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DISTRIBUTION AND ABUNDANCE OF SKIPJACK TUNA LARVAE

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INTRODUCTION

The distribution of tuna larvae, particularly that of skipjack tuna, has been fairly well documented for the Pacific Ocean, and to a lesser degree for the Indian and Atlantic Oceans. The source of data has been mainly from plankton net tows and although a large number of net tows have been accumulated over the years by various agencies, the collective data suffer from differences in the size of nets, in towing methods, and from inadequate coverage in vital areas of the oceans. Consequently, while the data provide valuable qualitative information, they are not entirely reliable for oceanwide quantitative analyses. It is important, therefore, to examine the status of our knowledge concerning larval skipjack tuna and to point out what needs to be done.

DISTRIBUTION

The distribution of skipjack tuna larvae can be looked at from various aspects: geographically, vertically, environmentally, and seasonally.

(a) Geographic distribution.--We know that skipjack tuna larvae are found over extremely wide areas of the oceans. Figure 1 shows the capture sites of skipjack tuna larvae in the Pacific and Indian Oceans as obtained from the literature (Matsumoto 1958; Strasburg 1960; Klawe 1963, 1970, 1971, 1972, 1974; Nakamura and Matsumoto 1967; Ueyanagi 1969; Chen and Tan 1973) and from unpublished data (Southwest Fisheries Center, Fig. 1

Honolulu Laboratory files). The distribution is broad in the central and western Pacific (from 30°-35°N to 35°-40°S) and narrow in the eastern Pacific (from 15°N to 15°-20°S). Both the northern limit of distribution is relatively firm, but the southern limit could be better defined with additional sampling. The distribution in the Indian Ocean is not quite as extensive as in the Pacific, the northern boundary being limited to about 10°-12°N by the Asian Continent. The southern boundary could be modified with further sampling, particularly in the central and eastern sectors.

(b) Vertical distribution.--The vertical distribution of tuna larvae has been studied by various researchers. Matsumoto (1958) speculated that few tuna larvae occurred in waters much deeper than 50 m in the central Pacific, on the basis of simultaneous horizontal triple-net tows made at depths of 0, 50, 100; 0, 100, 200; 0, 150, 300 m. Klawe (1963) found no evidence of tuna larvae in waters deeper than the thermocline (12-48 m) in the eastern Pacific. Strasburg (1960), who used opening and closing nets, found six times more skipjack tuna larvae at the 0-60 m depth than at the 70-130 m depth, and practically none (only one larva) at the 140-200 m depth. He also found that surface tows caught twice as many skipjack tuna larvae as the 0-60 m depth tows. Finally, Ueyanagi (1969) found little difference in the catches of horizontal tows made simultaneously at the surface and at the 20-30 m depth. It is evident from these observations that skipjack tuna larvae are concentrated in waters near the surface, that the occurrence may be uniform to at least 30 m, and that only a small portion is found in depths greater than 60 m.

(c) Distribution relative to thermocline.--The absence of skipjack tuna larvae below the thermocline in the eastern Pacific (Klawe 1963) could be a valid local phenomenon. In the central Pacific, the situation may be quite different. Strasburg (1960), in analyzing the catches of tuna larvae taken in opening- and closing-net tows, showed that while most of the skipjack tuna larvae were found above the thermocline (79 larvae in 6 tows), some were found at greater depths (8 larvae in 3 tows at 70-130 m and 1 larva at 140-200 m). The thermocline depth in the sampling area ranged from 30 to 60 m.

(d) Distribution relative to surface currents.--The broad latitudinal distribution of skipjack tuna larvae in the western Pacific and the narrow distribution in the eastern Pacific (Figure 1) is primarily due to the prevailing surface currents (Matsumoto 1975). In the western part of the ocean, the equatorial currents flow poleward, carrying warm water suitable for skipjack tuna spawning away from the equatorial region and thereby expanding the spawning area. Conversely, in the eastern part of the ocean, cold currents from high latitudes flow toward the equator causing the area of warm water favorable for spawning to be contracted to a relatively narrow band along the equator. The configuration of the warm area in the Pacific is shown by the 24°C isotherms in Figure 1. Differences in the surface current patterns in the Indian Ocean cause the distribution of skipjack tuna larvae there to differ from that in the Pacific Ocean. The distribution in the eastern sector is not narrowed as it is in the Pacific because the short western Australian coast, which terminates at around 35°S, does not extend southward far enough to effectively funnel the cold polar water northward as the South American Continent does in the Pacific Ocean. The northward extension of the distribution, of course, is restricted by the Asian Continent.

