OBSERVATIONS ON DISTRIBUTION AND LIFE HISTORY OF SKIPJACK TUNA, *KATSUWONUS PELAMIS*, IN AUSTRALIAN WATERS

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ABSTRACT

Skipjack tuna occur in many areas around Australia, but have been little fished or investigated there because of low commercial demand. Their distribution in Australian coastal waters is not continuous, although suitable temperatures occur in all areas. Abundance in coastal waters is probably highest in the southeast. The southern limit of skipjack tuna range varies seasonally with the 15° C surface isotherm, and that temperature appears to be limiting. Length-frequency polygons for skipjack tuna of southeastern Australia show modes at about 37, 46, 53, and 59 cm fork length in the southern summer. The regression of weight W (grams) upon length L (millimeters) for east coast skipjack tuna is $W = 0.000000839 L^{3.5202}$. Gonads of coastal skipjack tuna are all immature. The euphausiid *Nyctiphanes australis* is the principal food in east Australian waters south of latitude 34° S. Small fish such as clupeoids are eaten in some of those areas and are the principal food elsewhere.

The skipjack tuna, *Katsuwonus pelamis* (Linnaeus), occurs in tropical and warm temperate waters of all oceans. It supports large fisheries in many areas and is considered to have much potential for further exploitation (Gulland 1971). The scientific literature on the species is large (Klawe and Miyake 1967) and growing. Australian contributions to that literature have been few, although the organized collection of data on Australian skipjack tuna began in 1938. One reason is that the Australian tuna industry has shown little interest in skipjack tuna. It operates principally upon southern bluefin tuna, *Thunnus maccoyii*.

The purpose of this paper is to present unpublished biological information on skipjack tuna in Australian waters and relate it to what has been published from the region. Many of the observations were made by us. We do not discuss fishing operations or prospects, except to note briefly here that skipjack tuna have been caught in Australian coastal waters by live-bait fishing, purse seining, mesh netting, and trolling. Most of those catches were incidental to fishing for southern bluefin tuna. In the year 1974-75 the Australian tuna catch was 11,288 t, of which 2,375 t was skipjack tuna and the rest southern bluefin tuna (Anonymous 1975, 1976). It is our opinion, admittedly subjective, that the biomass of skipjack tuna in Australian coastal waters is at least as high as that of southern bluefin tuna. It was much higher than the biomass of southern bluefin tuna off eastern Tasmania in 1965, according to estimates from aerial surveys (Hynd and Robins 1967).

One of us originally proposed the name "striped tuna" for this species in Australia, instead of "skipjack" which is the usual English vernacular elsewhere (Serventy 1941). The intention was to avoid confusion with another pelagic fish which is sometimes called "skipjack" in Australia, namely *Pomatomus saltator*. "Striped tuna" has not gained acceptance as an English vernacular outside Australia, however, and both names are now used in Australia. Therefore we now refer to *Katsuwonus pelamis* as skipjack.

METHODS

Our summaries of biological data are based on skipjack tuna taken from 1938 to 1965. All were obtained by hook fishing at the sea surface, except for some Victorian samples which may have been caught near the surface in nets. Thus our biological observations essentially refer to surface fish. The same applies to other specimens mentioned in literature cited, except those noted to be from Japanese longliners.

Length was measured from the tip of the snout to the caudal fin fork (FL), sometimes in millime-

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ters and sometimes to the nearest centimeter. Other authors whom we quote measured in the same way. Weight of fish was measured ungutted, usually at sea, in pounds and ounces. These weights were converted to grams and rounded to the nearest 50 g. Gonads were weighed fresh to the nearest gram, usually at sea.

Statements about mean positions of isotherms are based on charts by Vaux (1970) and Gorshkov (1974).

SPATIAL DISTRIBUTION

Skipjack tuna have an extensive distribution in the Australian region (Figure 1), but prior to 1938 they had been recorded only off New South Wales. It is now known that they have a continuous range in east Australian coastal waters from Lady Elliott Island to Storm Bay, although the limits may vary seasonally as discussed later. The RV *Warreen* and RV *Stanley Fowler* of the Commonwealth Scientific and Industrial Research Organization (CSIRO) established this distribution from trolling surveys between 1938 and 1951. Most specimens were taken on the continental shelf, many of them close inshore.

