INTERPRETATION OF THE SCALES OF THE YELLOW-EYE MULLET, *ALDRICHETTA FORSTERI* (CUVIER & VALENCIENNES) (MUGILIDAE)

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Summary

The yellow-eye mullet scale is of the typical percomorph type, feebly ctenoid in most cases, but cycloid in the mid-flank region, which provides the best scale for age and growth determinations. The annual "break" is more obvious in the posterior sector than in the anterior. Above a length of 5 cm (length to caudal fork) there is a straight-line relationship between increments in dimensions of scale and increments in length of the fish. The scales of Victorian and Tasmanian fish are smaller than those of Western Australian fish, which is in accord with the rather larger number of scales in eastern fish. The annual "breaks" become apparent in spring when growth recommences after the winter cessation. As western fish are winter spawners and eastern fish summer spawners, the age and size attained at the time of formation of the annuli differs in the two stocks. Females grow faster than males. Lengths (cm) attained each winter average as follows:

Year	I	II	III	IV	V	VI	VII
Western fish	11	18–19	24–25	29–32	32–35	38	39
Eastern fish	5	12–13	19–21	24–27	30		

The Petersen method of modal progression gives rather higher readings in the first and second years, probably as a result of mesh selection.

I. Introduction

The scales of fish have been used frequently to estimate the age and rate of growth of fish. As Van Oosten (1941) has emphasized, it should not be assumed that scale growth bears a constant relationship to the increase in body length, or that each break or zone of slow growth necessarily indicates a year's growth since the previous break or zone was formed. In order to facilitate the study of the growth rate of the yellow-eye mullet, *Aldrichetta forsteri* (Cuvier & Valenciennes), a critical analysis of the scale pattern and structure is presented here. Most of the data are available from Western Australia. The majority of the fish referred to as "eastern" in this paper come from Victoria and Tasmania, though some unsexed and mostly immature material from South Australia and southern New South Wales was also studied.

II. Scale Pattern

On each side of the body of *A. forsteri* 16–18 rows of imbricated scales can be counted diagonally between the first dorsal and the ventral fins. In the ensuing discussion the most common number of rows, 17 (165 of 184 fish inspected), will be assumed. These rows, running from the pectoral fin region to the base of the caudal fin, grow fewer towards the tail, there being only 12 at the least depth of the caudal

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peduncle. As a datum point from which any scale may be particularized, the second scale above the anterior end of the pectoral fin base is taken (the first scale above the base is minute and distorted). This is the first scale of the eighth row of scales, counting downwards from the first dorsal fin. It will be referred to as scale VIII, 1, in the notation adopted. Counting diagonally cephalad upwards (not far from the vertical in this part of the body) scales 1 of rows VII to III are clearly distinguished. But above III, 1, the distorted unevenly spaced head and back scales are found. Row II does not commence as a distinguishable row until the level of the eighth scale of the rows beneath it. Its first scale is therefore referred to as II, 8. Similarly row I does not commence until scale I, 18, about four scales in front of the first dorsal fin origin. Ventrally from row VIII the pectoral fin occupies the area where the first few scales of the rows immediately ventral to row VIII would lie. Rows IX to XI commence at scale 3, counting diagonally caudad from VIII, 3. At the lower corner of the pectoral there is a patch of small distorted scales, and it is impossible to distinguish any continuation of the more ventral rows amongst these. Hence rows XII to XVII commence at scale 5. It is possible to follow rows XIV to XVII forwards, but the scales in the triangle anterior to the line connecting scales XI, 4, and XVII, 5, are distorted and cannot be utilized in age and growth studies.

Posteriorly the scale rows become reduced as the body depth lessens. Row I, after being disrupted by the obbasal scale of the first dorsal fin and its preceding small misshapen scales, continues to the origin of the second dorsal. Rows II and III merge five or six scales in front of the base of the caudal fin. Rows XIV and XV merge about half way along the anal fin. Row XVI ends at the anal fin origin and row XVII at the anus.

The datum row, VIII, has 54–58 scales in Western Australian fish, 55–59 in South Australian fish, and 59–64 in those from the more eastern waters. Typical scale numbers per row for western fish are shown in Table 1. There are minute scales on all the fins except the first dorsal and four or five of intermediate size between the body scales proper and the minute scalation of the caudal fin. These and the three rows of cheek scales are useless for age or growth studies.

