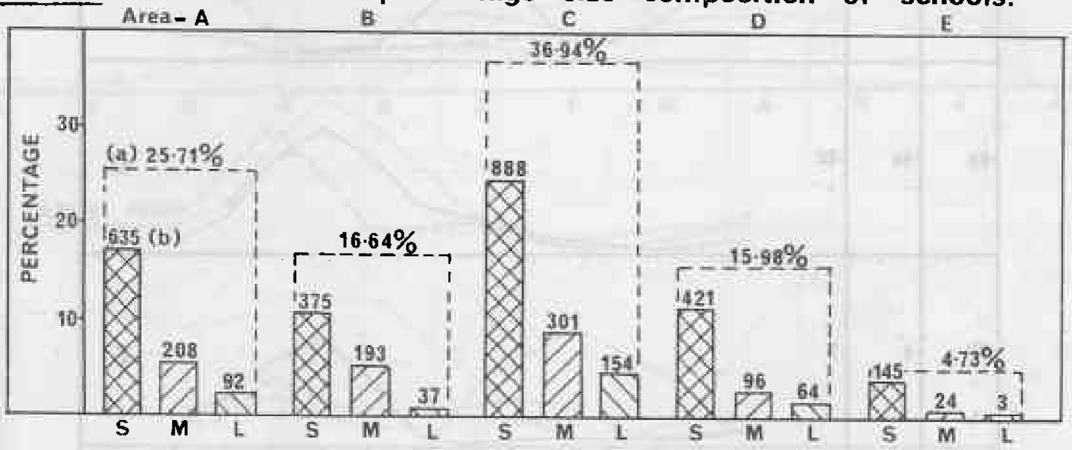



FIG.13(b) Between-area percentage size composition of schools.