East coast inshore waters north of Lady Elliott Island lie within the Great Barrier Reef. Skipjack tuna are unknown there, although most of the area is well fished by sports and commercial fishermen (Marshall 1964; Hynd 1968). The *Warreen* and *Stanley Fowler* prospected by trolling in northern Australian waters from July to October 1949, traversing much of the coast from Torres Strait to Broome. Skipjack tuna were found on banks near the edge of the Australian continental shelf to the south of Timor, but nowhere else, and no other records exist from northern coastal waters. Thus the distribution appears to be quite limited in coastal waters around northeast and northern Australia (Figure 1). This is not true of the adjacent oceanic waters, however. Japanese longline vessels began to fish for tuna in the area of Figure 1 about 1950. They did not seek skipjack tuna but took them incidentally. Figure 1 shows the general areas in which those vessels took any skipjack tuna in the years 1964-67, as established by Matsumoto (1975). Evidently skipjack tuna occur to some extent almost everywhere in ocean waters east, north, and west of the Australian mainland and New Guinea. Skipjack tuna were first recorded in Papua New Guinea waters between 1948 and 1950 by the Australian RV *Fairwind*, in localities shown in Figure 1 (Munro 1958). Japanese longlining began there at about the same time. About 1969 vessels of the Japanese live-bait fishery began taking skipjack tuna north and northeast of New Guinea, and a similar fishery was later established by nationals of Papua New Guinea within the same area (Kasahara 1977; Lewis and Smith 1977). Figure 1 shows the general area of the Japanese live-bait fishery in 1973, as reported by Kasahara (1977).

Skipjack tuna were first recorded off the west coast of Australia in 1945. By 1951 an apparently continuous range from Onslow to Albany had been established, mostly by trolling surveys of the *Warreen*. Later surveys, made by the Department of Fisheries and Wildlife of Western Australia, extended this range to Broome (Robins 1975). Skipjack tuna in Western Australia appear to be less abundant than in southeastern Australia, at least on the continental shelf. Most were taken on the outer part of the shelf or just beyond the shelf edge.

On the southern coast of Australia east of Albany, skipjack tuna were first found by the CSIRO RV *Derwent Hunter* in 1953, near the edge of the shelf in the eastern part of the Great Australian Bight. Soviet workers extended the known range to the western part of the Bight, again in waters near the shelf edge (Shuntov 1969). In 1978 the CSIRO RV *Courageous* found skipjack tuna between the western end of the Bight and Albany (Maxwell[3]). East of the Bight, skipjack tuna have been taken by South Australian tuna fishermen almost to Kangaroo Island, from the shelf edge to near the coast (Olsen[4]; Williams[5]). Thus there is probably a continuous distribution along the southern coast of Australia to Kangaroo Island (Figure 1).

We know of no certain skipjack tuna occurrences between Kangaroo Island and Australian east coast waters. The most westerly of the east coast records are Lakes Entrance in eastern Victoria, the mouth of the Tamar River in northeast Tasmania (Scott 1975) and Storm Bay in southeast Tasmania (Figure 1). The apparent gap in skipjack tuna distribution to the west of those places is not readily explained. The skipjack tuna food or-

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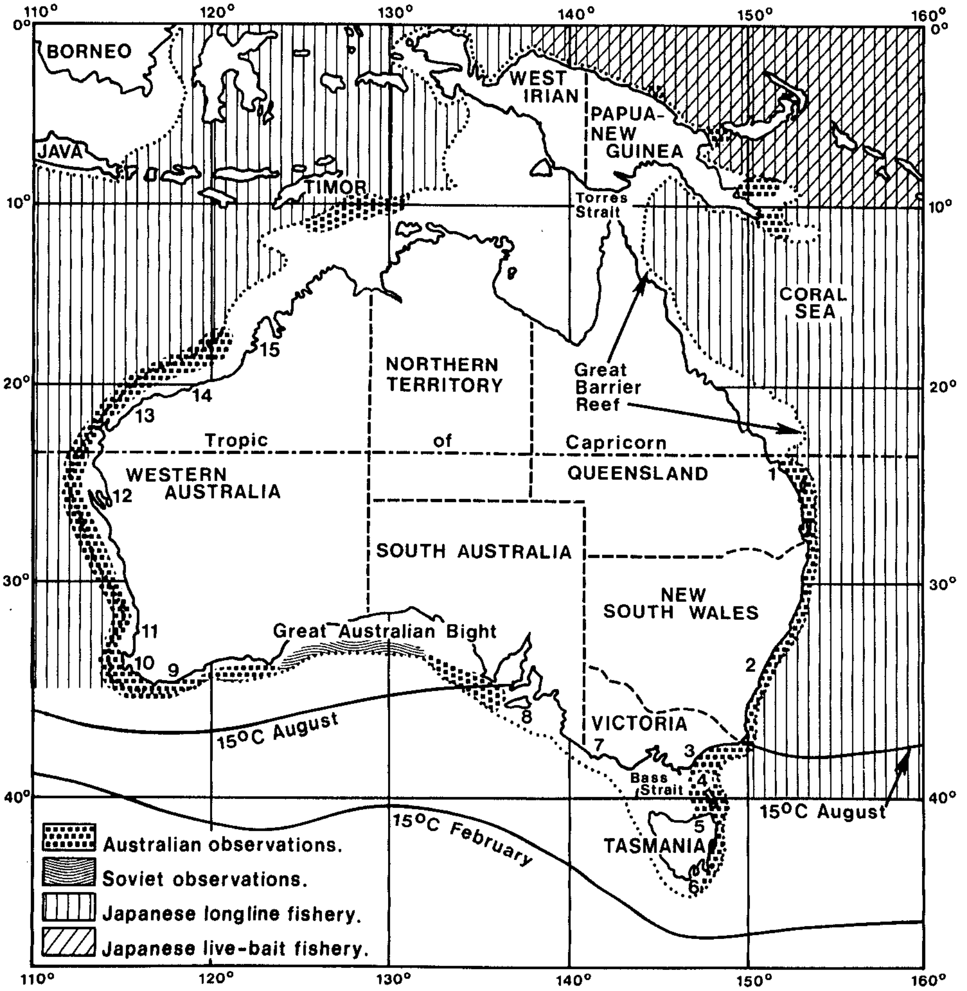