III. Scale Form

(a) *Surface Appearance*

The scales of the dorsolateral region are almost symmetrical. Away from this area they become distorted in varying degrees. Scale VIII, 16, which lies under the tip of the pectoral fin, may be taken as typical (Plate 1). It has almost straight anterior (basal) and lateral borders. The posterior (apical) border is rounded. Thomson (1954) described the scales of this species as cycloid except on the cheek, but actually many of the body scales are feebly ctenoid. In fact only some of those scales on the flat portions of the flanks (scales 7–37) are cycloid. Table 1 shows that rows IX–XI have more cycloid scales than the others. The scales of dorsal rows I–VI and the ventral rows XIII–XVII are all ctenoid, those of rows I–III and XIV–XVII strongly so throughout.

The nucleus (the focus of Taylor (1916) and Lagler (1947, 1950)) is displaced posteriorly owing to unequal growth of posterior and anterior fields (Plate 1). From the small blank area of the nucleus diverge an anterior and a posterior pair of axes, termed the shoulders, which divide the surface area into four sectors—the anterior (basal), posterior (apical), and two lateral fields. These fields are delineated by changes in direction of the circuli (see below) and sometimes by changes in the number of circuli, and also by more or less prominent ridging of the shoulders, of which the anterior pair are prominent, giving the illusion that the anterior sector lies in a plane differing from lateral fields. The posterior shoulders are discernible under the microscope or when the image is projected, but they are not obvious to the naked eye.

TABLE 1

RESUMÉ OF SCALE PATTERN OF 18 WESTERN AUSTRALIAN MULLET OVER 21 CM L.C.F.*

Row	Determinable Scales	No. of Asymmetrical Scales	No. of Cycloid Scales	No. with Mucous Canal	Anteriormost Scale with Length Greater than Breadth
I	18–28	8	0	4	22
II	8–44	19	0	34	24
III	1–59	17	0	35	26
IV	1–56	8	0	36	26
V	1–51	2	0	29	26
VI	1–52	6	0	24	26
VII	1–53	8	7	31	26
VIII	1–54	12	7	40	26
IX	1–53	12	19	30	25
X	3–53	6	20	33	22
XI	3–55	18	14	40	20
XII	5–54	15	10	45	17
XIII	5–52	23	0	48	15
XIV	5–52	25	0	41	14
XV	5–36	20	0	32	12
XVI	5–34	20	0	32	12
XVII	5–26	21	0	22	8

* Length to caudal fork.

The shoulders are referred to as radii by Pillay (1951), but this term usually refers (Cockerell 1913; Taylor 1916; Lagler 1950) to the grooves diverging from the nucleus towards the edge of the anterior sector. Primary radii diverge from the nucleus. Secondary radii may develop further out as the scale increases in area. A typical scale from the mid-lateral region has 4 primary radii and there may be 4–10 secondary radii.

Outside the nucleus the scale is marked by lines known as circuli (or striae) which are more or less parallel within each field. The number of circuli in the anterior field is approximately double the number in the lateral fields, where a circulus may meet anything from one to four circuli of the anterior field. The posterior field has as many circuli as the lateral fields except that several extra ones occur in the vicinity of the "annuli", which will be described below. There are no initial circuli differing from the true circuli in the vicinity of the nucleus as described for *Mugil cephalus* Linnaeus by Jacot (1920) and Pillay (1951).

The regular disposition of the circuli is broken by lines or "breaks" which may tentatively be identified as annuli, since they have all the characteristics listed by Kesteven (1942) for the annuli of *Mugil cephalus* (syn. *M. dobula* Günther) except that they differ in being most prominent in the posterior field instead of the anterior. (It should be noted that Kesteven (1942) has the notation of anterior and posterior reversed from that adopted here and by most authors, and from the natural position of the scales on the fish.)