S - Small
M - Medium
L - Large

FIG.14

**Sightings / E.H. / Area / Month of**

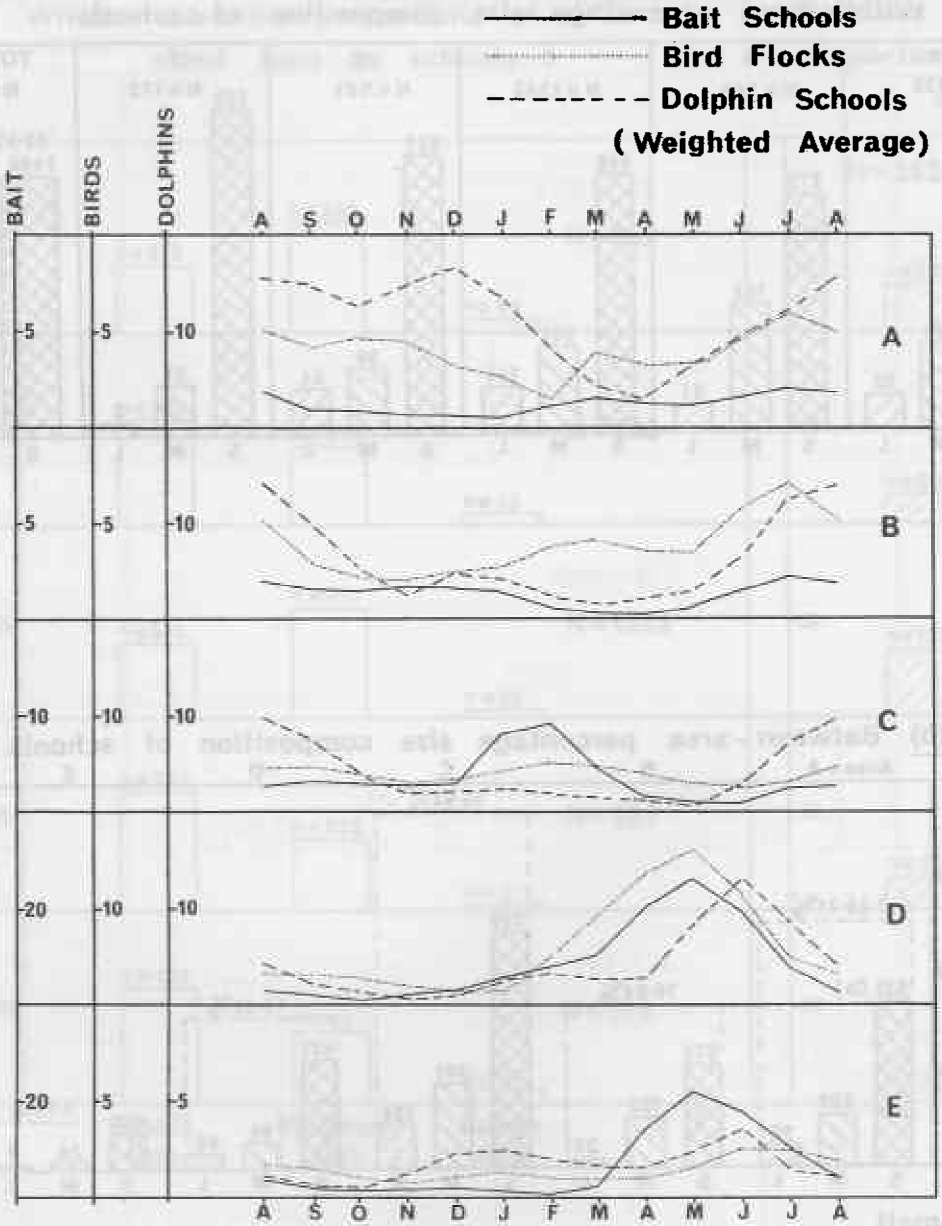
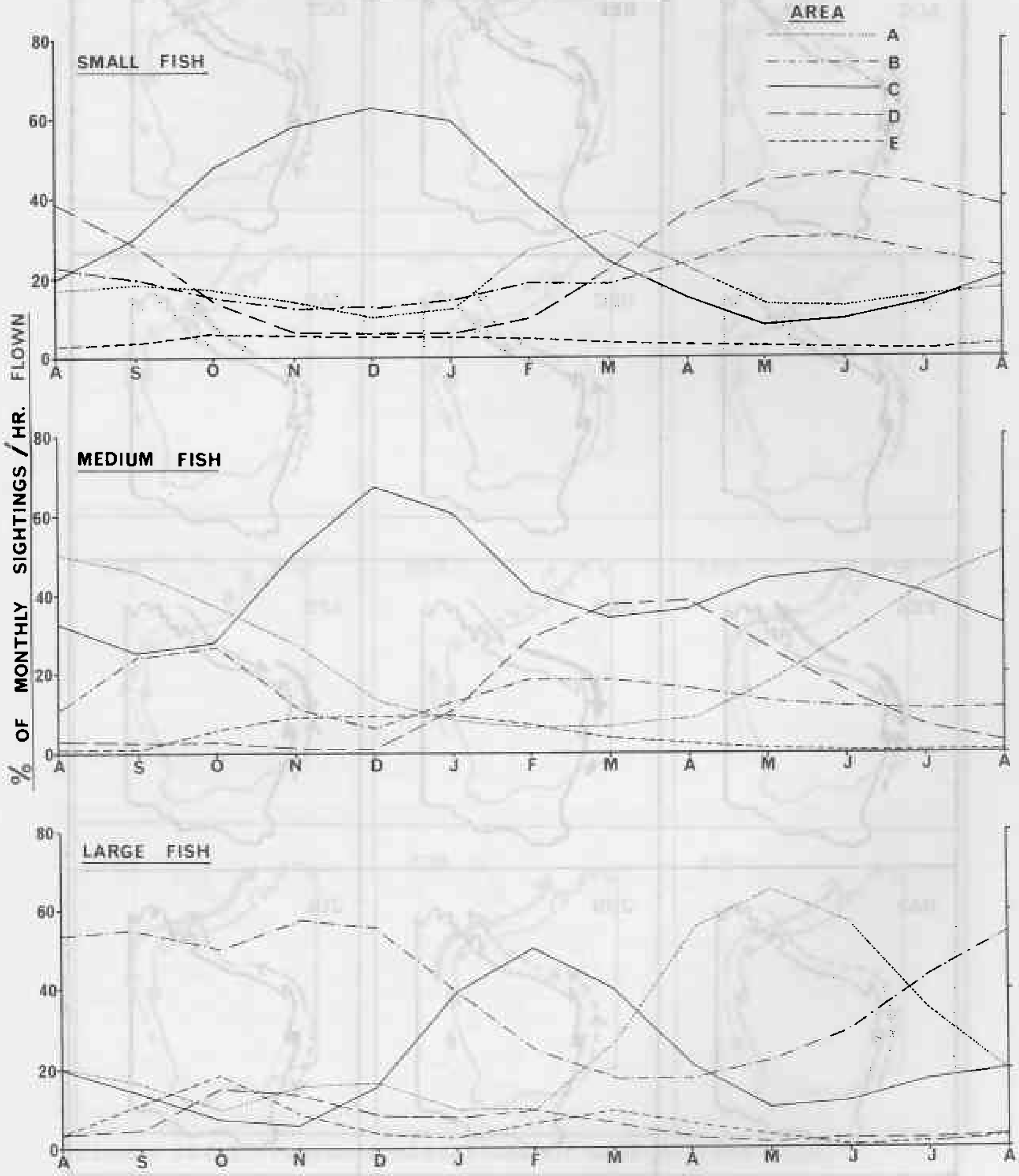