(e) Surface temperature.--The mean 24°C isotherms shown in Figure 1 fairly well define the northern and southern limits of larval skipjack tuna distribution. The isotherms shown represent that of the warmest month in each hemisphere, i.e., northern summer in the north and southern summer in the south. The several points shown outside of the isotherms represent catches made either in colder water or in years when the warm water may have been displaced farther poleward.

Both the minimum and maximum temperatures for larval skipjack tuna occurrence have been found to differ by areas. In the western North Pacific, a summary of surface night tows from 10 cruises of the *Shunyo Maru* (data from Ueyanagi 1969) showed that all except one larva were taken in waters 25°-29°C. The one exception was a larva taken in 30°C water. The most productive tows were in 28°C water, while the lowest temperature in which skipjack larvae were caught was 23.5°C in a subsurface tow. In the central North Pacific (Hawaiian Islands area) a summary of surface night tows from nine cruises of the *Cromwell* (Matsumoto and Skillman, MS[1]) showed that nearly all of the skipjack tuna

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[1] Matsumoto, W. M., and R. A. Skillman. Synopsis of biological data on skipjack tuna, *Katsuwonus pelamis* (Linnaeus). Manuscript in preparation. Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

larvae taken had been from waters 23° to 26°C, and the most productive tows in terms of occurrence and number of larvae were in 25° and 24°C, water, respectively. The lowest temperature in which skipjack tuna larvae were caught was 22.1°C.

(f) Seasonal distribution.--It is generally known that skipjack tuna spawn the year round in tropical waters, and seasonally in subtropical waters. The seasonal shifts in the distribution of skipjack larvae are clearly seen in the western North Pacific (Figures 2a and 2b). Seasonal spawning occurs in Hawaiian waters also, but it is not evident from the figures because the longer spawning period there, March or April to October or November, extends beyond the 6-month period used to designate the warm and cold seasons in the figures (the figures were reproduced mainly from Ueyanagi 1969). Seasonal shifts in the distribution of larvae is not evident in the western South Pacific (west of 140°W) because of insufficient sampling south of 25°S in the southern summer (Figure 2a). Many of the larval captures shown south of 30°S in the southern winter in both the Pacific and Indian Oceans (Figure 2b) could be due to (a) the spawning seasons not being coincident with the designated 6-month period, much as was the case in the Hawaiian area, (b) larvae taken in waters nearer the lower temperature limit, or (c) larvae taken in years when the southward shift of warm water was at its maximum.

Although it may be generalized that spawning occurs throughout the year in tropical waters, Honolulu Laboratory data indicate that seasonal differences may sometimes occur there. Plankton net tows made at 3-month intervals over a 14-month period at five stations along long.

145°W between lat. 12°N and 3°S resulted in no larval skipjack tuna captures in one or more seasons at each of the site sampled, and no captures at all sites sampled in winter (Table 1). Table 1

RELATIVE ABUNDANCE

Past attempts at measuring relative abundance have relied primarily upon catch rates. Ueyanagi (1969) compared the relative abundance of skipjack tuna larvae, including that of other tunas, across the equatorial Pacific between 0° and 10°N. His comparison was based on the average catch (catch per tow) of larvae taken in 15-min surface horizontal tows with a 1.4-m net. His results indicated an increase in the density of skipjack tuna larvae westward (Figure 3), but because the comparison was restricted to only 10° latitude and did not include areas of heavy spawning outside of the 0°-10°N zone, his results may not truly represent larval skipjack tuna abundance across the entire Pacific. Fig. 3

Matsumoto (1975) also attempted measuring relative abundance of skipjack tuna larvae across the Pacific. Using data from various sources, he adjusted the catches made with different net sizes and towing durations, and included tows taken only during spawning seasons from a wider latitudinal range than Ueyanagi (Table 2). The high spawning densities between long. 140°W and 160°E, with the peak at slightly east of 180° (Figure 4), differed from Ueyanagi's results. One probable weakness in the results was the relatively small numbers of Table 2 Fig. 4

tows in the central and eastern Pacific. However, the similarity in the catch trends of both larval and adult skipjack tuna, the latter taken on tuna longline in areas and seasons comparable to those of larval captures, suggests that the limited number of net tows had not noticeably biased the results.