(*b*) *Mucous Canals*

Mucous canals are frequent on mugilid scales. Fée (1869), Jacot (1920), and Pillay (1951) referred to them as being part of the lateral line canal system. Mugilids have no prominent lateral line such as is found in many fish. But the mucous canals are found in at least some of the scales in every row (Table 1) and no canal system joins them in any way. The underlying cells seem to be not neuromasts but of a secretory nature. Scales with mucous canals are most frequent in rows XI–XIV. Only row I has fewer scales with mucous canals than without. The mucous canal generally runs through or close to the nucleus but occasionally it may be displaced considerably from the nucleus (Plate 2, Fig. 1), probably as the result of displacement of the scale. The mucous canal is hollowed out of the outer surface of the scale and consists of two portions, a posterior basal portion which is wider and deeper, usually ending at the level of the nucleus, where it is continued in the narrow shallow anterior canal. Connexion to the under-side of the scale is through a minute tissue-plugged pore in the trough of the basal portion of the mucous canal. The anterior canal is sometimes in a straight line with the posterior but more usually it is at an angle to it. The base itself may lie at any angle between about 40° on either side of the long axis of the body, and the anterior canal may turn up or down from it. The canals generally turn up and down alternately in a row of scales, though sometimes successively two, but rarely more, may turn the same way. The mucous canal of this species covers only about a fifth of the length of the scale. Occasionally the basal portion is duplicated, probably as a result of partial rotation of the scale in its socket, such as Van Oosten (1929) has described, for such scales usually show a double nucleus. Even more rarely, and usually on distorted scales near the tail, the anterior canal may be duplicated.

(*c*) *Granulated Scales*

Two types of granulated scales were found on *A. forsteri*. In one type the granulations were irregular in outline and mostly confined to the anterior and posterior fields (Plate 2, Fig. 2). Van Oosten (1929) has suggested that such granulation is due to repair of local injuries to the edge of the scale at a younger stage. The present granulations suggest rather a corrosion of the scale. The second type of granulation is that found on scales commonly referred to as eroded or regenerated, or more correctly as replacement scales. In such scales the granulated area is more or less even in outline (Plate 2, Fig. 3). Outside the central granulated area, which represents the amount of growth the regenerated scale had to make to reach approximately normal size, the scale has the attributes of a normal scale, except that radii tend to be more numerous in replacement scales, and mucous canals and ctenii are redeveloped only on those which are replaced at an early stage (usually before the formation of the first annulus). Replacement scales also tend to be of slightly smaller dimensions than the original scale would have been.

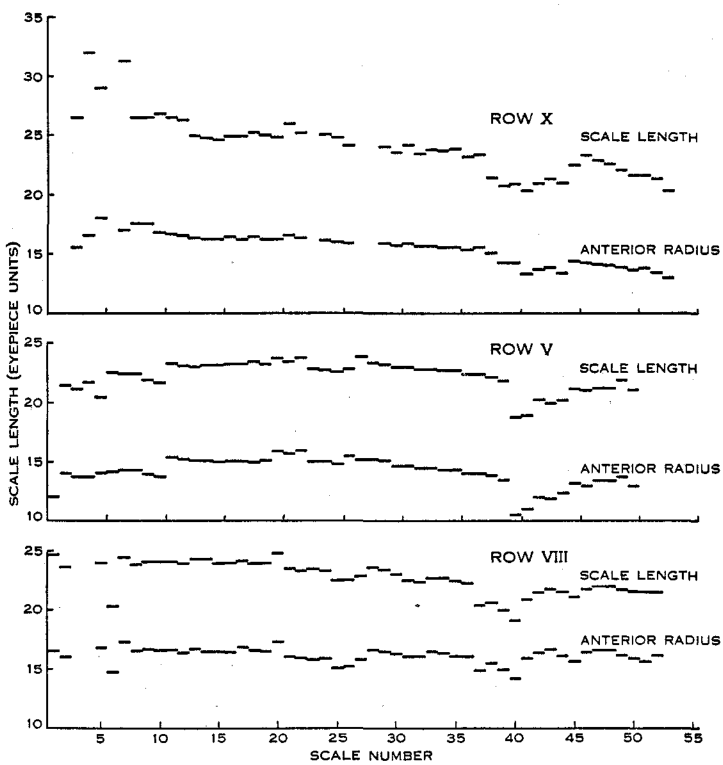

Fig. 1.—Comparative scale lengths and anterior radius lengths (arbitrary micrometer eyepiece units) of scale rows V, VIII, and X, of a fish 25·8 cm L.C.F. from Wilson Inlet, W.A.

(*d*) *Size and Dimensions of the Scales*

The proportions of the scales vary. The nucleus is nearer the posterior edge of the scales farther posterior along each row. Considering those scales which are symmetrical or only slightly asymmetrical, the more anterior are wider than long; whereas those behind scale 25 or 26 of the mid-flank region, and even farther forward in other rows, have the scale longer than broad (Table 1).