**FIG.15 Monthly percentage distribution, by area, of small-, medium and large-sized fish**



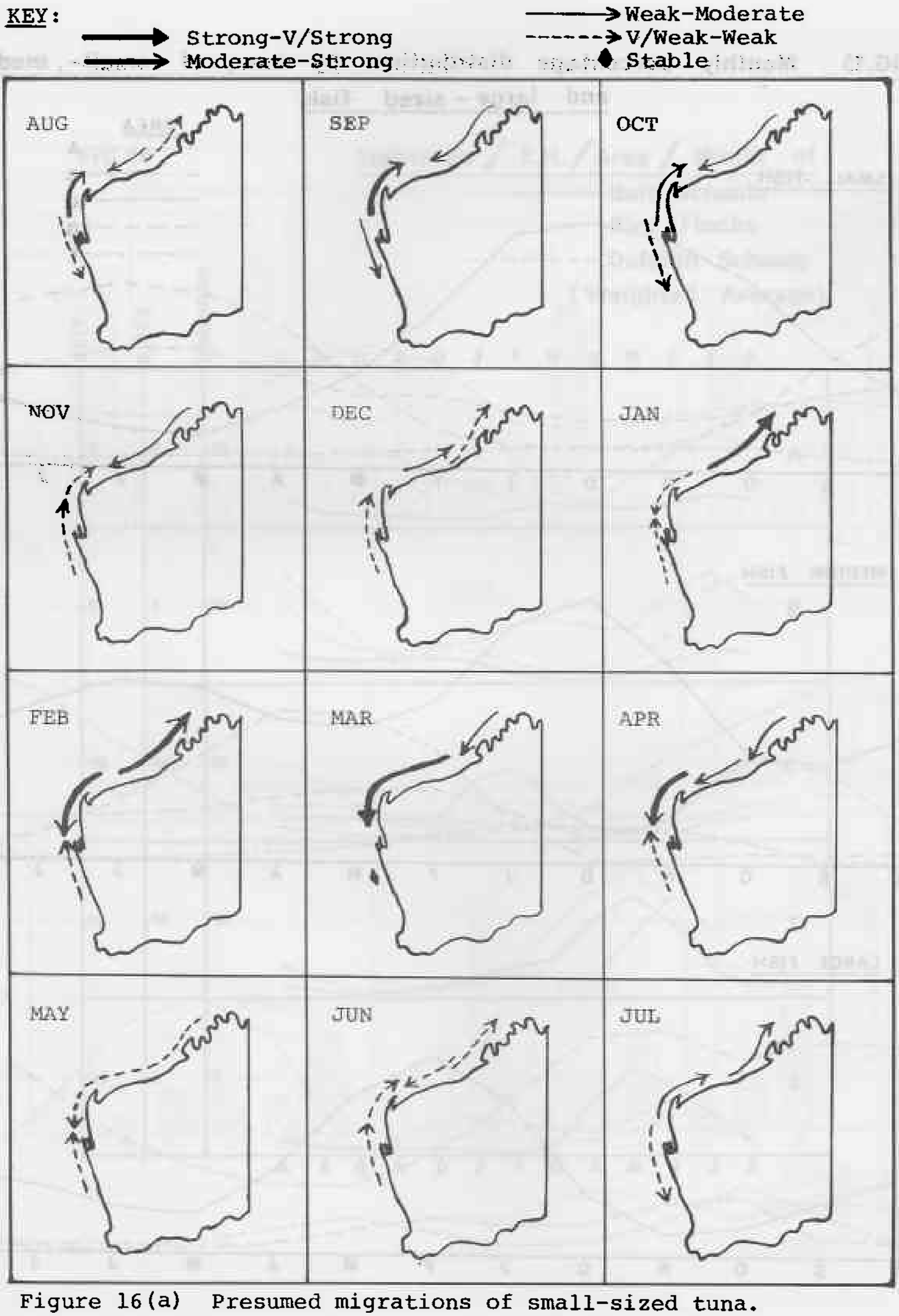