FIGURE 1.—Australia and vicinity, showing areas of skipjack investigations and fisheries, edge of continental shelf (dotted line), mean February and August positions of the 15° C surface isotherm, and the following localities mentioned in the text: 1—Lady Elliott Island, 2—Sydney, 3—Lakes Entrance, 4—Furneaux Group, 5—Tamar River, 6—Storm Bay, 7—Portland, 8—Kangaroo Island, 9—Albany, 10—Cape Leeuwin, 11—Fremantle, 12—Shark Bay, 13—Onslow, 14—Port Hedland, 15—Broome.

ganism *Nyctiphanes australis*, mentioned later, is abundant. Skipjack tuna can tolerate temperatures down to 15° C as shown below, and all waters in the area of no skipjack records have mean surface temperatures over 15° C in some months in most years. Aerial sightings of presumed skipjack tuna have been made near Portland and off western Tasmania (Williams footnote 5). Nevertheless, we think the gap is real, at least in central and western Bass Strait. We and our colleagues have done much trolling in those areas in various seasons and years without catching any skipjack tuna. Southern bluefin tuna are likewise absent or very rare in central and western Bass Strait, although quite plentiful east and west of that region (Serventy 1956). Hynd and Robins (1967) showed that surface temperatures in the western approaches to Bass Strait are under 15° C in parts of the summer because of upwelling, and perhaps as cold as that all summer in some years. This might restrict the distribution of skipjack tuna in waters east of Kangaroo Island. Hynd and Robins (1967) discussed the possibility of a similar effect upon southern bluefin tuna. Another possibility is that Bass Strait is too turbid for skipjack tuna, since it is shallow, receives several rivers, and is well mixed by waves and tides. Very little is known about effects of turbidity on tunas, however.

SEASONAL DISTRIBUTION

The range of skipjack tuna in eastern coastal waters is subject to seasonal variation. Table 1 shows where specimens have been taken in those waters in each month, in investigations made by or in cooperation with CSIRO, with data of all years combined. The southern limit of the range is farthest south in February-March and farthest north in July-August, and this variation is explicable. All positions of the limit lie in the well-surveyed waters south of Sydney (approximately lat. 34° S), and they generally agree with positions of limiting sea surface isotherms as was shown by Robins (1952). Figure 1 shows the mean February and August positions of the 15° C surface isotherm, the one closest to the lowest temperature at which any skipjack tuna have been caught (14.7° C, by Robins). The isotherm positions agree fairly well with the observed limits of skipjack tuna range in the same months, considering that no observations were made south of lat. 44° S. The lower limiting temperature for skipjack in abundance is about 16° C according to Robins (1952). The mean positions of that surface isotherm (about 2° of latitude north of the 15° C surface isotherm in each month) agree almost exactly with the skipjack tuna range limits in Table 1. From 1938 to 1942 skipjack tuna were hardly ever found south of lat. 43° S and seldom found south of lat. 42° S. They were fairly numerous between lat. 43° and 44° S in 1951, when temperatures were unusually high (Robins 1952). Hynd and Robins (1967) reported aerial sightings of a few schools of presumed skipjack tuna off the southern tip of Tasmania where surface temperatures were probably about 13° C. Neither the species nor the temperature was confirmed, however.