The size of any particular scale dimension is not uniform over the fish's body. So although there may be a constant relationship between the size of the fish and any particular scale (Section IV (*a*) (ii)), the mathematical relationship will vary with each scale. Consequently, in sampling, either a particular scale would have to be used from each fish, which would entail greater time in locating the key scale which might be missing or granulated, or a group of scales whose dimensions differ only slightly could be utilized. Figure 1 shows the whole scale length and anterior radius length from three selected rows (V, VIII, and X). It is apparent that the scales are most uniform in this dimension between scales 12 and 22, that is, roughly in the region reached by the tip of the pectoral fin.

IV. Age and Growth Studies

(a) *Appraisal of the Scales*

As stated above, there are marks or breaks on the scales which seem to correspond to the annuli of *M. cephalus* described by Kesteven (1942). Van Oosten (1929) and Lagler (1950) have listed the conditions under which these "annuli" may be considered as year marks.

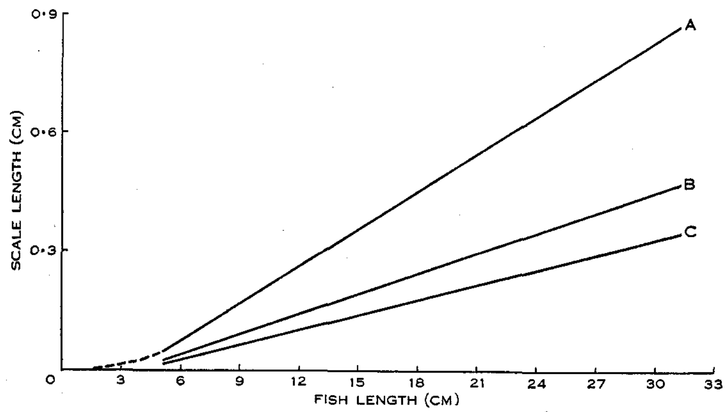

Fig. 2.—Correlation of fish length with: *A*, length of scale; *B*, length of anterior radius; *C*, length of posterior radius.

(i) *Constancy in Number and Identity of Scales.*—The nuclear area of scales from older fish is identical in appearance with the scales of young fish. Regenerated scales have a typical granular central part. The number of scales appears to be constant in an individual. It has not, of course, been possible to check this on an individual fish, but although the lateral count of scales varies from 54 to 58 there is no correlation between number of scales and size of fish.

(ii) *Correlation between Growth of Body and Scale.*—Scales from rows VI–X in the vicinity of the tip of the pectoral fin are relatively uniform in size (Fig. 1). Figure 2, illustrating the relationship of scale length to length of fish, was prepared using scales from this region. There is considerable scatter about the line of best fit which, however, appears to be a straight line. Calculated from data on 1789 fish from Western Australia and 297 from eastern Australia between the sizes of 5 and 31·5 cm, the regression line formulae of whole scale length (*SW*) (anterior-posterior axis), of anterior radius (S_a), and of posterior radius (S_p) on length to the caudal fork (L) for Western Australian and eastern Australian fish are as follows:

Western Australia	Eastern Australia
$L = 3{\cdot}57+33{\cdot}4S_w \pm 2{\cdot}76$	$L = 3{\cdot}58+34{\cdot}7S_w \pm 2{\cdot}01$
$L = 3{\cdot}46+59{\cdot}8S_a \pm 2{\cdot}91$	$L = 3{\cdot}16+60{\cdot}3S_a \pm 3{\cdot}25$
$L = 3{\cdot}25+77{\cdot}6S_p \pm 5{\cdot}22$	$L = 4{\cdot}82+72{\cdot}0S_p \pm 5{\cdot}61$

This indicates that in correlation with the somewhat larger number of scales on eastern Australian yellow-eye mullet (Section II) these fish have scales which are slightly smaller than those on Western Australian fish of the same size; the anterior radius of eastern scales is proportionately large and the posterior small compared with western scales.

TABLE 2

SEASONAL GROWTH OF II+ YELLOW-EYE MULLET CALCULATED FROM MARGINAL INCREMENTS OF 1025 FISH

All localities Western Australia. Measurements in centimetres

No. of Annuli	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	4·7	7·0	7·4	8·6	8·5	8·5	8·4	8·3	8·8	0·6		
2	4·7	6·4	6·8	5·9	7·0	7·2		7·2	7·2 (1·1)*	1·0	2·0	3·8
3	3·6		4·3	4·8	5·5	5·9			5·7 (0·5)*	0·8		
4		2·7	3·1		4·1	4·2		4·1	4·1			
5			2·0									
No. of fish:	116	84	210	188	386	177	78	101	200	115	20	84

* The figures in parenthesis indicate the increments at a later date in the month.

