SYNOPSIS OF BIOLOGICAL INFORMATION ON THE AUSTRALIAN ANCHOVY *ENGRAULIS AUSTRALIS* (WHITE)

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INTRODUCTION

Engraulis australis (White), sometimes known as the Australian anchovy, was investigated by the writer in Australia at various times and places between 1937 and 1948. The work was done as opportunities offered in the course of other duties. It was generally hard to obtain material because the annual commercial catch is only 50 to 100 tons, although it could be much higher if a good demand existed for the fish.

Most of the information was published in two papers (Blackburn 1941, and especially Blackburn 1950a). The present paper summarizes the facts and interpretations presented in the former papers, and the very few observations on *E. australis* in Australia that have been published since 1950, and adds a little new information. There appear to have been no detailed studies of occurrences of the same species in New Zealand.

IDENTITY

The adult *E. australis* was well described and figured by McCulloch (1920), who listed most prior references. Blackburn described the eggs and larvae

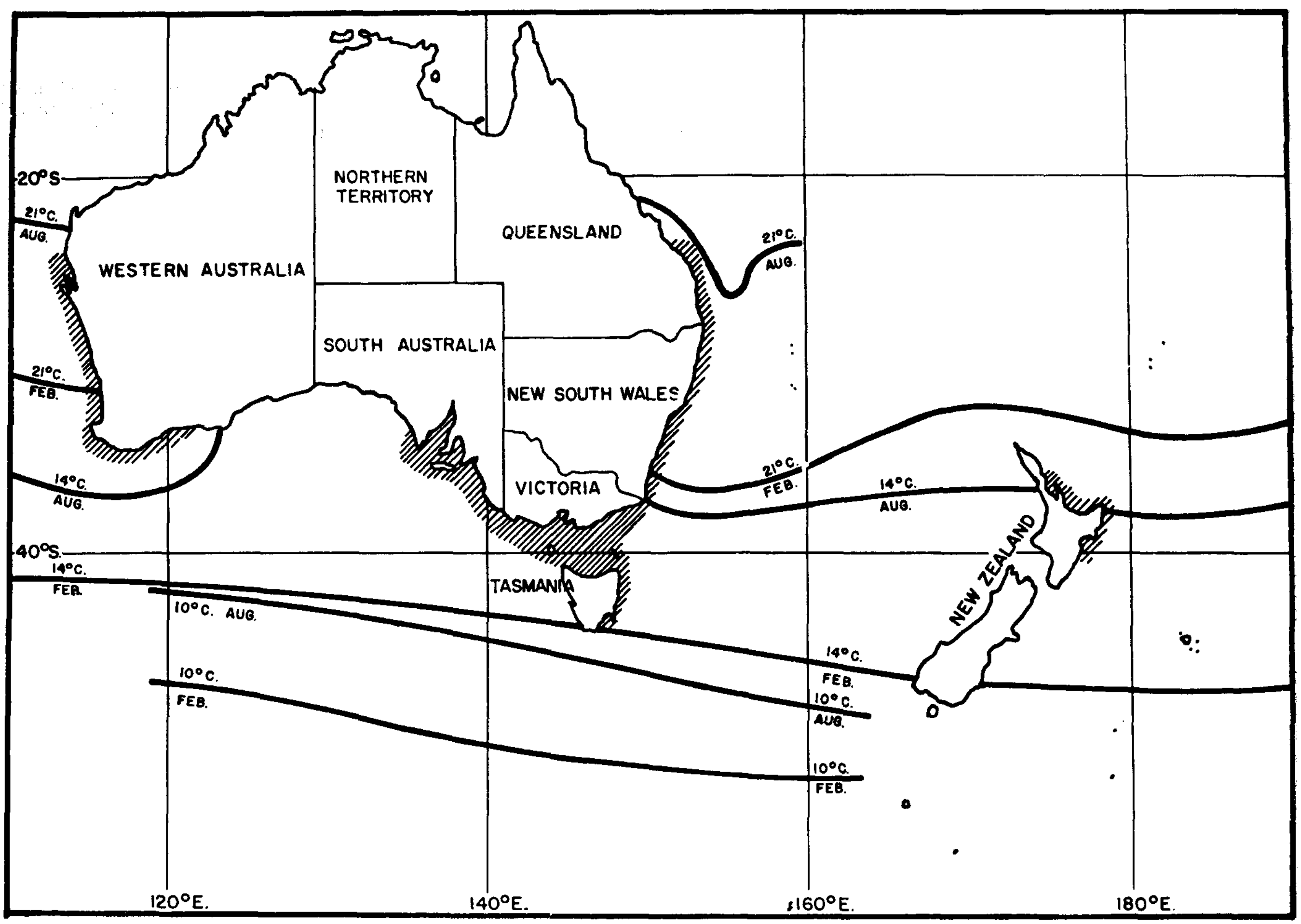

FIGURE 1. Known range of *Engraulis australis* (hatched areas), and mean positions of certain surface isotherms in February and August, in waters near Australia and New Zealand.

(1941) and listed additional references (1941, 1950a). The species falls in the genus *Engraulis* as defined by Jordan and Seale (1926) and Hildebrand (1943). It is the only engraulid species known to occur in Australian waters south of 28° S. latitude, and the only one in New Zealand waters; it is not known from tropical Australian waters, although several species of other engraulid genera occur there, or from any of the smaller islands near Australia and New Zealand.

SPATIAL DISTRIBUTION

E. australis has been found along most sections of the Australian coast south of the Tropic of Capricorn (Blackburn 1950 a), as shown in Figure 1. The range in latitude is from 23° to 43° S. The species is unrecorded from the west coast of Tasmania and from a section of coastline near the South Australia-Western Australia border, but this probably reflects the comparative lack of human settlement, fishing, and marine investigations in those regions, rather than absence of the fish. For similar reasons, the distribution along the coast of New Zealand is probably more extensive than that recorded in the literature (Blackburn 1941) and shown in Figure 1.