PREDICTING AVAILABILITY FROM LARVAL DATA

(a) Past attempts.--Attempts to predict the availability or potential production of harvestable skipjack tuna have been made by the Japanese. Ueyanagi (In Kikawa, Koto, Shingu, and Nishikawa 1969) estimated a skipjack tuna resource of 800,000 to 1,000,000 metric tons (MT) in the Pacific Ocean on the basis of larval occurrences and 300,000 to 400,000 MT in the Indian Ocean on the basis of proportionate favorable spawning areas in the two oceans. Suda (In Kawasaki 1972) elaborated on these estimates by saying that since 1.7-1.8 times (rounded to 2) more skipjack tuna larvae were taken in plankton tows than larvae of all other tunas, the spawning stock of skipjack tuna was also roughly 2 times that of other tunas and that therefore the potential production of skipjack tuna should be at least 2 times more than that of all other tunas. Since the annual production of large tunas from the Pacific is 400,000 to 500,000 MT, the potential production of skipjack tuna was between 800,000 and 1,000,000 MT. He further believed that, on the basis of ocean areas (probably of areas suitable for skipjack tuna), there was a standing stock of 200,000 to 400,000 MT of skipjack tuna in each of these oceans.

Both Kawasaki (1972) and Matsumoto (1974) felt that Suda's projection of adult skipjack tuna catch from larval abundance was oversimplified. By citing differences in fecundity and average body sizes between skipjack and other tunas, Matsumoto showed that Suda's conversion ratio of 2:1 in favor of the skipjack tuna was not logical. One other important factor not taken into account by Suda was the difference in the efficiency of the different types of gear used in taking the various species of tunas and the effect this would have on the conversion ratio.

(b) Other approaches.--A better approach in using larval data to predict availability of adults would be to consider the skipjack tuna apart from other tunas. This would eliminate the need to adjust for fish size, where all other tunas are grouped into one, size of spawnings (which also vary greatly by species and fish size), and for the vast differences in the efficiency of fishing gear presently used in catching the various species of tunas (longline versus pole and line and purse seine). Furthermore, if we accept Fujino's (1972) separation of the skipjack tuna population into a western Pacific subpopulation and central-eastern (C-E) Pacific subpopulation as being valid, and we consider that the western subpopulation is now being harvested at near its maximum yield (some authors already believe that the catch in the western Pacific cannot be increased appreciably), then we can make a more reliable estimate of the skipjack tuna potential in the Pacific Ocean.

For example, assuming that the figures of relative abundance given by Matsumoto (1975) and discussed above are valid, the catch per tow of skipjack tuna larvae east of 180° projects to be 2.32 times that west of 160°E (omitting for the present the data from long. 160°E-180°, since the boundaries of the two subpopulations run through there with possible mixing occurring at those boundaries. If we further assume that larval abundance in the western Pacific is proportional to the adult population there and that the same proportionality holds true in the central and eastern Pacific, we could estimate the harvestable C-E subpopulation of skipjack tuna to be about 464,000 MT, based on 200,000 MT as representing the present harvest in the western Pacific. But, since nearly 100,000 MT are now being harvested in the central and eastern Pacific, roughly only 360,000 MT of additional skipjack tuna could be taken there. The total potential harvest of skipjack tuna in the Pacific Ocean thus would be somewhere slightly above 660,000 MT, well below the 800,000-1,000,000 MT estimated by Ueyanagi and Suda.

Although the procedure followed here in obtaining the estimates may be an improvement over that used by Ueyanagi and Suda, the accuracy of the estimates could be contested because the estimates are based on relatively few plankton tows in the areas east of long. 180° (Table 2).