Figure 16(a) Presumed migrations of small-sized tuna.

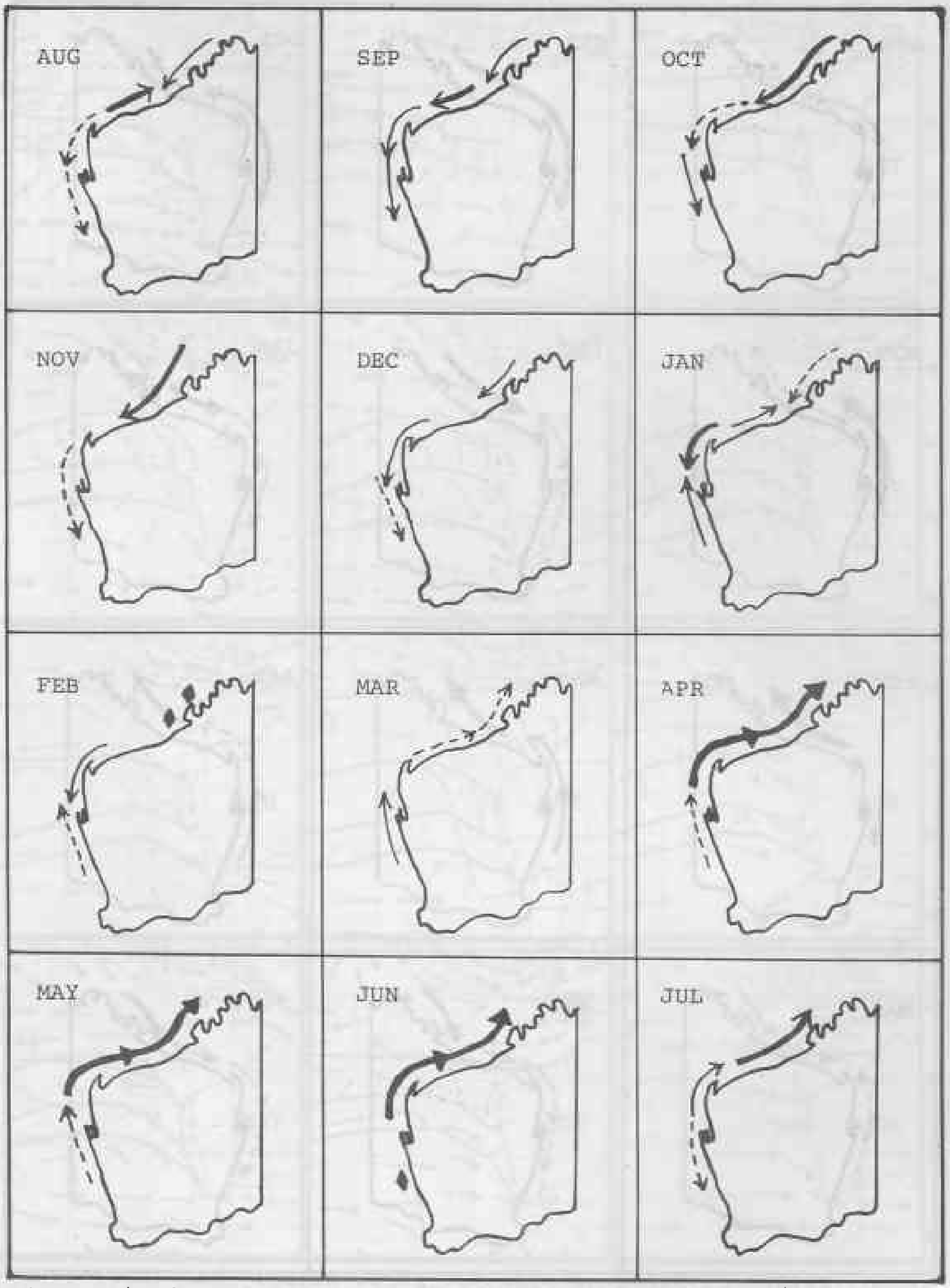


Figure 16(b) Presumed migrations of medium-sized tuna.