Along the coasts where it occurs, *E. australis* inhabits estuaries, bays, and open waters over the generally narrow continental shelf; a few larvae have been taken in plankton hauls over the continental slope, and nothing is known of any occurrences

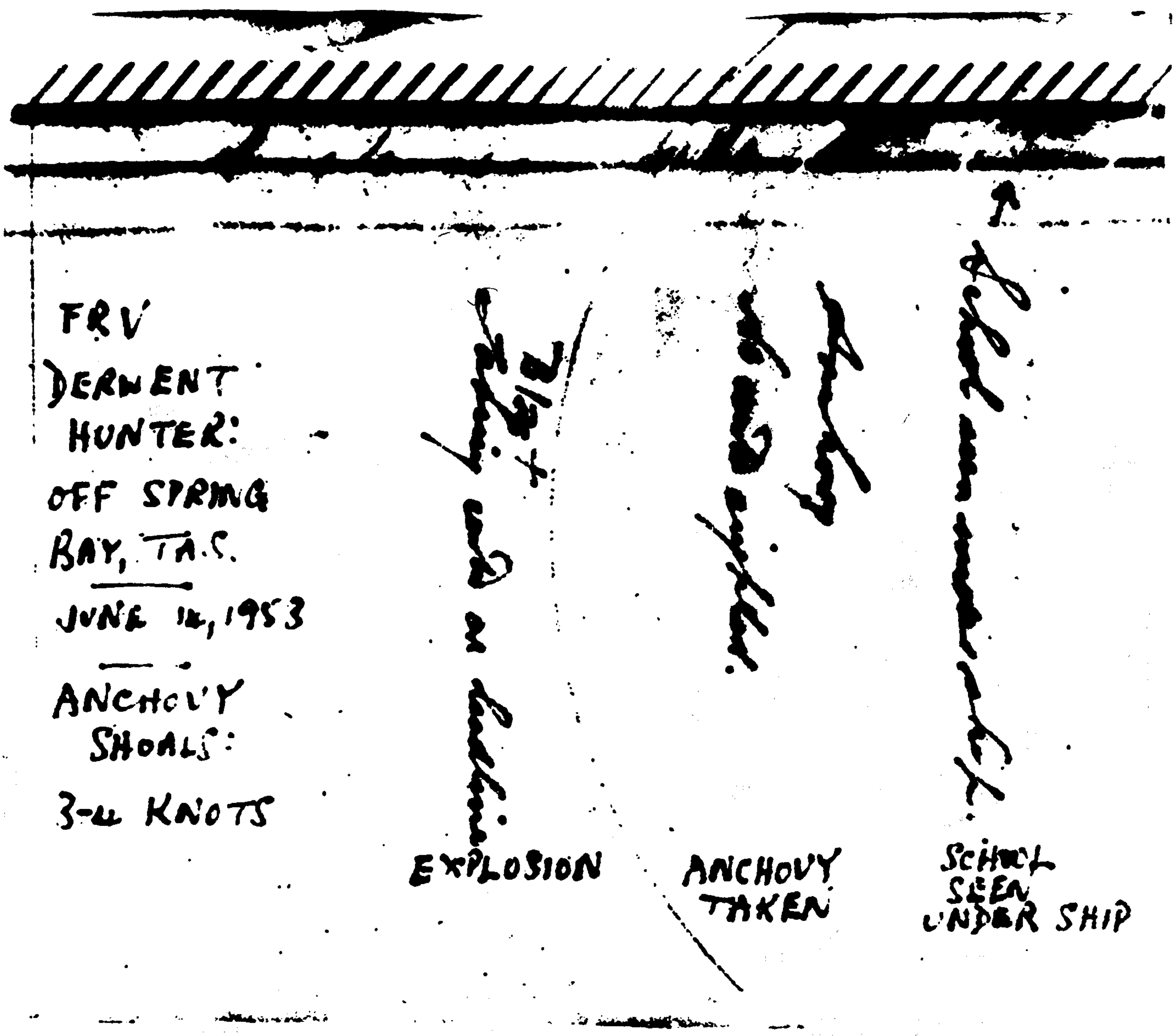

FIGURE 2. Echogram of schools of *E. australis* in 20 m of water off Spring Bay, Tasmania. Time scale across top is in minutes; ship speed was 3 to 4 knots; identification was made from fish killed by exploding TNT in the school.

further offshore (Blackburn 1941, 1950 a). There is no reliable information about the vertical distribution of *E. australis* in the sea. It is found frequently in the stomachs of large scombriform fish hooked at the sea surface (Blackburn 1950 a), but not at all in the stomachs of *Neoplatycephalus macrodon,* which is one of the most abundant and active demersal fishes of continental shelf waters over 50 m (Fairbridge 1951); this suggests that it is much commoner near the surface than near the bottom, in those waters. In shallower waters, such as 20 m, echograms show that the species can occur from top to bottom (Figure 2).

Charts of surface temperature and salinity from various sources (Schott 1935; U.S. Navy Hydrographic Office 1944; U.S.S.R. Ministry of Defense 1953; Muromtsev 1958; Rochford 1962) have been compared with the general spatial distribution of *E. australis* (Figure 1) and the seasonal changes that occur in it. This showed that the species tolerates temperatures at least from 10 to 21° C.; it may encounter temperatures up to 25° C. if it occurs in surface waters as far north in summer as it does in winter, but this is not certain; it probably encounters 9° C. in certain inshore waters in winter, but this also is not certain. The same comparison shows a tolerance of salinities from about 35.1 to 35.8‰, but data obtained from various inshore waters, at times and places where anchovies occurred, indicate that the range is actually from about 2 to 37‰ (Blackburn 1950 a, Gippsland Lakes rivers; Rochford 1957, St. Vincent's Gulf). The range of breeding temperature was investigated by comparing seasonal temperature data (including those for bays and estuaries in various volumes of the Australian "Oceanographical Station List") with information on spawning places and seasons; this range is at least 14 to 20° C. and possibly includes 13° C.

The above-mentioned temperature ranges for *E. australis* are almost the same as those for the Australian sardine, *Sardinops neopilchardus,* which has an almost identical distribution along the Australian coast (Blackburn 1960 and references). The sardine is not known to occur in waters of salinity below about 33.5‰, however, and thus it is not estuarine, whereas the anchovy is. Another difference in spatial distribution between the two species is obvious when their relative abundances are compared within different parts of their common total range of distribution (including saline bays and gulfs where both species occur); to the north of about 37° S. latitude the sardine is more abundant than the anchovy (shown mainly by differences in numbers of larvae, as there are no good data for eggs or adults of the anchovy; Blackburn 1941); to the south of 37° S. the anchovy is more abundant than the sardine (shown by differences in numbers of eggs and larvae, and general scarcity of adult sardines; Blackburn 1950 a, 1950 b, 1957).