Such relationships rarely, if ever, hold at small sizes (see Lagler 1950 for brief review). These formulae would indicate that the scales appear at a fish length of 3·0–4·8 cm. Field collections of young fry indicate that scales appear at about 1·8 cm. This implies a curve towards zero at the lower end of the regression line as figured by Ricker and Lagler (1942) for the white crappie *Pomoxis annularis* Rafinesque and the large-mouth bass *Micropterus salmoides* (Lacépède), whereas Blackburn (1949) and Miller (1955), studying clupeoids, found a curve away from zero; in other words, in the clupeoid studies, the size at first appearance of the scales was greater than that indicated by the regression line.

(iii) *Frequency and Time of Formation of the "Annuli".*—The marks and breaks referred to in Section II as annuli appear at intervals upon the scales of larger yellow-eye mullet. Examination of scales collected at various times of the year will show when the annuli are formed. The marginal increments, i.e. the width of the scale border outside the annuli, are smallest in late September and early October (Table 2). The size of marginal increment is practically the same from June to September, indicating that growth in all age groups ceases during July, August, and early September. The annulus thus becomes apparent when the scale starts to grow in the spring, a situation paralleling that found in the sea mullet (*Mugil cephalus* Linnaeus) in the same waters (Thomson 1951).

The possibility that seasonal growth of scale and fish might not be contemporaneous is disproved by graphing the mean values of scale size from fish of a selected length taken at different times of the year. The graph (Fig. 3) shows a normal scatter about an average value and not a sine curve as found by Duff (1929) for cod.

(*b*) *Age for Size*

As all the rings are formed at the same time of the year, those subsequent to the first will appear at yearly intervals and thus give a valid indication of the age since the appearance of the first annulus. The first annulus will form at the end of the first 12 months of life only in those fish spawned in late September (the time when

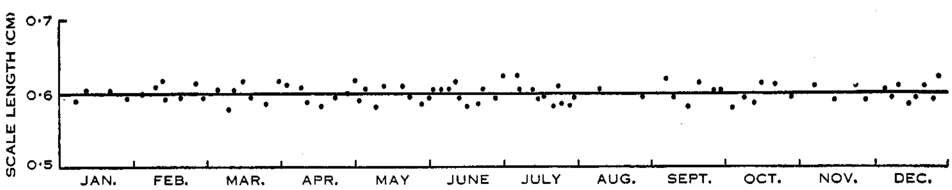

Fig. 3.—The scale size of fish of 20 cm L.C.F. taken at various times of year.

the annulus appears). In Western Australia this is the end of the 4-month spawning season. In the eastern States yellow-eye mullet spawn from December to February (Thomson, unpublished data). Consequently the first scale ring or annulus of a western fish may appear 9–12 months after spawning; but in eastern fish only 7–9 months after spawning. It also means that western fish have a 9- or 10-month growing period before growth ceases in winter, whereas eastern fish have only 4–6 months' growth. Consequently the first annulus on the scales of eastern fish is formed at a much smaller size than on those of western fish.

In the discussion that follows, the usual notation of 0, I, II, etc., for age groups will be used, although this will designate fish with scales bearing corresponding numbers of annuli and will not necessarily imply that the fish are less than 12 months old, 12–24 months old, etc.

Because of the spread of spawning over several months the range of size attained at the time of formation of the annuli is considerable. As a result the age group to which a fish belongs cannot be gauged from its length alone; the time of year at which it is taken has also to be taken into account. Table 3 shows the age-for-length distribution for fish from Western Australia. There are insufficient data on the older age groups from eastern Australia to provide a similar table. Of the 1759 readable scale samples from Western Australia, 1536 had data on sex available; similar data were available for 83 of the 273 scales from eastern fish. It is quite evident that, age for age, female fish are larger than males. The oldest fish taken during sampling (and these were the largest yellow-eye mullet the author has seen at any time) belonged to age group VII. But few females and still fewer males seem to live more than 5 or 6 years.

Table 3 can be interpreted as meaning: (1) In Western Australia, 0 group fish comprise all yellow-eye at 6 cm or less, and some up to 11 cm; (2) the I group include some between 6 cm and 11 cm, all between 11 cm and 13 cm, and some between 13 cm and 19 cm.