REMARKS ON PAST DATA

It is unfortunate that despite the numerous plankton net samples collected to date throughout the Pacific Ocean, involving effort in decades and tows in the thousands, the larval skipjack tuna catch data from the western and central Pacific cannot be compared directly, owing to differences in net sizes and towing methods used. Initially, probably because of the need for large numbers of larvae to permit studies on species identification and developmental stages, Japanese workers resorted to the use of large nets, 1.4 and 2.0 m in diameter, without the use of flowmeters and towed for short periods (15-20 min.) at or near the surface. Such large nets often assured large catches, but the short towing time usually resulted in lower percentage of successful tows (Figure 3) because of patchy distribution of the larvae, unless sampling had occurred in areas of unusually heavy concentrations of patches of larvae. The absence of a flowmeter, of course, made the data suspect for quantitative assessments, since the catch per tow values could be biased considerably, depending upon variations in the towing speed from day to day and from cruise to cruise, from changing weather and sea conditions, and even from towing in directions other than the normal 10° to 15° heading from the prevailing seas.

In the eastern and central Pacific, larval fish sampling has been done primarily with a 1-m net equipped with a flowmeter. The tows, however, were planned mainly for other studies, such as assessment of zooplankton and fish eggs and larvae. Consequently, most of these tows were made to depths well beyond the range of larval tunas. Some sampling at or near the surface have been done in the central and eastern Pacific, but the number and areal coverage by such tows has not been adequate enough for assessing larval tuna abundance on an oceanwide basis (Table 2).

Some years ago the Working Party on Method of Collecting Tuna Larvae, FAO Expert Panel for the Facilitation of Tuna Research, recommended the use of a 1-m plankton net with flowmeter and a 30-min. oblique tow to 60 m as the standard for sampling tuna larvae (Matsumoto et al. 1966). However, sampling for tuna larvae since then has been at a low level and the recommended tow has not come into general usage due to various reasons. In the eastern Pacific, for example, where tows to 200 m have been the standard for many decades to monitor all fish larvae, a shallower tow would have been inadequate for their purpose, and making an additional tow specially for tuna larvae would have meant doubling the cost of processing the samples; a cost most agencies would not be able to bear.

ACTION AND STUDIES REQUIRED

(a) Although adding a special plankton net tow for tuna larvae to the existing sampling procedures would entail added costs, such an attempt must be made if we wish to obtain more information from larval tuna data. One way to reduce the cost of an added tow would be to sort the samples for tuna larvae at sea prior to fixing them in Formalin.[2] This was done on several occasions by the Honlulu Laboratory with good results. Although sorting at sea is difficult at times, especially during rough weather, sorting freshly caught samples only for tuna larvae, was found to be much easier and required less time (less than an hour for most 30-min. samples) than sorting through preserved samples.

(b) Future north-south sampling transects should extend between the 24°C isotherms in the northern and southern hemispheres or at least between lat. 20°N and 20°S, with nearly equal runs within each 15°-20° longitude interval across the entire Pacific Ocean. Sampling, of course, should be done with a uniform net towed in an identical manner.

(c) During the time the samples are being accumulated, experimental work comparing the 2- and 1-m nets, and the 1.4- and 1-m nets, should be initiated to obtain a more reliable conversion factor from the existing data and to derive a better usable measure of abundance across the Pacific Ocean.

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[2] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

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Table 1.--Larval skipjack taken in plankton net tows along long. 145°W.

Month (Season)	May (Spring)	July (Summer)	October (Fall)	January (Winter)	April (Spring)
Location	Larvae/1000m^3 (No. of tows)				
12°00'N	0.05(11)	0.05(12)	0.04(15)	0.00(16)	0.00(14)
7°30'N	0.20(15)	0.00(14)	0.17(15)	0.00(9)	0.20(13)
3°30'N	1.23(15)	0.05(15)	0.00(17)	0.00(6)	0.00(15)
0°	0.14(12)	0.65(15)	0.00(15)	0.00(15)	2.91(15)
3°30'S	0.04(14)	2.45(15)	0.14(17)	0.00(12)	1.11(15)

Table 2.--Catch rates of larval skipjack in night surface tows across the Pacific Ocean.