INTRASPECIFIC POPULATIONS

Blackburn (1950 a) presented and analyzed the total vertebral counts, including urostyle, of 5,804 *E. australis* from 21 localities around the Australian coast. Analysis of variance indicated that significant differences existed between vertebral count means for certain localities, and the variability was further investigated by the graphical method of Hubbs and Perlmutter (1942).

Figures 3 and 4, from Blackburn (1950 a), show the result. The localities listed in Figure 3 appear in the order in which they occur around the Australian coast, from north-east (top) to south-west (bottom). With one exception (Gippsland Lakes rivers, discussed below) the means fall clearly into eastern, southern, and western groups which were given subspecific names (*E. a. australis, E. a. antipodum,* and *E. a. fraseri,* respectively). The locality-means in the eastern group show a cline with means increasing from north to south (28 to 36° S. latitude, 43.1 to 44.0 vertebrae). Means in the western group are numerically similar to those of the eastern group at similar latitudes, and suggest a similar cline. The existence of clines, whether north-south or east-west, is doubtful in the means of the southern group; these means are all at least one vertebra higher (45.1 to 45.8 vertebrae) than any of the means of the other two groups, and this difference is statistically highly significant. Some of the differences between means within each group are significant.

The Gippsland Lakes are situated on the east coast of the state of Victoria. As shown in Figure 5 (left inset), this is a system of three rivers entering a coastal lagoon or lake which is permanently open to the sea. *E. australis* occurs in the sea outside the entrance, at the entrance, in the lake, and in the rivers (Blackburn 1950 a). Samples sufficient for vertebral count study were available only from the entrance (salinity about 35.5‰) and the rivers (salinity about 2‰), and these two localities are distinguished in Figure 3. The river fish have a mean about two-thirds of a vertebra lower than the mean for the entrance, a highly significant difference. This finding resembles that of Hubbs (1925) for *Engraulis mordax* in San Francisco Bay, California.

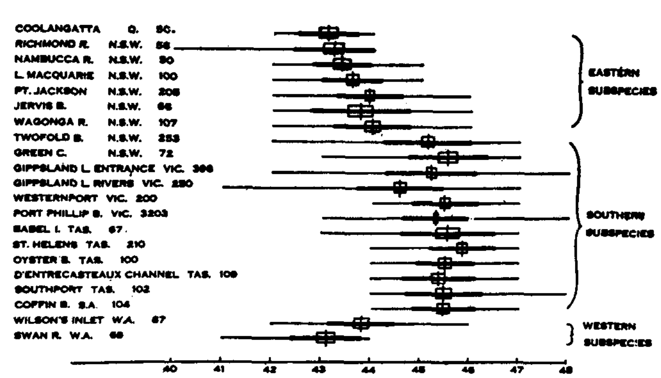

FIGURE 3. Summary of data on vertebral counts of *E. australis.* Numbers at the left are numbers of counts from different localities. The horizontal line for each sample is the range, the vertical cross-bar is the mean, the thickened portion of the line is one standard deviation on each side of the mean, and the hollow rectangle is twice the standard error on each side of the mean (from Blackburn 1950a).