TABLE 1.—Records of captured skipjack tuna (X) and sightings of skipjack tuna (S) in Australian east coast waters by months. Sources are Robins (1952), Hynd (1968), and unpublished data from the Commonwealth Scientific and Industrial Research Organization for the period 1938-78. Waters between lat. 33° and 24° S were completely covered only in May, July, and September, and not covered at all in November and December. Waters between lat. 33° and 44° S were completely covered in all months.

Lat. S	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
24°-25°		X	S			X						
25°-26°										S		
26°-27°												
27°-28°					X		S					
28°-29°												
29°-30°					X			X				
30°-31°	X			X				X	X	X		
31°-32°				X	X	X			X	X		
32°-33°		X	X	X		X	X	X	X	X		
33°-34°	X	X		X		X	X	X	X	X	X	
34°-35°	X	X	X	X	X	X	X	X	X	X	X	X
35°-36°	X	X	X	X	X		X	X	X	X	X	X
36°-37°	X	X	X	X	X				X	X	X	X
37°-38°	X	X	X	X	X	X					X	X
38°-39°					X	X						
39°-40°	X	X	X	X	X							X
40°-41°		X	X	X	X							
41°-42°		X	X	X	X							
42°-43°		X	X	X	X							
43°-44°		X	X									

The occurrence of skipjack tuna at temperatures down to 15° C is of special interest, because the species has not been found in such cool waters in other parts of the world. It has been recorded at temperatures down to 17° C in the eastern Pacific (Williams 1970) and 18° C near Japan (Uda 1957). Dizon et al. (1977) exposed four captive Hawaiian skipjack tuna to gradually decreasing water temperatures with the following results. Three fish stopped feeding at 17° C and died at 16° C; corresponding temperatures for the fourth fish were 15° and 14° C.

It is difficult to recognize or hypothesize any seasonal change in the northern limit of skipjack tuna range in eastern coastal waters, especially in view of the incomplete vessel coverage north of Sydney (Table 1). The northern limit of any occurrence (excluding offshore data from Japanese longliners) is between lat. 24° and 25° S, and skipjack tuna were found there in February and June. If data from sightings are accepted there is evidence of skipjack tuna between lat. 24° and 26° S in various months from February to October. It would not be surprising if skipjack tuna occurred in those waters to some extent in all months. Mean monthly surface temperatures are maximal between 27° and 28° C, whereas skipjack tuna can tolerate 30° to 32° C (Williams 1970; Dizon et al. 1977).

On the other hand, the northern limit of the range of skipjack tuna in abundance could be south of the limit of total range and could vary with season, as Robins (1952) claimed. He put the northern limit of the main area of occurrence at about lat. 30° S in August-September and lat. 38° S in February, corresponding to the positions of the 19° C surface isotherm in those months. Robins considered that temperatures about 19° C were limiting for the main occurrence of skipjack tuna, 18° C limiting for occurrence in abundance, and 20.5° C limiting for any occurrence, at the warm end of the distribution along the east coast. The data in Table 1 are insufficient to support or deny Robins' conclusions as far as the actual skipjack tuna distribution is concerned. We note however that skipjack tuna are often abundant in other parts of the world at temperatures much above those mentioned (Blackburn 1965; Williams 1970). They have been found plentifully at 24° C off New South Wales (Williams footnote 5). Of course, abundance may reflect other conditions, as well as the distributions of temperature most suitable for adults. The occurrence of skipjack tuna in coastal waters north of Sydney, and its possible connections with offshore distributions to the east and northeast, should be further investigated.

Our knowledge of seasonal distribution in other coastal waters of Australia is incomplete. Off Western Australia skipjack tuna have been taken as follows, including records by Robins (1975): Broome to Port Hedland, July, August, and October; Port Hedland to Shark Bay, January, April-June, August, September, and November; Shark Bay to Cape Leeuwin, February, March, and June-August; off Albany, May-July. Our records for the area south of Timor are for September and October. Australian and Soviet records between Albany and Kangaroo Island are all for the period December-May. All the areas just mentioned and others in northern Australia where no skipjack tuna have been found are warm enough for some skipjack tuna to occur all year (i.e., over 15° C at the sea surface, Figure 1).