Longitude	Latitude	Quarter sampled	Net diameter	Duration of tow	Number of tows	Total larvae	Conversion factor	Adjusted catch	Adjusted larvae per tow
			Meter	*Minutes*		*Number*			
80°-100°W	4°-15°N	I, II	1	30	33	7	[2]1.836	12.85	0.39
100°-120°W	10°-15°N	II	1	30	10	11	[2]1.836	20.20	1.63
100°-120°W	0°-7°S	I	1	30	12	19	[3]0.827	15.71	
120°-140°W	10°S-10°N	I, IV	1	30	21	42	[3]0.827	34.73	1.65
140°-160°W	10°S-20°N	I, III	1	30	32	239	[3]0.827	195.18	6.10
160°W-180°	10°S-20°N	I, II, III	1	30	45	389	[3]0.827	321.70	7.15
160°E-180°	10°S-20°N	I, III	1	30	6	45	[3]0.827	37.22	4.94
160°E-180°	10°S-20°N	II, IV	2	20	44	560	[4]0.375	210.00	
140°-160°E	10°S-20°N	II, III, IV	2	20	112	562	[4]0.375	210.75	1.88
120°-140°E	0°-20°N	II, IV	2	20	141	581	[4]0.375	217.88	1.54

[1] Conversion factor is the ratio of standard to average volume of water strained. Standard volume used was 1,454 m^3.

[2] Computed from average volume of 792 m^3 from 62 tows in the eastern Pacific. (Data from Klawe 1963.)

[3] Computed from average volume of 1,759 m^3 from 289 tows in the central Pacific. (Data from BCF Biological Laboratory, Honolulu files and Strasburg 1960.)

[4] Computed from estimated volume of 3,878 m^3, the volume strained at a given towing speed of 1.03 m/s (2 knots) in the western Pacific. (Catch data from Ueyanagi 1969.)