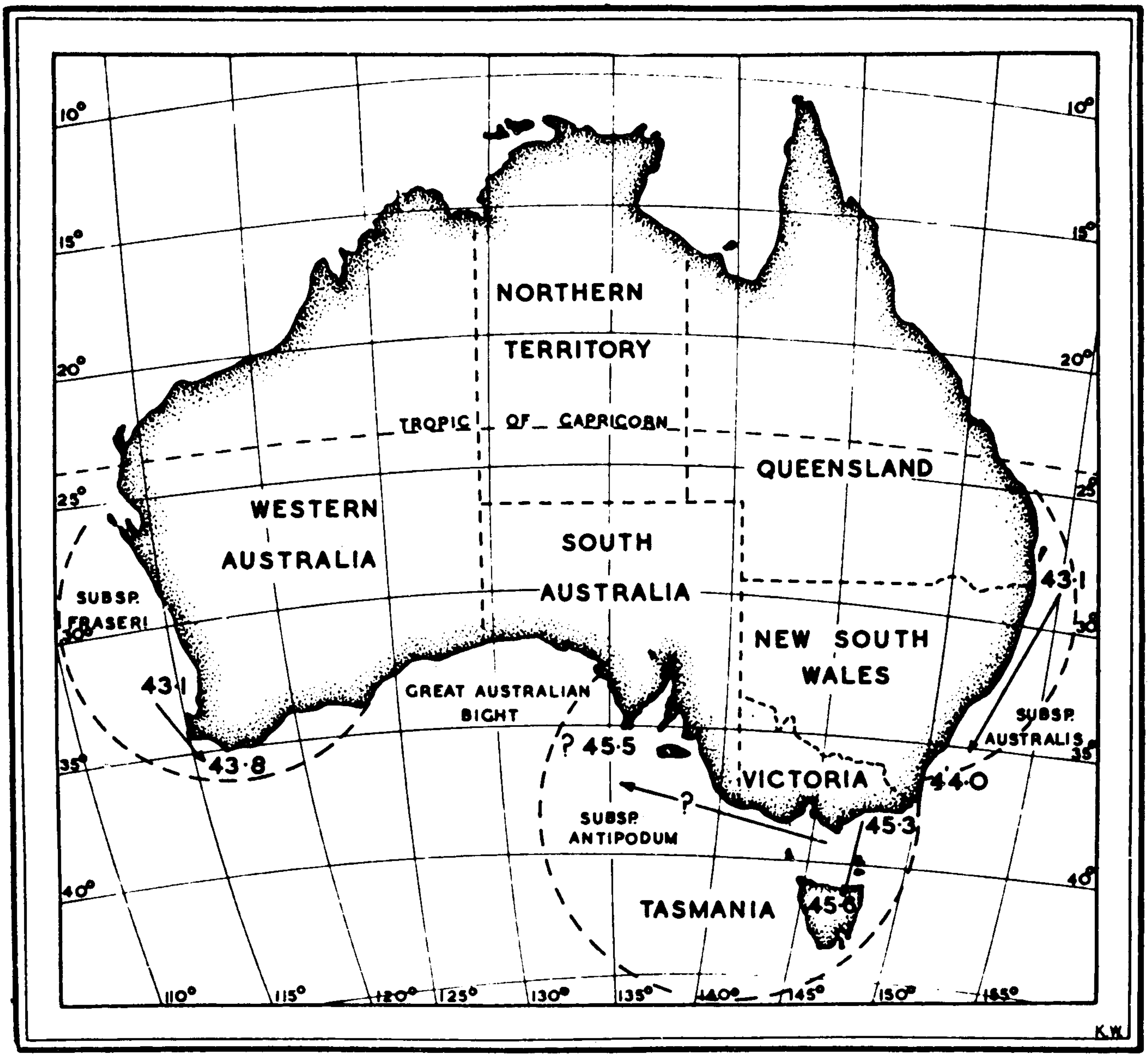

FIGURE 4. Approximate disposition of subspecies of *E. australis* in Australian waters, based on data in Figure 3. Arrows indicate clines in mean vertebra numbers (from Blackburn 1950a).

Although these various differences in mean vertebra number may be phenotypic rather than genotypic, their size and geographical distribution (and, for some well-studied localities, their consistency over many years) indicate that *E. australis* is a complex of different local, at least partly segregated, groups. There are three major groups (two of them morphologically similar, but separated geographically by a third which is morphologically different); within these, minor, less well differentiated, groups occur.

GROWTH

Growth in length was investigated by scale-reading and inspection of length frequency distributions (Blackburn 1950 a). These studies were reasonably adequate only for Victorian fish (members of the southern subspecies), for which about 21,000 length measurements, and scales from 450 fish, were available and useful. Samples from the other five states yielded scales from 314 fish, and about 12,000 lengths which were obtained too irregularly to be useful for length-frequency studies. The deciduous nature of the scales limited the amount of scale material available, especially for small fish.

About three scales, all taken from the flank in the region of the dorsal fin, were usually read for each fish. The appearance of scales from this region is shown in Figures 6, 7, 8, and 9 (from Blackburn

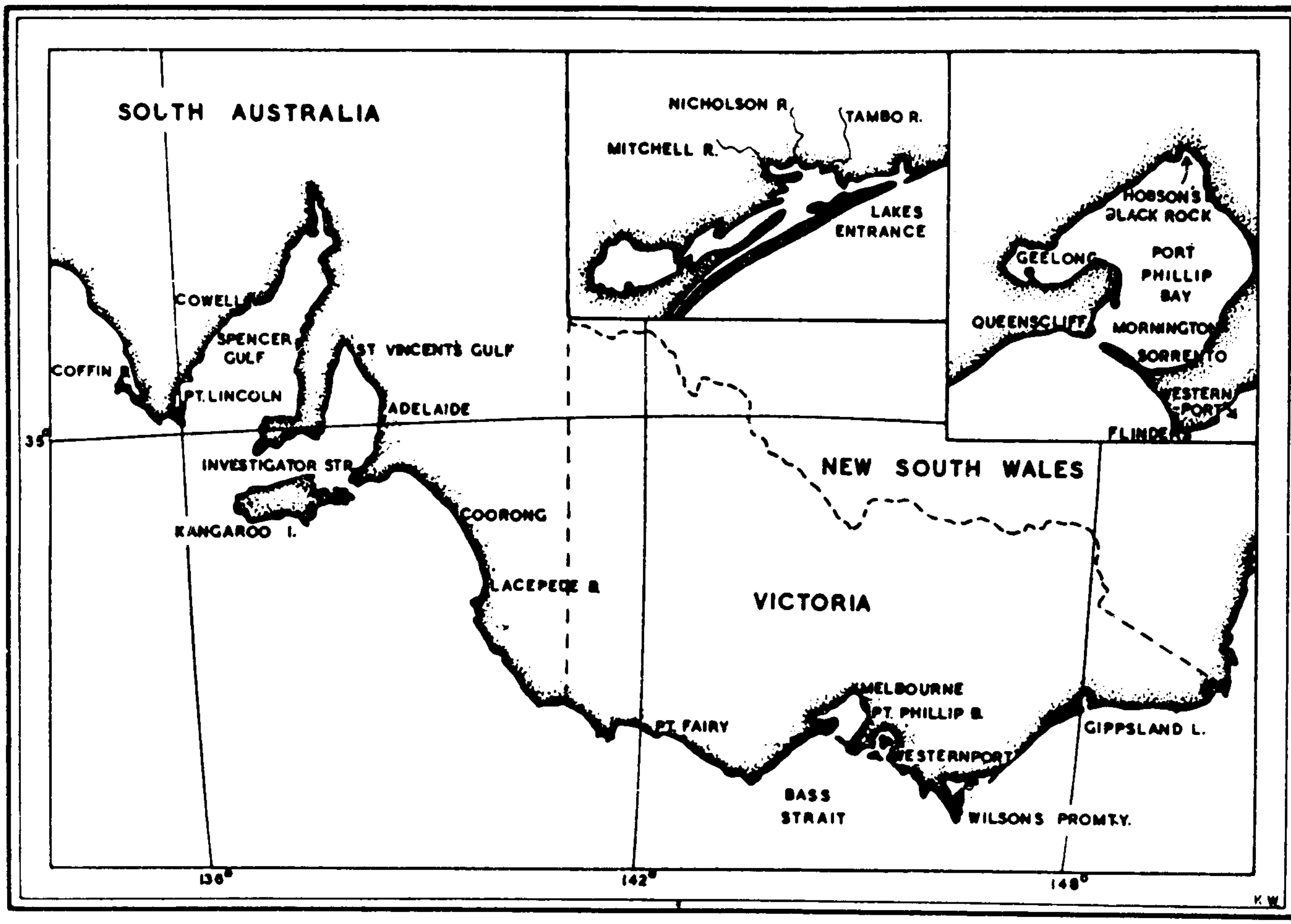

FIGURE 5. Map showing localities mentioned in the text, with Gippsland Lakes and Port Phillip Bay in insets (from Blackburn 1950a).