TABLE 3

MALE AND FEMALE AGE-FOR-LENGTH DISTRIBUTION, WESTERN AUSTRALIA

Length, L.C.F. (cm)	Male					Female						
	I	II	III	IV	V	I	II	III	IV	V	VI	VII
13	7					2						
14	3	1				2						
15	2	2				2	1					
16	1					1	1					
17	2	8				3	2					
18		14				5	9					
19		26	1			1	27					
20		41	19				53	2				
21		25	30				40	25				
22		5	40				16	70				
23			39	1			6	39				
24			34	6			2	42	3			
25			16	15				40	9			
26			5	20				43	41			
27				27	4			14	39			
28				12	10			2	38	1		
29				3	6				30	4		
30					3				13	16		
31									4	22		
32										15		
33										4	2	
34										4	7	
35												
36											1	
37												
38												1
39												1
Total	15	120	184	84	23	16	157	277	177	66	10	2

The older age groups can be interpreted similarly, with the added complication of the sexual differences, which become clearly established in the third year.

(c) *Growth Rate*

Direct evidence of growth rate can be obtained by measuring fish at time of tagging and at recapture. Such evidence is lacking for yellow-eye mullet, as the operculum tag used in the contemporaneous study of the sea mullet (Thomson 1951) did not prove suitable for long periods of attachment on yellow-eye.

The growth rate has therefore been estimated from scale reading, and some measure of independent check is given by the Petersen technique of interpreting the modes of a graph of size distribution as the modal lengths of successive year groups.

(i) *Annual Growth.*—It has been demonstrated in Section IV(*a*)(ii) that the increments of scale size and body bear a constant relationship to each other. As a consequence of the non-linear relationship of scale and fish lengths before a size of

TABLE 4

INTERMEDIATE LENGTHS, WESTERN AUSTRALIA

Annulus:	I	II	III	IV	V	VI	VII
Male:							
Length (cm)	11·09	18·97	24·71	29·23	32·76		
Number	426	411	291	107	23		
Female:							
Length (cm)	11·20	19·68	26·42	31·74	35·21	37·90	39·33
Number	905	889	532	255	80	12	2

5 cm is reached, the relationship is between the increments and not the absolute sizes, and therefore the size of the fish at any intermediate length cannot be estimated from the dimensions of the scale by simple proportion.

The intermediate length as calculated by simple proportion must be "corrected" by use of the formula

$$L_n = L'_n + A\left(1 - \frac{L'_n}{L}\right),$$

where L_n is the required intermediate length; L'_n is the estimate of the intermediate

TABLE 5

INTERMEDIATE LENGTHS, EASTERN AUSTRALIA

Annulus:	I	II	III	IV	V
Male:					
Length (cm)	5·00	12·87	19·55	24·88	
Number	32	12	4	2	
Female:					
Length (cm)	5·23	13·56	20·99	26·72	30·61
Number	51	28	15	10	3

length obtained by simple proportion; A is the Y-intercept constant in the appropriate regression equation describing the relationship between scale and fish length; and L is the length of the fish when sampled.

The mean lengths to the caudal fork (L.C.F.) attained each year at the time of formation of the annuli are shown in Tables 4 and 5.

The female yellow-eye mullet clearly grows at a greater rate than the male. The difference in the first year's growth is not significant, but in subsequent years the difference is clearly established.

The actual rate of growth of the eastern fish seems to be similar to that of the western fish as the curves are parallel, but owing to the different time of spawning of the eastern stock, the absolute size at the time of formation of the annulus differs.

TABLE 6

LOCAL VARIATION IN MEAN CALCULATED INTERMEDIATE LENGTHS (CM L.C.F.)