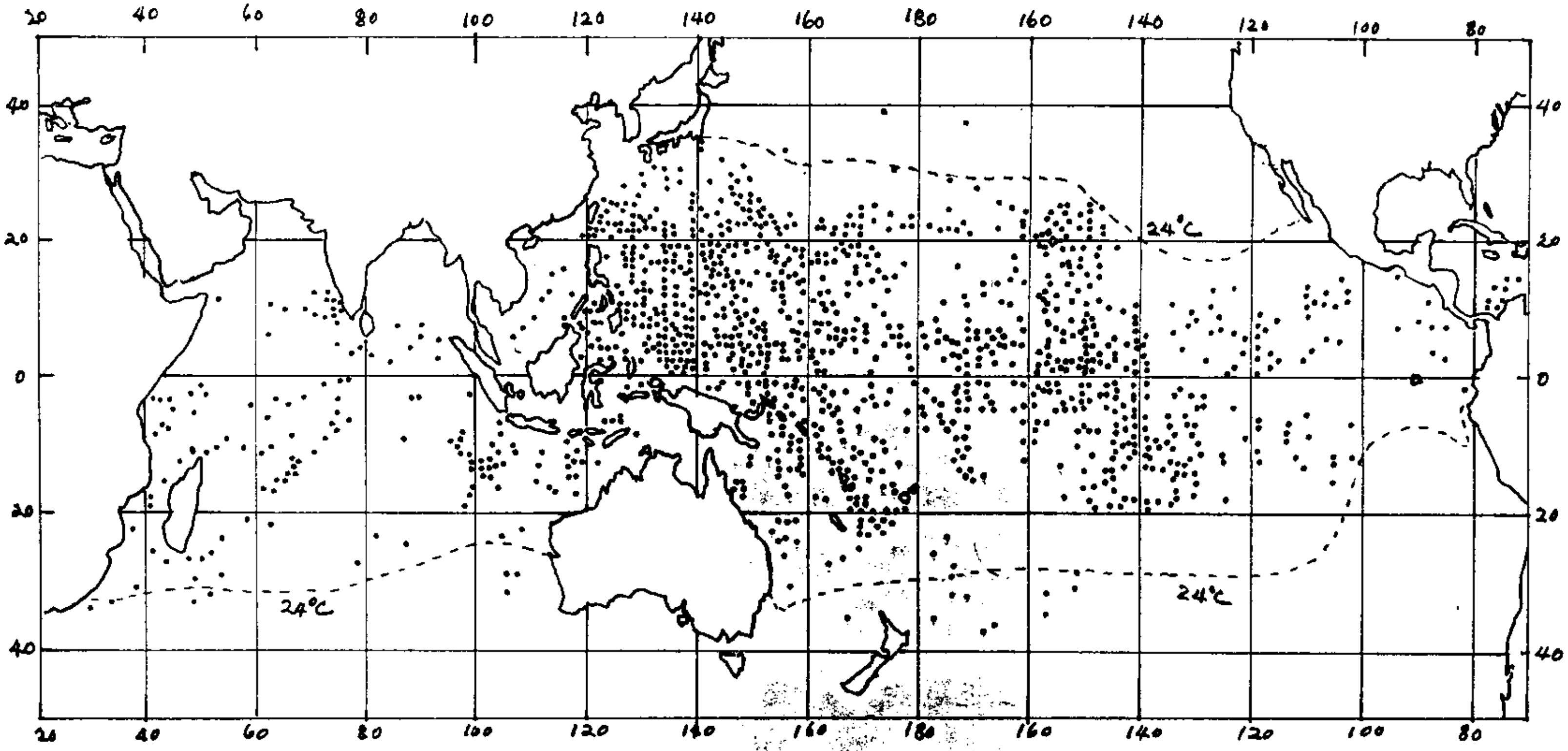

Fig. 1.--Capture sites of skipjack larvae in the Pacific and Indian Oceans. Each dot represents presence of larvae.

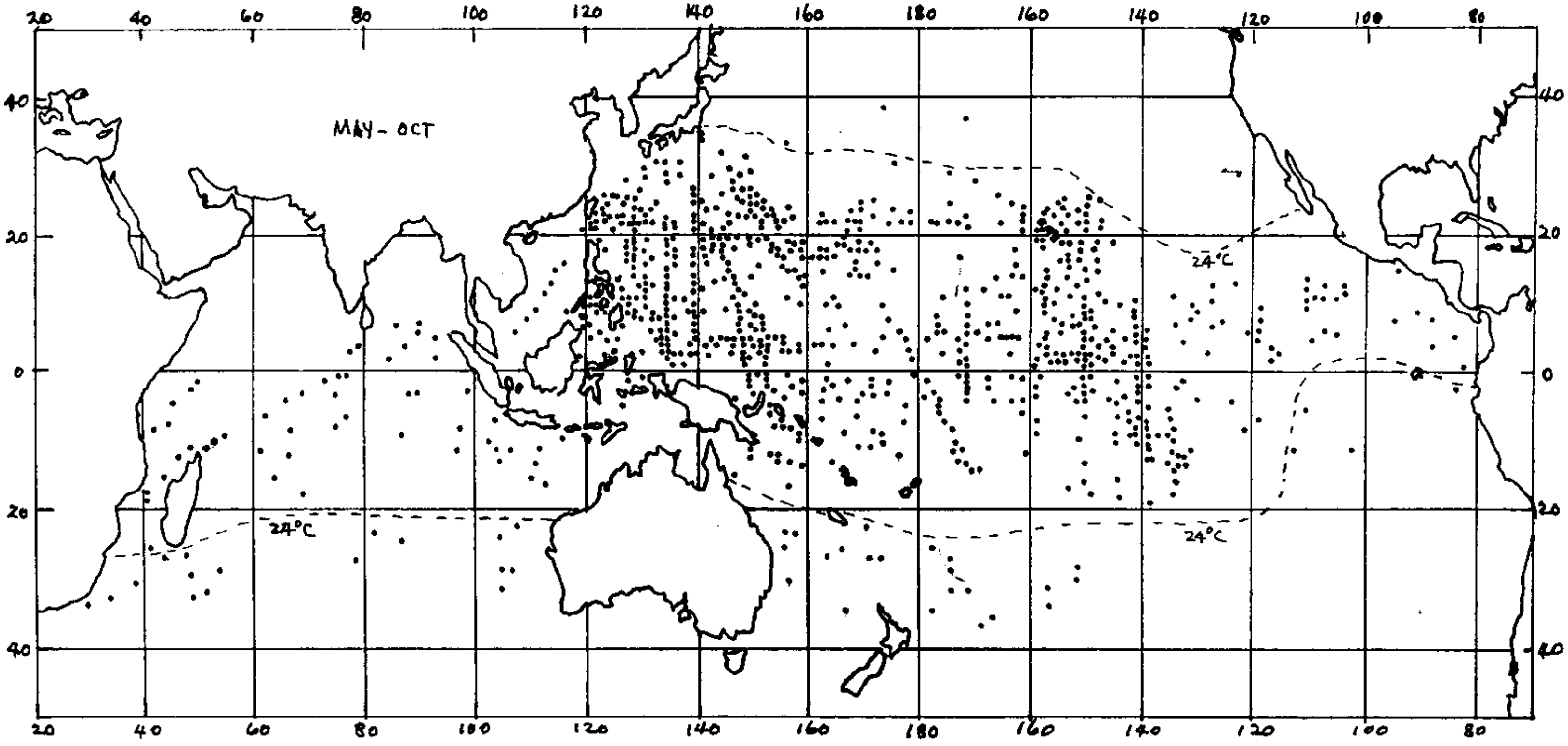

Fig. 2a.--Sites of larval skipjack captures during May-October.