In the Japanese longline fishing area east of Queensland there may be some seasonal change in abundance of skipjack (Matsumoto 1975), but the pattern is not clear. In the similar area west of Western Australia the abundance appears to be low at all seasons. In surface waters of Papua New Guinea, according to Lewis and Smith (1977), there is no obvious seasonal change.

LENGTH AND WEIGHT

Length measurements of about 4,500 east coast skipjack tuna were made in CSIRO investigations to the end of 1965. The observed range was 30-65 cm FL north of Sydney, 35-66 cm FL in mainland waters south of Sydney, and 35-66 cm FL off Tasmania. We have no length data for Great Australian Bight or South Australian fish except those of Shuntov (1969), which were 48-52 cm FL. Larger skipjack tuna to about 80 cm have been taken off New South Wales and South Australia in recent years (Williams footnote 5). Robins (1975) measured about 300 skipjack tuna from Western Australia, which were 29-78 cm FL. Our earlier measurements from the same area fall in that range. For Papua New Guinea a range of 35-62 cm FL was reported by Kearney et al. (1972). All these skipjack tuna were taken very near the sea surface. Barkley et al. (1978) hypothesized that large skipjack tuna require lower temperatures than small skipjack tuna and are therefore more abundant in the upper thermocline than at the sea surface, in the tropical Pacific.

Figure 2 summarizes most of the east coast data in length-frequency polygons for various periods. Most of these sets of measurements are rather small in number, even when combined for certain months and years as in some of the polygons. Data for the Southern Hemisphere winter (polygons A, H, and M) show modes at about 34, 44, and 51 cm. Polygons for the southern summer (C, E, F, G, and J) have modes at about 37, 46, 53, and 59 cm. The first three modes for the summer are close to the three for the winter and are shown as I, II, and III, respectively, for each season. Modes at similar sizes in other polygons are labelled in the same way. This labelling does not imply that the modes represent successive age-groups a year apart, or that the absolute age is known for any mode, because such conclusions could not be drawn with confidence from these scattered data. If the modes do represent successive age-groups, the mean growth rate of east coast skipjack tuna must be about 6-10 cm/yr for fish between 35 and 60 cm. Most published estimates of skipjack tuna growth rate in that range of length are higher, as discussed by Shomura (1966), Joseph and Calkins (1969), and Chi and Yang (1973) for Hawaii, Japan, the eastern Pacific, and Taiwan. The range of annual growth increment in those studies was 11-27 cm, with many values near 15 cm, and some of those estimates were obtained from tagging. On the other hand, Batts (1972) estimated 8-9 cm/yr for skipjack tuna >40 cm from North Carolina, from annuli in cross sections of dorsal spines. Kearney[6] referred to an estimate of 7 cm/yr for Papua New Guinea skipjack tuna, based on tagging, but gave no details.

Skipjack tuna of modal group I were obtained only from 1938 to 1941 in east coast waters. They may have been particularly abundant then, or there may have been some difference in trolling

[6]Kearney, R. E. 1978. Some hypotheses on skipjack (*Katsuwonus pelamis*) in the Pacific Ocean. South Pac. Comm., Noumea, New Caledonia, Occas. Pap. 7, 23 p.