Locality	l_1		l_2		l_3		l_4		l_5		l_6	l_7
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♀	♀
Bowes River		11·1		19·7		25·5						
Swan River	8·1	8·8										
Safety Bay	9·4	9·0	19·6	20·0								
Whitford's Beach	9·0	10·2	18·0	21·1	23·6							
Peel Inlet	8·7	9·4	18·4	19·0	24·1	26·4		31·5				
Leschenault Inlet	9·1	9·1	18·7	19·2								
Margaret River	11·4	11·5	18·8	18·9	25·8	27·2						
Hardy Inlet	10·3	10·2	19·1	19·7	25·6	26·9		31·8				
Nornalup	11·2	11·4	19·7	19·9								
Brooks Inlet		11·3		19·8		26·5		32·4		35·6	37·8	
Irwin Inlet	9·9	10·1	18·0	19·9								
Wilson Inlet	10·7	10·8	19·4	20·7	24·1	25·9	28·4	31·8	32·8	35·2	37·9	39·4
Torbay	11·5	11·5	19·3	19·8	25·0	27·1		31·9				
Oyster Harbour	10·2	10·3	18·5	18·4	24·2	26·3						
Nannerup	11·2	11·1	19·6	20·0	25·9	27·1	28·8	32·2		36·2		
Bandy Creek		11·7		20·1		28·2		32·8				
Hopetoun	11·3	11·0		19·1		25·8						

There is some local variation in growth rate (Table 6).

The means from all districts are fairly close despite the wide variation in individual size at the time of formation of the annulus (Section IV(*c*)(iii)). There is more variation apparent at the time of formation of the first annulus than later, the difference between the lowest locality mean and the highest in Western Australia being 25 per cent. of the grand mean for the State. The absolute difference remains much the same over the years but the proportional difference declines with age.

There is no continuing trend of growth at a slow or fast rate in any particular locality. This can be seen from Table 6, but is more clearly expressed in Table 7, where annual differences are recorded for certain localities from which adequate samples are available. Annual variation in growth rate occurs in the various localities as illustrated by Wilson and Peel Inlets (Table 7). As sexual difference in growth rate is very small in the first 2 years (Table 4) this factor is ignored here.

(ii) *Individual Growth.*—The growth data presented in the preceding section were derived from the means of group samples and indicate the general trend of growth for the stock as a whole. The individual growth curve may vary significantly from that of the hypothetical average fish as shown in Figure 4.

(iii) *Seasonal Growth*.—It has already been shown in Table 2 that growth generally ceases in July, August, and early September, at least in Western Australian waters; it is also apparent from the cumulative increments that growth is most rapid during midsummer—December to February.

TABLE 7

ANNUAL VARIATION IN LENGTH AT TIME OF FORMATION OF FIRST AND SECOND ANNULI, WILSON INLET AND PEEL INLET

Year Class	Wilson Inlet		Peel Inlet	
	l_1 (cm)	l_2 (cm)	l_1 (cm)	l_2 (cm)
1935	10·31	20·55		
1936	11·65	19·07	8·80	18·75
1937	9·24	18·79	9·33	19·01
1938			7·95	17·66
1942	10·53	19·51	8·58	18·54
1943	9·72	19·76	9·07	18·98
1944	10·53	19·09	9·12	18·65
1945	9·96	18·87	8·77	18·21
1951	8·98	18·06		
1952	10·00	19·75		
1953	9·02	19·11		

(*d*) *Confirmation of Scale Analysis by the Petersen Method*

Petersen's method of interpreting the modes of a graph size distribution as the modal lengths of successive year groups can be used successfully when there are short spawning periods and marked annual growth.

Although the spawning period of the yellow-eye mullet is prolonged over several months and the sexes display different rates of growth in later years, the first three size groups can be traced by this means (Fig. 5). From the modes of the curves at the end of winter or in early spring, corresponding to the time of formation of the annuli, the size of the three year groups at this time would appear to be approximately 15, 20, and either 24 or 26 cm respectively. The first figure is markedly higher than that obtained by scale reading (Table 5) but is probably due to the catching bias of the net used ($1\frac{1}{4}$ in. mesh), the fish of this group being taken in experimental hauls. The second year group is marked at 20 cm by the Petersen method and somewhat below this by scale reading. Again this could be due to bias of the nets, as the fishermen aim at catching as little as possible below 20 cm L.C.F. (= 9 in. total length) which is the legal minimum length in Western Australia. The alternative figures for the third year group, derived from the curves for August and September, accord well with the scale reading results for the two sexes and might be conceived to be the result of a preponderance of a different sex in the two months.

The growth rate as portrayed by the progression of the modes shows a maximum from January to March, which accords well with the figures obtained for the marginal increments of the scales in those months (Table 2).