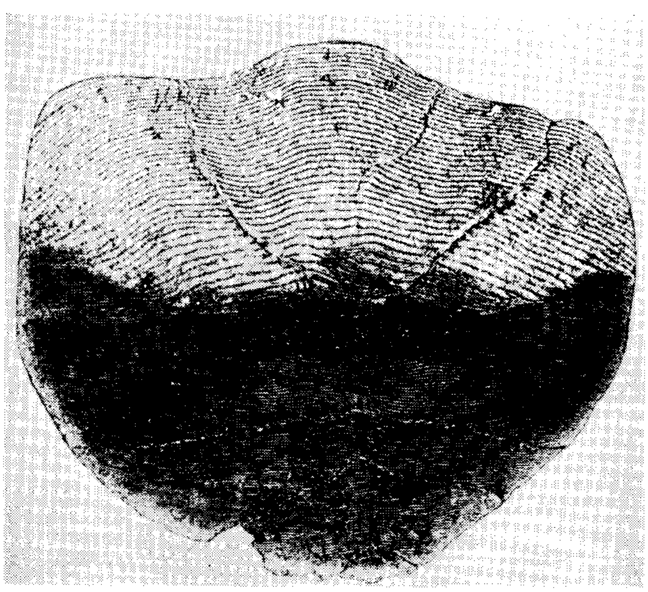

FIGURE 6. Scale from *E. australis* of standard length 64 mm taken in March, with first zone of crowded striae forming at the anterior edge (from Blackburn 1950a).

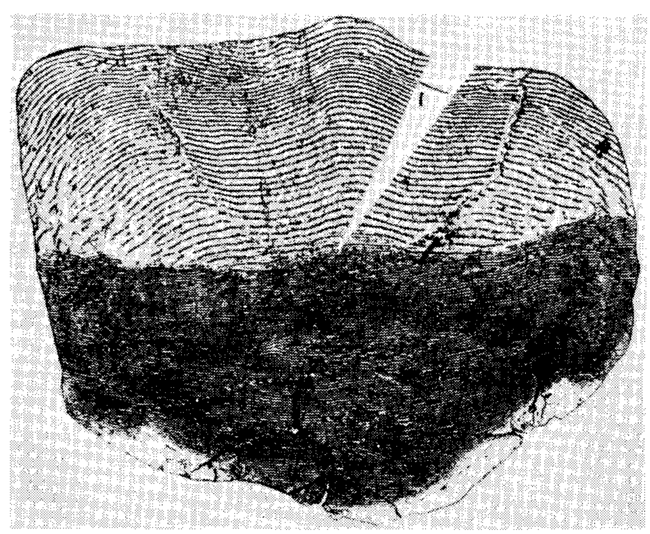

FIGURE 7. Scale from *E. australis* of standard length 64 mm taken in November, with first zone of crowded striae completely formed and succeeded by a zone of more widely spaced striae (from Blackburn 1950a).

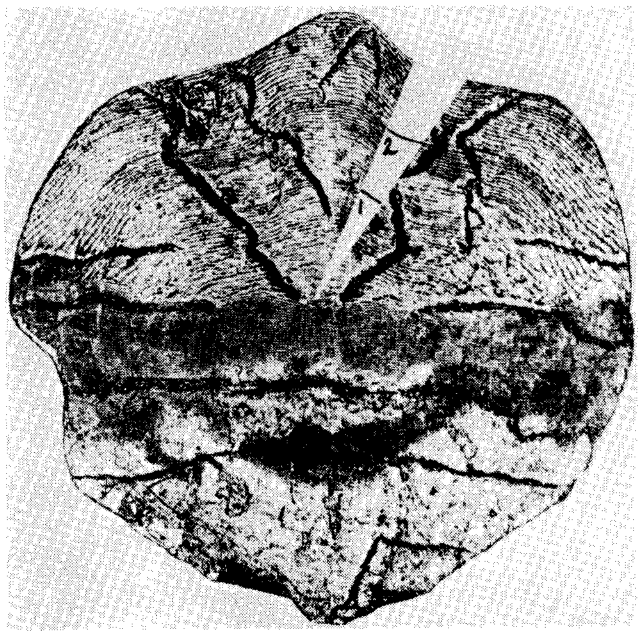

FIGURE 8. Scale from *E. australis* of standard length 75 mm taken in June, with third zone of crowded striae forming at the anterior edge (from Blackburn 1950a).

1950 a); the embedded anterior portion is shown uppermost. The striae on the anterior portion are semi-concentric; they run parallel to the anterior edge of the scale and obliquely towards the lateral edges. In the region where they lie parallel to the edge, bands of widely spaced striae alternate with bands of narrowly spaced striae, in a way reminiscent of a salmonoid scale pattern.

It can be shown that this pattern is annual, and that the period at which the striae become most crowded is in winter. For instance, Figure 6 shows a March scale on which the striae are becoming crowded along the anterior edge, and Figure 7 shows a November scale on which a similar zone of crowded striae has been succeeded by one of widely spaced striae. A similar comparison may be made for the outermost zone of crowded striae in Figure 8 (June) and Figure 9 (October). Further information was given by Blackburn (1950 a). Each zone of crowded striae was therefore considered to represent one winter of life, with very few exceptions. Other apparently periodic features of the scale pattern might have been used, but were not, to indicate the age (e.g., the zones of interrupted, branched, or fragmented striae which occur more or less parallel to the scale sides).

Table 1, from Blackburn (1950 a), shows the frequency of occurrence of different numbers of winter "rings" (zones of crowded striae) in successive length-groups of fish; the lengths are standard lengths, snout tip to end of body excluding caudal fin (this applies to all lengths mentioned in this paper); 4.5 cm means 45 to 49 mm inclusive, and other length-groups likewise. Table 1 gives a general idea of the growth-rate of the Victorian *E. australis;*

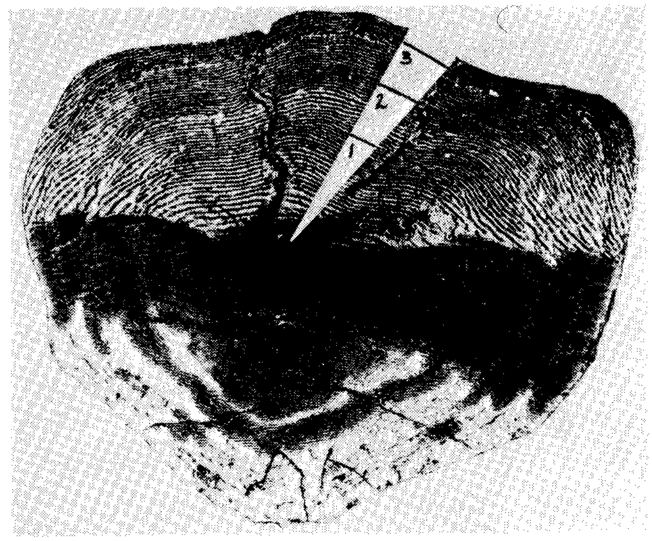

FIGURE 9. Scale from *E. australis* of standard length 81 mm taken in October, with third zone of crowded striae completely formed and succeeded by a zone of more widely spaced striae (from Blackburn 1950a).