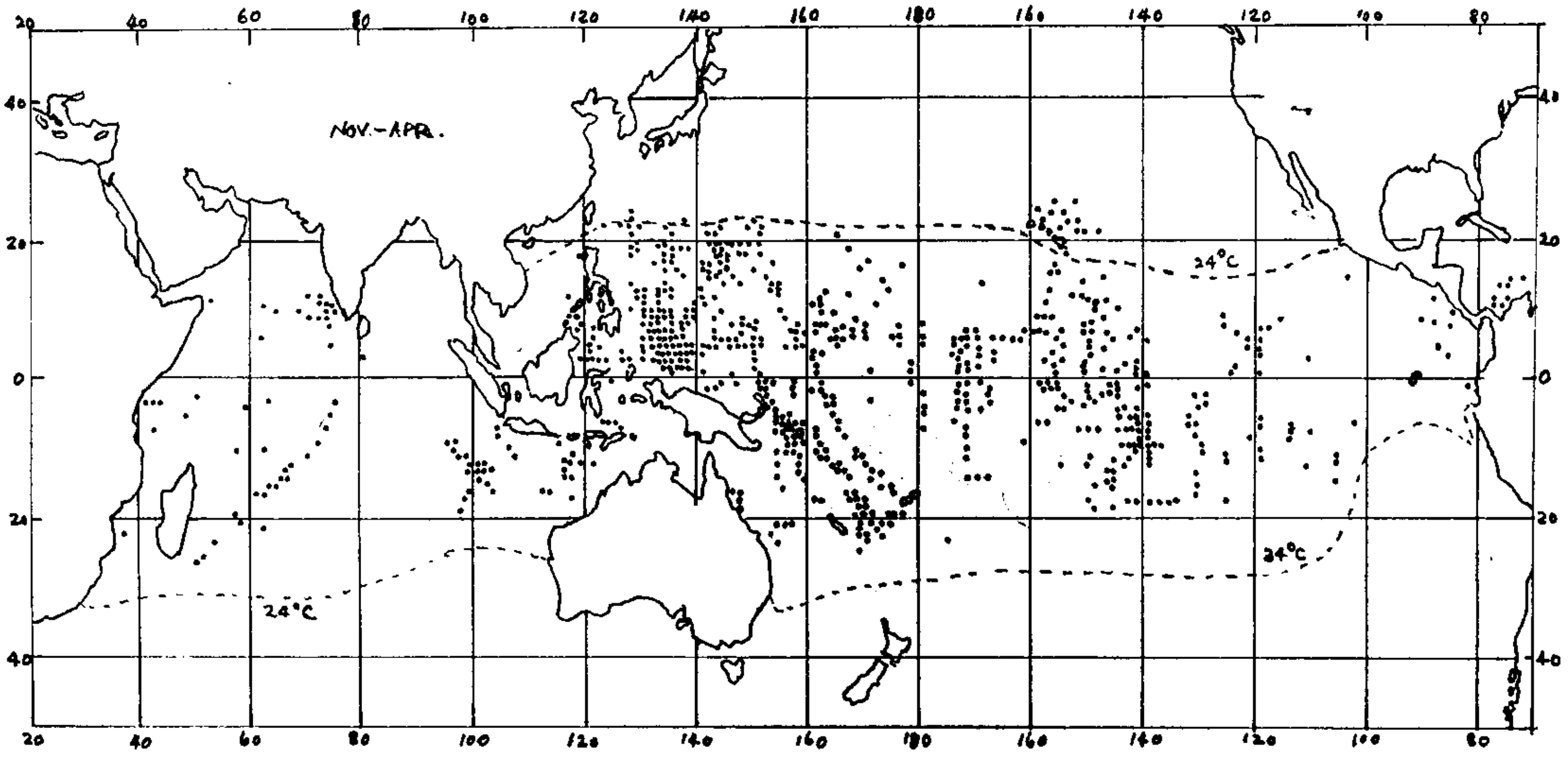

Fig. 2b.--Sites of larval skipjack captures during November-April.