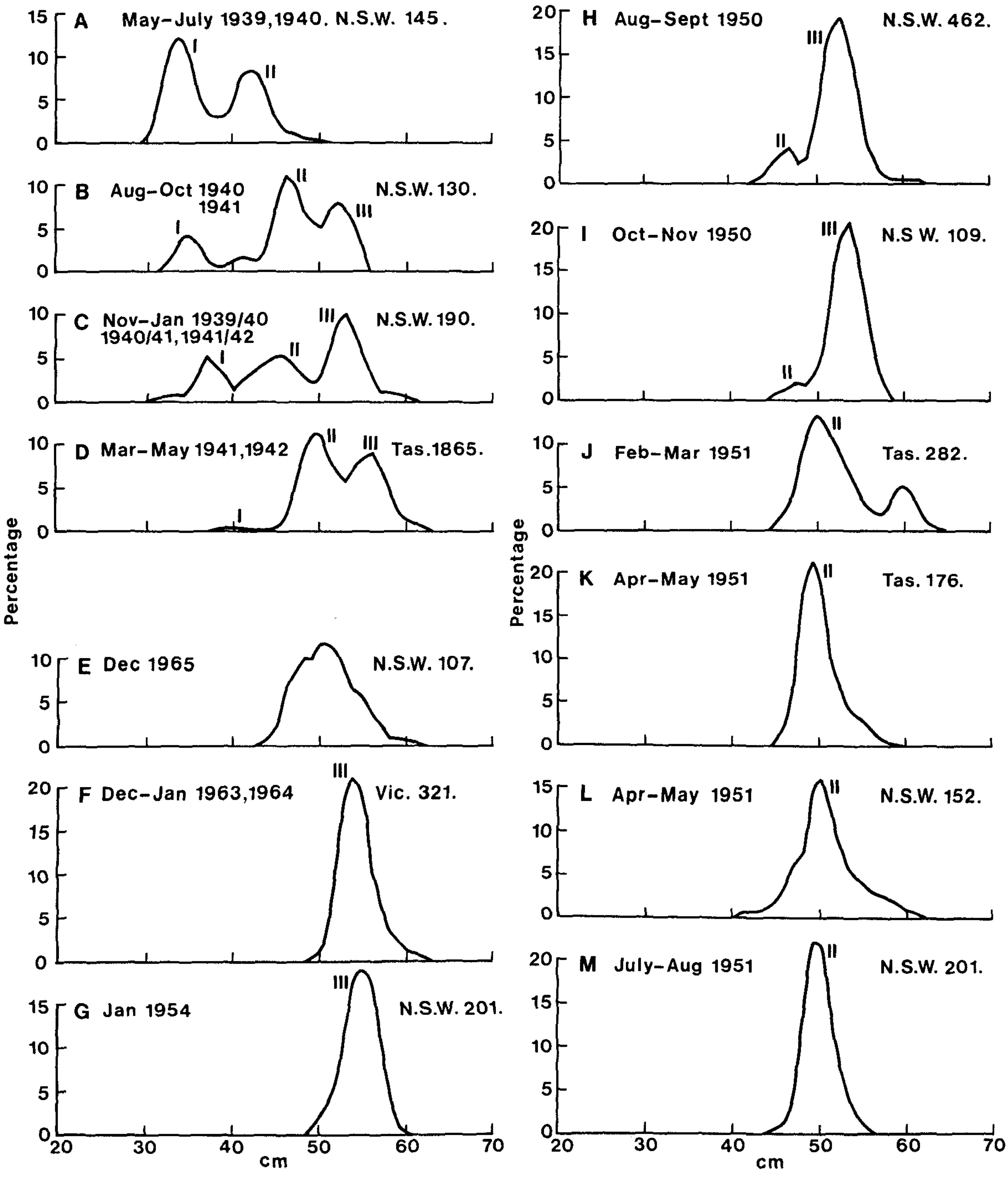

FIGURE 2.—Percentage fork length (centimeters) frequency polygons of skipjack from New South Wales (mostly south of Sydney), Victoria (Lakes Entrance), and Tasmania (Furneaux Group to Storm Bay). The data are smoothed by a moving average of three. The number of specimens is given after the locality abbreviation in each polygon. Polygons A to D, E to G, and H to M show data for 1939-42, 1954-65, and 1950-51, respectively. The order of the polygons in each of those groups is based on the month or months in which the data were taken. Roman numerals are for identification of modes, and do not necessarily indicate ages.

method (e.g., speed, lure type, lure size) between that period and later. Robins (1975) took similar fish in the period April-June off Western Australia, mostly by purse seining but occasionally by trolling.

Weight as well as length was measured for 607 east coast skipjack tuna. The following significant linear regression was found between the common logarithms of the variables:

$$\log W = -6.0762 + 3.5202 (\log L)$$

where W is weight (grams) and L is fork length (millimeters). The coefficient of determination, R^2, is 0.856. Standard errors of the first and second constants in the equation are 0.1595 and 0.0586, respectively. The equation is equivalent to:

$$W = 0.000000839\ L^{3.5202}.$$

The range of L in the data used is 410-645 mm. The heaviest fish weighed 5.67 kg.

The 95% confidence limits of the regression coefficient are 3.4048 and 3.6356, calculated from the standard error. Other published regressions of skipjack tuna weight on length for large samples (>200) indicate regression coefficients from 3.2164 to 3.67. Those samples were taken in the eastern, central, and northwestern Pacific (Nakamura and Uchiyama 1966, and references there) and off North Carolina (Batts 1972). Standard errors of the coefficients were not published in most cases. The standard error can be calculated from data of Hennemuth (1959), for a regression coefficient of weight on length for 1,280 skipjack tuna from the eastern Pacific (combined areas). The coefficient was 3.336, with 95% confidence limits 3.296 and 3.376. Thus the east Australian and eastern Pacific regressions are significantly different at the 5% level of probability. The meaning of this difference is not clear. The two groups of skipjack tuna probably belong to different populations (Fujino 1972; Sharp 1978). However, Hennemuth (1959) found regression coefficients from 3.144 to 3.555 in different areas of the eastern Pacific north of the Equator, a region considered to contain only one skipjack tuna population (Fujino 1972; Sharp 1978), and some of those coefficients were significantly different.