TABLE 1

***ENGRAULIS AUSTRALIS,* VICTORIAN SPECIMENS, RECORDED BY NUMBER OF ANNUAL (WINTER) SCALE-RINGS AND STANDARD LENGTH OF FISH; FOR FURTHER EXPLANATION SEE TEXT. (FROM BLACKBURN 1950a).**

Length-group (cm.)	0 Rings	1 Ring	2 Rings	3 Rings	4 Rings	5 Rings	6 Rings	Uncertain	Total
4.5	3	--	--	--	--	--	--	--	3
5.0	2	5	--	--	--	--	--	--	7
5.5	--	13	4	--	--	--	--	--	17
6.0	--	25	21	--	--	--	--	1	47
6.5	--	8	35	4	--	--	--	1	48
7.0	--	2	34	10	--	--	--	--	46
7.5	--	3	37	11	1	--	--	1	53
8.0	--	--	10	9	6	--	--	2	27
8.5	--	1	6	16	1	--	--	3	27
9.0	--	--	2	14	8	2	--	--	26
9.5	--	--	1	16	15	4	--	10	46
10.0	--	--	--	8	15	2	--	15	40
10.5	--	--	--	1	13	7	--	16	37
11.0	--	--	--	--	5	8	--	9	22
11.5	--	--	--	--	1	--	1	2	4
								Total	450

it is shown below that the fish are hatched in summer, so they are about 0.5 year old at the first ring, 1.5 years at the second, etc.

More precise information was obtained by calculating the successive intermediate lengths of the fish (L_1, L_2, etc.) at the times when the successive zones of crowded striae (first, second, etc.) were completed. Such calculations required knowledge of the relationship between the fish-length and the radius of the scale selected for measurement, which was investigated empirically as shown in Figure 10. Fish-length and scale-radius increase in direct proportion only above a fish-length of 60 mm; at fish-lengths between 35 and 60 mm the scales, which may have one or two complete winter zones, grow faster than the fish. The calculations of L_1, L_2, etc., were described by

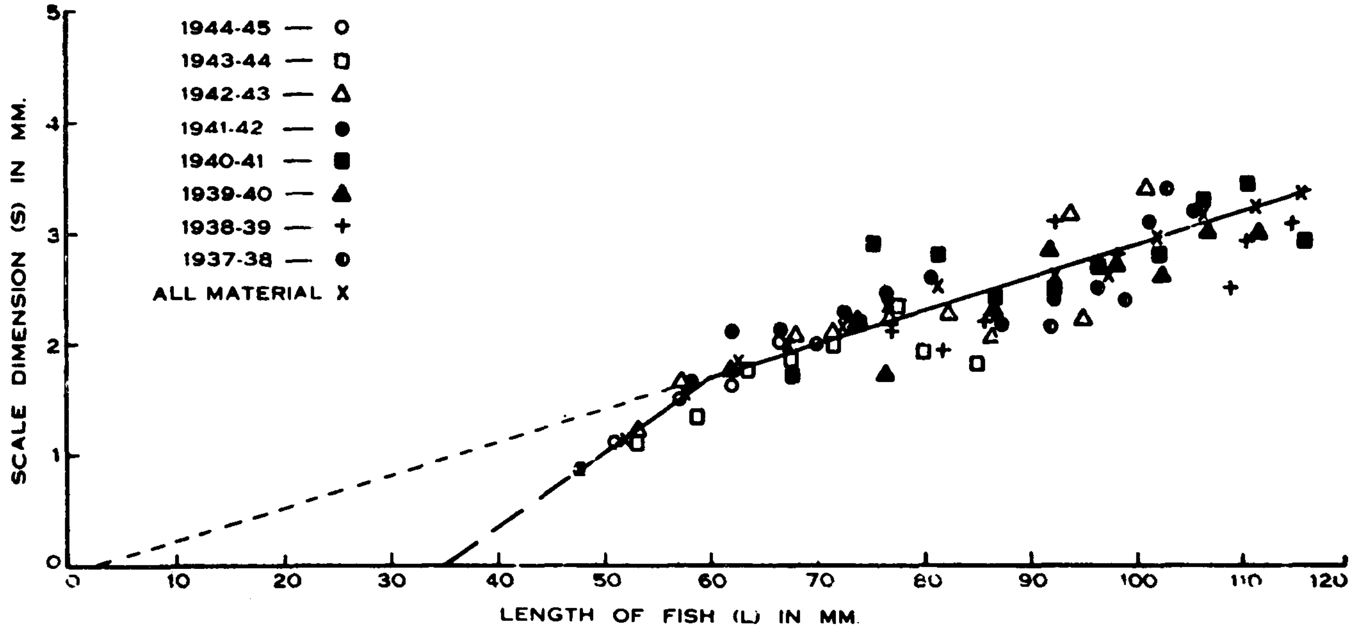

FIGURE 10. Relationship between standard length of fish and scale radius in Victorian specimens of *E. australis*. All scales were taken from the same part of the fish and measured in the same way. Regression lines are based on the material of all year-classes combined. For further explanation see text (from Blackburn 1950a).

Blackburn (1950 a), who analyzed the values in various ways exemplified by Table 2 (where L is actual fish-length at capture).

Table 2 shows that intermediate lengths are consistently higher in younger age-groups than in older; it is believed that this is a result of over-representation of comparatively large fish in the samples of the younger age-groups from which scales were available, because scales are more deciduous in small fish than in large; consequently, it is believed that the L_n means from the older age-groups are the most reliable. The best available estimates of mean L_1, L_2, L_3, L_4, and L_5 are therefore 53, 65, 77, 93, and 104 mm for Gippsland Lakes fish; L_1, L_2, and L_3 are slightly lower (50, 62, and 74 mm) for fish of Port Phillip, which is a saline bay about 170 miles west along the Victorian coast from Gippsland Lakes. These data are quantitatively meager but qualitatively very good. They may be combined to give the following estimates of mean length of Victorian anchovies at successive ages:

0.5 years— 50 mm
1.5 years— 62 mm
2.5 years— 75 mm
3.5 years— 90 mm
4.5 years—102 mm

No estimate is given for 5.5 years because only one fish of that age, and none that were certainly older, was found. The greatest length recorded for *E. australis* is 136 mm, so older fish may well exist.