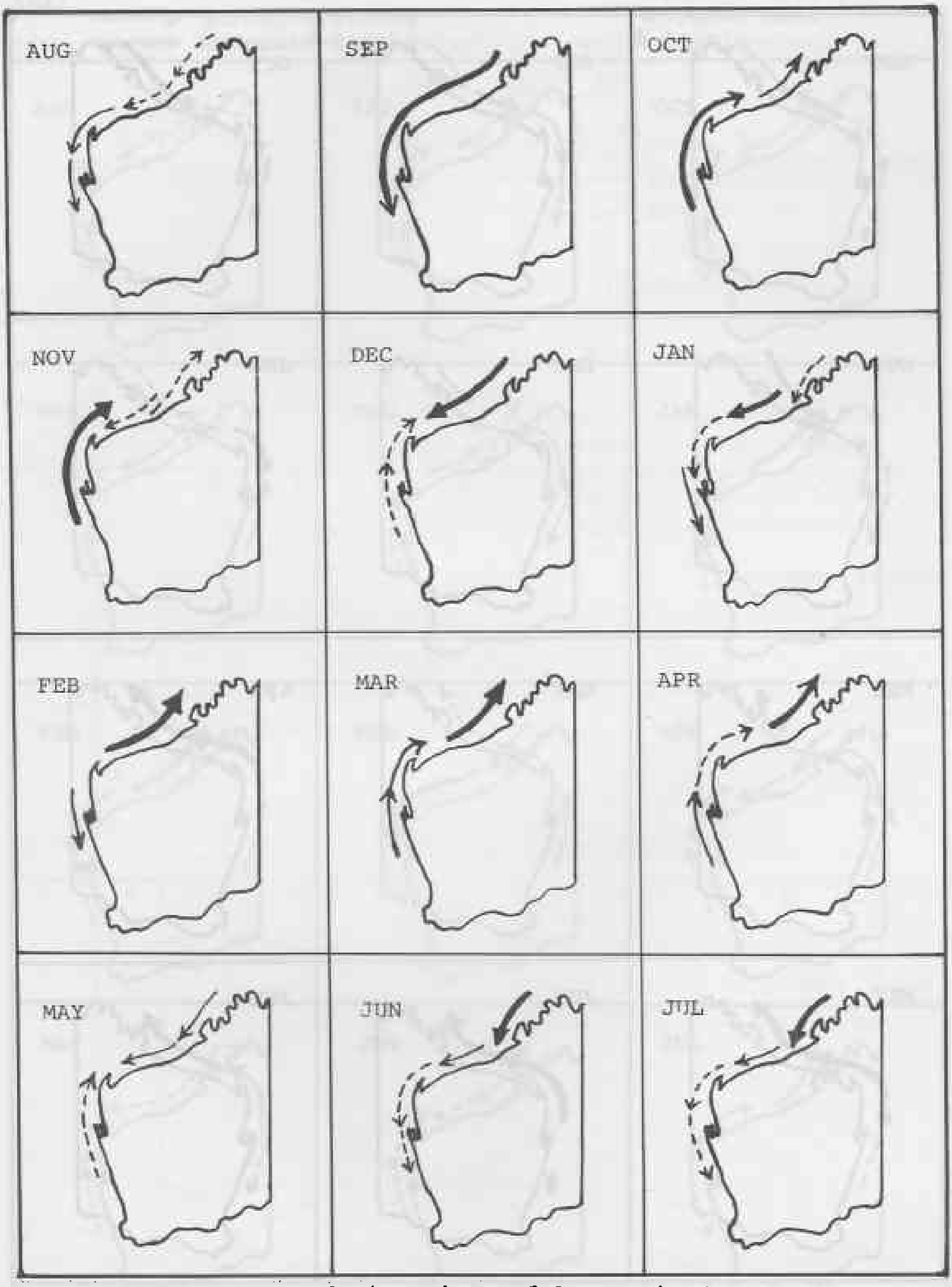



Figure 16(c) Presumed migrations of large-sized tuna.