SEXUAL CONDITION

The gonads of 418 east coast skipjack tuna were weighed. Ovary weights ranged from 4 to 30 g. Most ovaries were white to pink. Discrete small ova were visible to the naked eye in some ovaries, but large yolked ova were not observed. Ovaries of a reddish flaccid appearance, which might have been spent, were seen occasionally from April to August in New South Wales and Tasmanian waters. Testes were small, weighing mostly 1-2 g with a maximum of 13 g. Milt could sometimes be expressed from them by pressing. Similar observations were made on a small number of skipjack tuna from the west and northwest coasts of Australia, except that no gonads were weighed. A specimen taken off Fremantle in July was possibly spent. No gonad data are available from South Australia.

Orange (1961) compared ovaries of skipjack and yellowfin tunas by means of a "gonad index" equal to

$$(\text{gonad weight}) / (\text{fish length}^3)\ 10^8$$

with gonad weight in grams and fish length (fork length) in millimeters. This is a ratio between gonad weight and an estimate of fish weight. The estimate is not accurate for skipjack tuna, since weight increases with fork length to some power slightly higher than 3 in that species, as noted earlier. However Orange also compared gonad indices with the appearance of the ovaries and ova, and found that only indices over 30 indicated approaching sexual maturity in skipjack tuna. Naganuma (1979) made similar comparisons which indicated that spawning skipjack tuna have gonad indices of 80 or higher, measured on Orange's scale. Thus calibrated, the index has some utility, and it has been employed by other skipjack tuna investigators. None of the gonad indices in our east Australian material reached 30 (Table 2); only 2, out of 224, were slightly over 20. Thus no females appeared to be mature on the basis of gonad index, confirming the observations on the gonads themselves. Yet virtually all these skipjack tuna were at or over the size at which first sexual maturity has been found in other Pacific waters, i.e., about 45 cm (Kearney et al. 1972; Blackburn and Williams 1975; Naganuma 1979).

It is clear from these observations that skipjack tuna do not spawn to any significant extent in east Australian coastal waters, and there is no evidence that they spawn in any Australian coastal waters; nevertheless, they do spawn in the

TABLE 2.—Length range, sex ratio, and female gonad indices (see text) for three groups of Australian east coast skipjack tuna.

Area	Period	Fork length (cm)	Sex ratio (F/M)	Gonad index	
				Range	Mean
New South Wales, south of Sydney	Nov.-Dec. 1941	44-57	47/30	5.6-20.7	12.3
Tasmania	Mar.-May 1942	47-61	166/154	3.4-17.8	10.1
New South Wales, north of Sydney, and southern Queensland	June 1941, 1942	51-65	11/10	8.6-21.5	10.7

offshore tropical waters. Ueyanagi (1970) showed that skipjack tuna larvae occur between November and February in the Coral Sea east of tropical Queensland, north and east of New Guinea, and in ocean waters west of northwest Australia. From May to August the larvae are scarcer in Coral Sea and New Guinea waters than in the preceding period, and possibly so off northwest Australia. Gonad indices are higher in Coral Sea and New Guinea waters in the southern summer than in winter (Naganuma 1979). Thus the skipjack tuna spawning season in waters near Australia is probably the southern summer, and the principal spawning areas seem to be in offshore waters northeast and northwest of the continent.

FOOD

Observations were made on stomach contents of 660 skipjack tuna from east coast waters and 30 from west and northwest coast waters (Table 3). Euphausiids were mostly *Nyctiphanes australis* although *Thysanoessa gregaria* was occasionally observed. Also included with euphausiids were several stomachs which contained a red liquid. This liquid was often found together with euphausiids, never with any other food, and was certainly a product of the digestion of euphausiids.