These findings agree fairly well with those of Table 1, in which allowance must be made for growth in

TABLE 2

***E. AUSTRALIS*, VICTORIAN LOCALITIES: MEANS OF CALCULATED INTERMEDIATE LENGTHS (L_1, L_2, ETC.) FOR SUCCESSIVE AGE-GROUPS, WHERE n IS NUMBER OF FISH AND L IS THEIR MEAN LENGTH AT CAPTURE; FOR FURTHER EXPLANATION SEE TEXT. (FROM BLACKBURN 1950a).**

		L_1			L_2			L_3			L_4			L_5		
	Age Group	Mean L_1	Mean L	n	Mean L_2	Mean L	n	Mean L_3	Mean L	n	Mean L_4	Mean L	n	Mean L_5	Mean L	n
A. Port Phillip Bay	1	55.87	61.40	32	--	--	--	--	--	--	--	--	--			
	2	54.07	71.60	101	70.42	75.11	43	--	--	--	--	--	--			
	3	52.23	78.23	26	65.60	78.24	25	75.67	79.00	6	--	--	--			
	4	49.91	86.73	11	61.91	86.73	11	73.82	86.73	11	101.00	103.00	1			
B. Gippsland Lakes	1	53.00	68.00	1	--	--	--	--	--	--	--	--	--	--	--	--
	2	56.21	83.14	14	72.00	83.25	12	--	--	--	--	--	--	--	--	--
	3	53.35	92.35	46	68.65	92.25	48	85.04	93.46	30	--	--	--	--	--	--
	4	53.23	100.48	48	66.50	100.71	44	84.91	100.76	46	96.59	103.00	22	--	--	--
	5	53.00	104.58	17	64.93	104.40	15	77.27	103.60	15	92.82	104.31	16	104.20	110.00	5

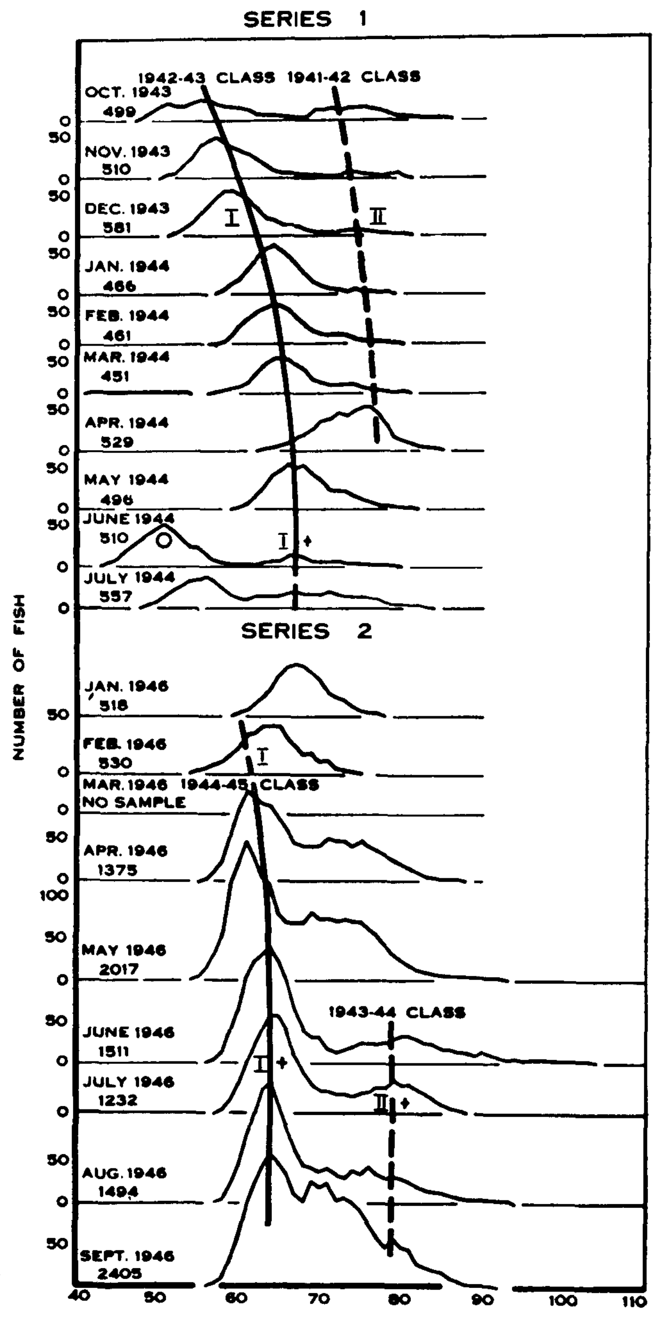

FIGURE 11. Length frequency polygons by months, two series for *E. australis* from Port Phillip Bay, Victoria. All samples in series 1 are from the head of the bay; in series 2 the January and February fish, and those from the younger age-group in later months, are from the head of the bay, and the others are from localities closer to the sea (from Blackburn 1950a).

length subsequent to "ring" formation on the scales. They also agree with length frequency data from Port Phillip, which are mainly for fish under three years of age, and some of which are shown in Figure 11 (Blackburn 1950 a). Figure 11 shows that most growth occurs in spring and summer, and none in winter. Scales read from anchovies obtained from other Australian states gave results which were less reliable, but on the whole consistent with the findings for Victoria.

REPRODUCTION

Gonad maturity stages of *E. australis* were described by Blackburn (1950 a). The running ripe stage was not found, so estimates of length at first maturity were based on frequency of occurrence of "full", "spent", and "recovering" gonads in fish of successive length-groups. This showed that virtually all fish of both sexes become sexually mature at one year of age (about 6 cm) in Victoria. Data from Tasmania were consistent with this result, and those from other states were too scanty to justify a conclusion.