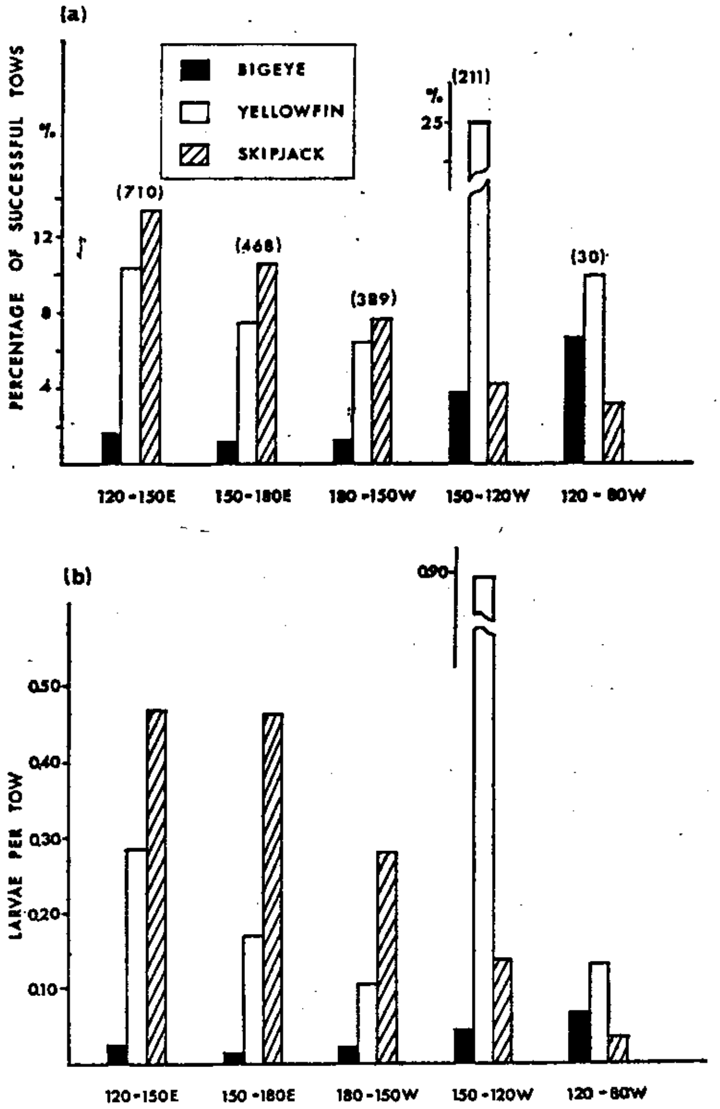

Fig. 3.--Occurrence and relative abundance of tuna larvae in the equatorial Pacific between lat. 0° and 10°N(Number of tows in parentheses).

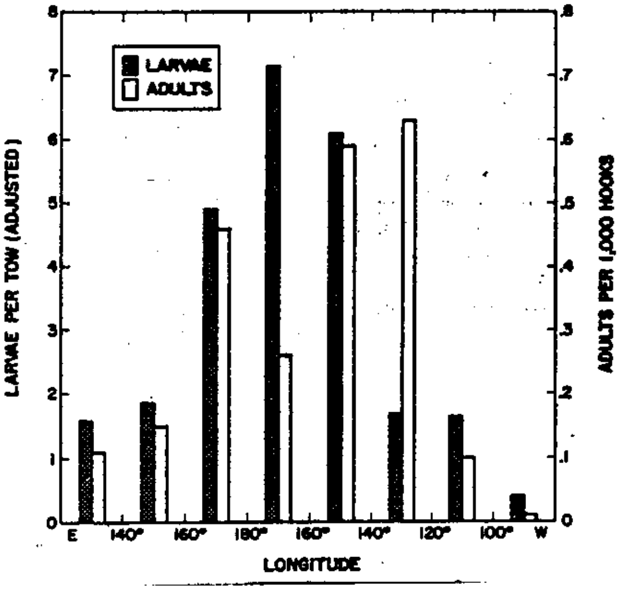

Fig. 4.--Catch rates of skipjack larvae and adults across the Pacific between lat. 10°S and 20°N.