The main point of interest in Table 3 is the proportion of stomachs with euphausiids. Evidently euphausiids are almost the sole food of skipjack tuna in Tasmania and the principal food in southern New South Wales, but a small component of diet in the other sampled areas. Small pelagic fish are a large food item in all areas except Tasmania. Cephalopods are a minor item in all areas. Table 3 does not include data on east coast skipjack tuna from Robins (1952) because they are nonquantitative, but his findings were similar, as follows. Euphausiids were the principal food in Tasmania and New South Wales waters south of Sydney. North of Sydney the principal food was fish, especially the young of pilchard, *Sardinops neopilchardus*, and anchovy, *Engraulis australis*. Park and Williams[7] found the following in stomachs of skipjack tuna taken near Sydney: fish larvae, mainly pilchard; *N. australis*; brachyuran and decapod larvae; copepods; and squid.

These changes in diet by area appear to reflect the kinds of small nekton and large zooplankton that are available to skipjack tuna in coastal waters. *Nyctiphanes australis* is the principal coastal euphausiid in the southeast Australian region. Its range along the east coast is from lat. 31° S to the southern end of Tasmania (Sheard 1953). It is abundant off Victoria and Tasmania (including all of Bass Strait) and also off southern New South Wales, but not common in waters north of Sydney (Blackburn 1980). The species is unrecorded off Western Australia, although it occurs in South Australian waters. Off eastern Tas-

[7]Park, J. S., and K. Williams. 1977. A study of the relationship between the composition of food organisms of skipjack tuna *Katsuwonus pelamis* and the abundance and species composition of the plankton in the waters adjacent to Cronulla, New South Wales, Australia. Unpubl. manuscr. Commonwealth Scientific and Industrial Research Organization, Division of Fisheries and Oceanography, Cronulla, 2230, Aust.

TABLE 3.—Foods of skipjack tuna collected in Australian coastal waters, by numbers of stomachs in which they occurred. Nil means empty stomachs.

Area	Nil	Euphausiids	Fish remains	Pilchard[1]	Mackerel[2]	Other fish	Squid	Mixed	Other[3]	Total
New South Wales, north of Sydney	16	1	7	12	1		1		6	44
New South Wales, Sydney and south	104	[4]77	10	2	4	[5]1	1	[6]5		204
Tasmania	82	322	1					[7]1	6	412
Western and northwestern Australia	14		6			[8]3	1	[9]6		30

[1]*Sardinops neopilchardus*.
[2]*Scomber australasicus*.
[3]Yellow liquid, except for two stomachs from Tasmania which contained salps.
[4]Including three stomachs which also contained hyperiid amphipods.
[5]Bellows fish (Macrorhamphosidae).
[6]Euphausiids plus fish or squid. Fish included *Scomberesox forsteri*, *Trachurus* sp. and Macrorhamphosidae.
[7]Euphausiids plus squid.
[8]Flying fish (Exocoetidae), juvenile *Gonorhynchus greyi*, *Harengula* sp. and anchovy (probably *Engraulis australis*).
[9]Fish plus crustaceans or cephalopods or pteropods. Fish included Myctophidae. Cephalopods included squid and paper nautilus.

mania, where skipjack tuna occur only in summer and autumn, *N. australis* is probably the only abundant food organism available to them. Pilchards are not common in that area (Blackburn 1950b). Mackerel, *Scomber australasicus*, have been recorded from Tasmania, but were not found there by us and are probably rare. Anchovies are common in Tasmania, but their occurrence in summer and autumn is mostly in inlets which skipjack tuna do not enter (Blackburn 1950a). Jack mackerel, *Trachurus declivis*, are also abundant, but mostly occur closer inshore than skipjack tuna (Hynd and Robins 1967).

DISCUSSION

The need for further information of various kinds on Australian skipjack tuna has been shown. It would be particularly interesting to know if the apparent discontinuities in distribution are real, and if so, what causes them. The probable determinants of skipjack tuna distribution in surface waters are temperature, food, and turbidity (Blackburn 1965, 1969). Dissolved oxygen concentration can be an additional limiting environmental property in the vertical plane, since skipjack tuna are stressed at concentrations below about 2.8 ml/l (Dizon 1977; Sharp 1978). Concentrations at 100 m in waters near Australia are higher than 3.0 ml/l, however, except in an area off the west coast of West Irian (Reid et al. 1978). Temperatures required by skipjack tuna larvae may be higher than those preferred by adults, causing spawning adults to seek warmer waters than those not spawning (Blackburn and Williams 1975). It has been shown that all surface waters around Australia are warm enough (>15° C) for adult skipjack tuna in the warm season, and most waters warm enough at all seasons. The absence or rarity of skipjack tuna in some of those areas probably indicates that suitable food organisms are scarce, that the waters are too turbid for the fish to find food, or that the vertical distribution of temperature is not such as to force the fish to the surface.

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