Spawning seasons and areas were identified by studying the distribution of advanced gonad stages in samples of fish old enough to be mature, and the distribution of eggs and larvae in plankton catches. The results (Blackburn 1941, 1950 a; Kott 1955) may be summarized as follows.

Southern subspecies.—Spawning occurs from October through April with a peak in summer, mostly in bays and estuaries and to a much less extent in open sea waters over the continental shelf.

Eastern subspecies.—The data are not nearly as good as for the southern subspecies. The peak spawning season in the southernmost part of the range is the summer, like that for the adjacent southern subspecies, but it appears to become progressively earlier, through spring and probably into late winter, in successively more northern areas. In the southern part of the range there is some spawning both in inlets and in the open sea, as with the southern subspecies; it is difficult to say which of these habitats is the more important for spawning in that region, but farther north, especially in Queensland, the inlets appear to be quite unimportant as spawning places compared with the sea.

Western subspecies.—The information is very scanty; all of it concerns gonad stages in inlet fish from the southern end of the range, and points to a summer peak of spawning.

CHANGES IN DISTRIBUTION WITH AGE AND SEASON

The following observations (Blackburn 1950 a, 1957) have been made on the southern subspecies, for which the best data on occurrence, growth, and reproduction are available.

1. In Port Phillip, anchovies under two years of age are most common at the head of the bay and older fish are most common closer to its mouth (e.g., Figure 11). No similarly detailed studies of distribution of age-groups were made in any other bays or estuaries.

2. Along the Victorian and Tasmanian coasts, anchovies of various sizes, but mainly large enough to be two and a half years or older, occur in the sea outside the inlets in the winter months. They are much less

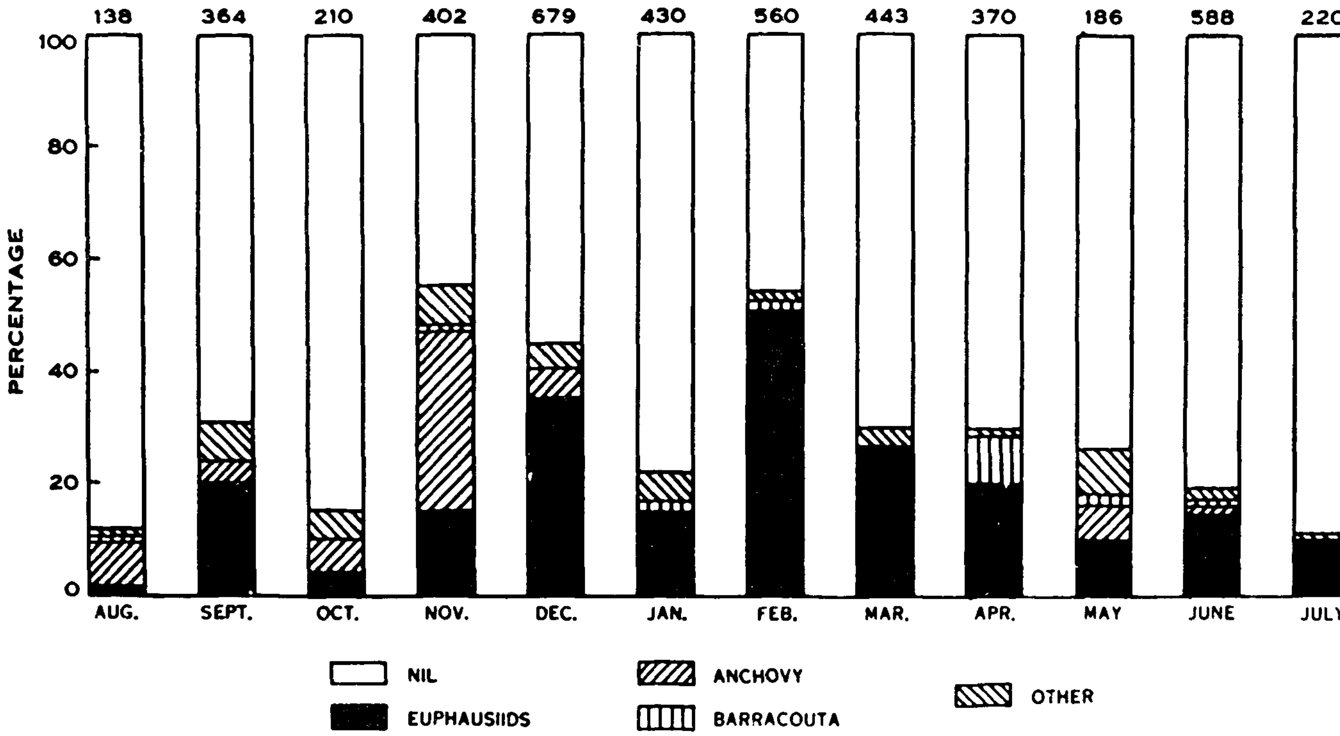

FIGURE 12. Percentage classification, according to contents, of stomachs of the gempylid fish *Thyrsites atun* taken along the south coast of Victoria in different months. Numbers of stomachs are above the columns. Anchovy means *E. australis*. For further explanation see text (from Blackburn 1957).

common there in summer. The best evidence for this statement is the seasonally changing representation of *E. australis* in the diet of the gempylid fish *Thyrsites atun*, which was studied by Blackburn (1957 and references there). This species occurs and is fished along the coasts close to land, but is not common at fishable sizes in bays. Figure 12 shows, for a section of the Victorian coast on to which Port Phillip and other inlet waters open, that *T. atun* feeds on *E. australis* from May through December, but not from January through April. Reports of anchovy schools at sea, by fishermen, indicate a similar pattern of seasonal change.

3. Schools of *E. australis*, of the sizes mentioned in the preceding paragraph, have been seen approaching and going through the entrances of Gippsland Lakes, Port Phillip, and Westernport (Victoria), from the sea, in the spring months. Records of similar schools going out to sea are lacking, however.

4. Anchovies of the sizes just mentioned are much more abundant in bays than in the sea in the summer, which is the spawning period. Some fish of these sizes remain in the bays in winter.

These observations reveal a tendency, increasing with age, for some *E. australis* of the southern subspecies to move each year from the inlets to the sea (probably in autumn) and back again (in spring). The inlets become colder than the sea in autumn and warmer than the sea in spring (e.g., Garner 1954, Port Phillip). The older anchovies may therefore be displaying positive thermotaxis.

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