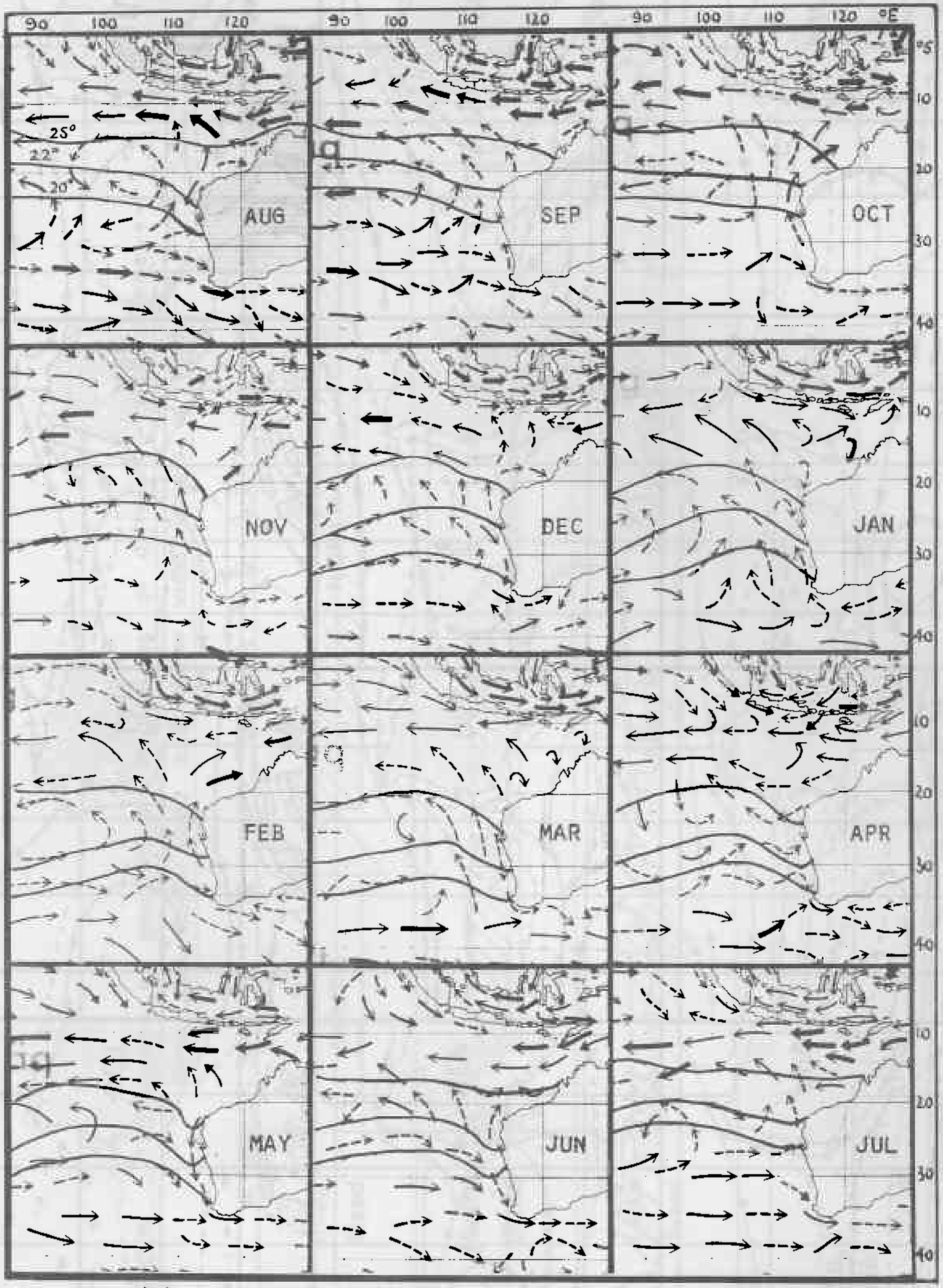



Figure 17(a) East Indian Ocean currents by month. (Source: Monatskarten für den Indischen Ozean (3rd Edition) - Deutsches Hydrographisches Institut, Hamburg 1960. Surface currents only.

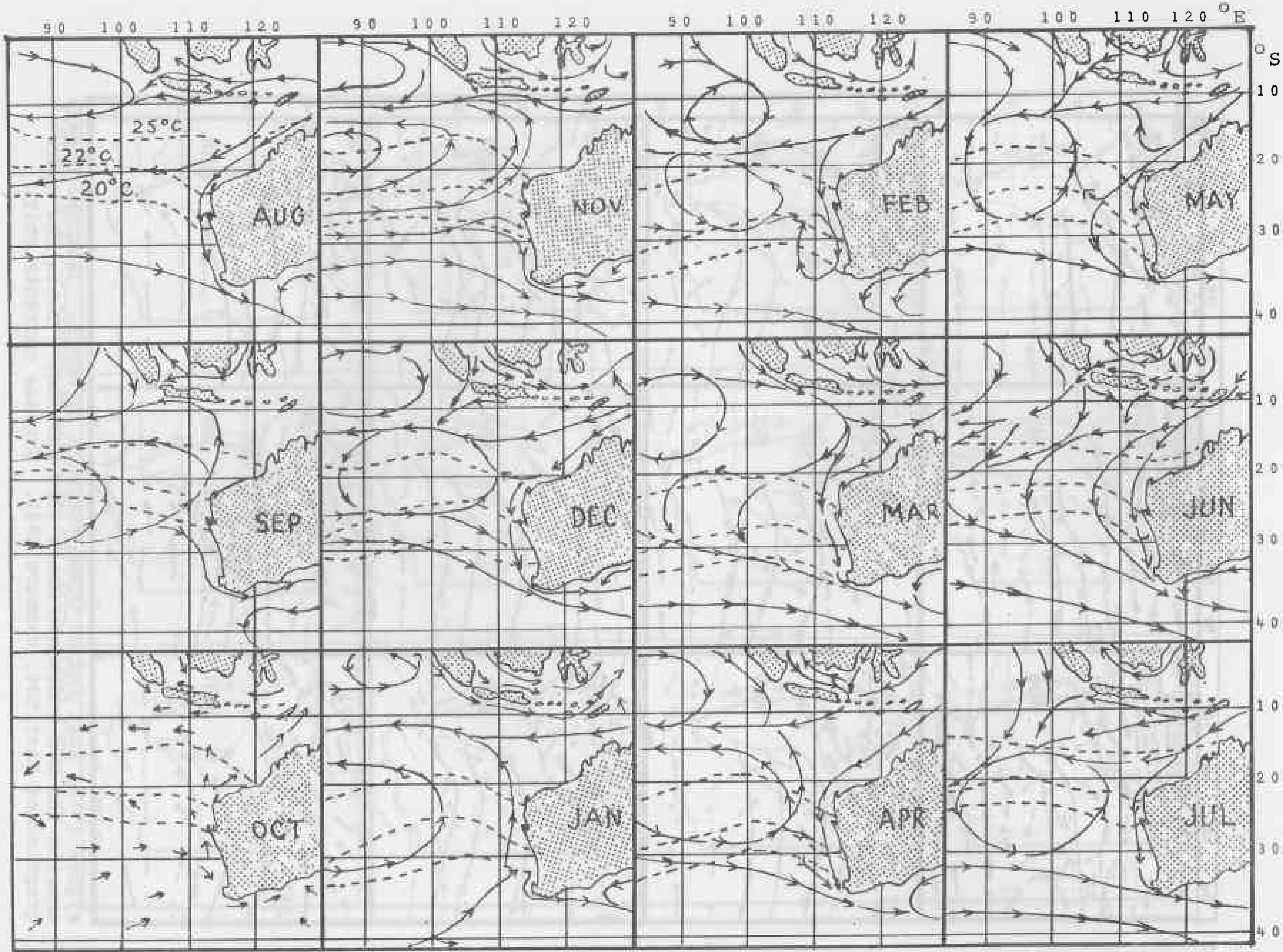



Figure 17(b) East Indian Ocean currents by month. (Source: Atlas of Pilot Charts - South Pacific and Indian Oceans - Publication No. 107. Defence Mapping Agency Hydrographic Centre, Washington D.C., U.S.A. Surface currents only.

FIG.18 Diagram of generalised migrations of different - sized tuna along the north - west and upper west coasts of W. A.