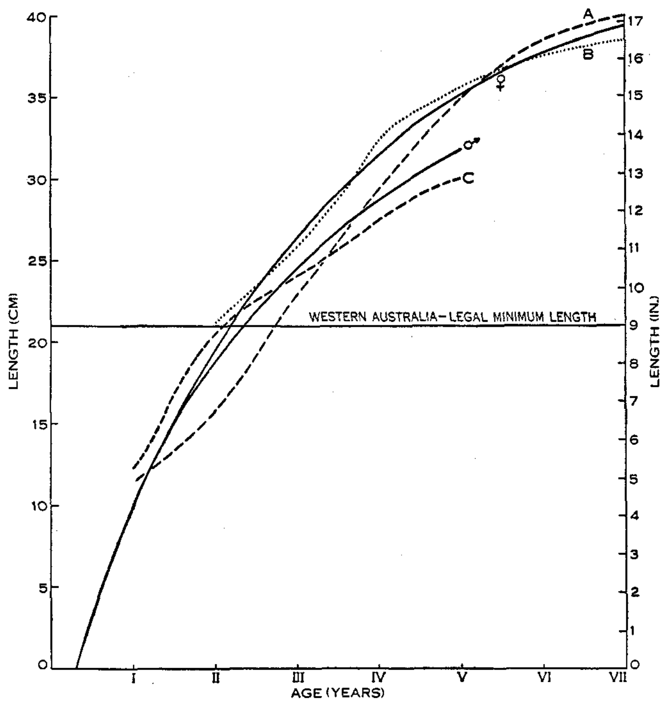

Fig. 4.—Annual growth curve for males and females (solid lines), and individual growth curves for two females (*A* and *B*) and a male (*C*) derived from scale readings.

V. Conclusions

Age and growth studies of the yellow-eye mullet may be successfully carried out by taking scales from the mid-flank region. Scales from other parts of the body are more or less distorted or obscured by ctenii or proliferation of the mucous canal. Scale rows VII–XII include cycloid scales which are easiest to read; the other rows are ctenoid throughout.

Annuli are formed by marks on the scale appearing when growth recommences in spring following a winter cessation. Scale reading suggests that on the average, fish which have formed the first annulus attain a length of 11·1 cm in Western Australia and about 5·16 in the eastern States; second year fish are 18 or 19 cm in the west and 12·5 to 13·5 in the east; third year fish 24–26 and 19–21 cm respectively; fourth year fish 29–31·75 and 24·5–26·75 cm; fifth year fish 32–35 and 30 cm; and in the west a few sixth and seventh year mullet have been taken at 37·9 and 39·3 cm.

The Petersen method gives rather higher readings for the first and second year but these probably result from the catching bias of the nets sampling the population. The differences in size at formation of annuli between eastern and western fish are due to the different spawning seasons—summer in the east, winter in the west.

Females grow rather faster than males, as becomes apparent in the third year. Seasonal growth rate is greatest in midsummer; growth virtually ceases in midwinter.

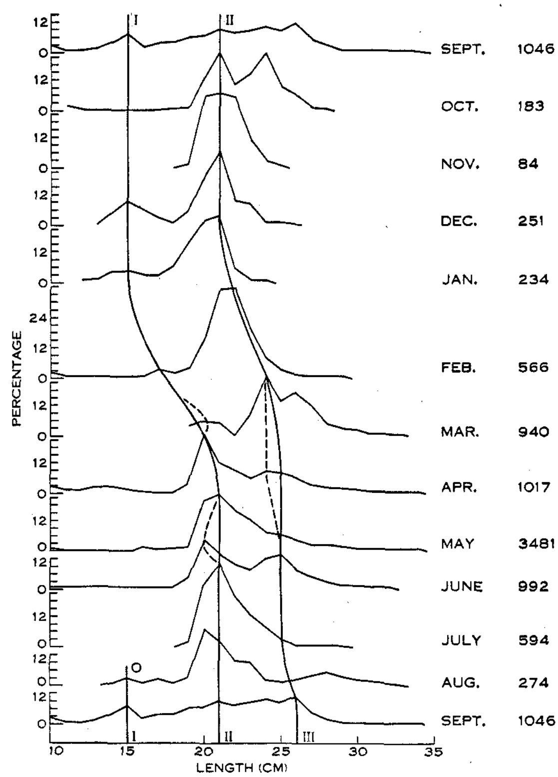

Fig. 5.—Monthly length frequency distribution from Western Australian market samples and experimental hauls, illustrating progression of the modes of year classes I and II.

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Explanation of Plates 1 and 2

Plate 1

Scale VIII, 16, from a III+ fish, 25·2 cm L.C.F. A typical scale.

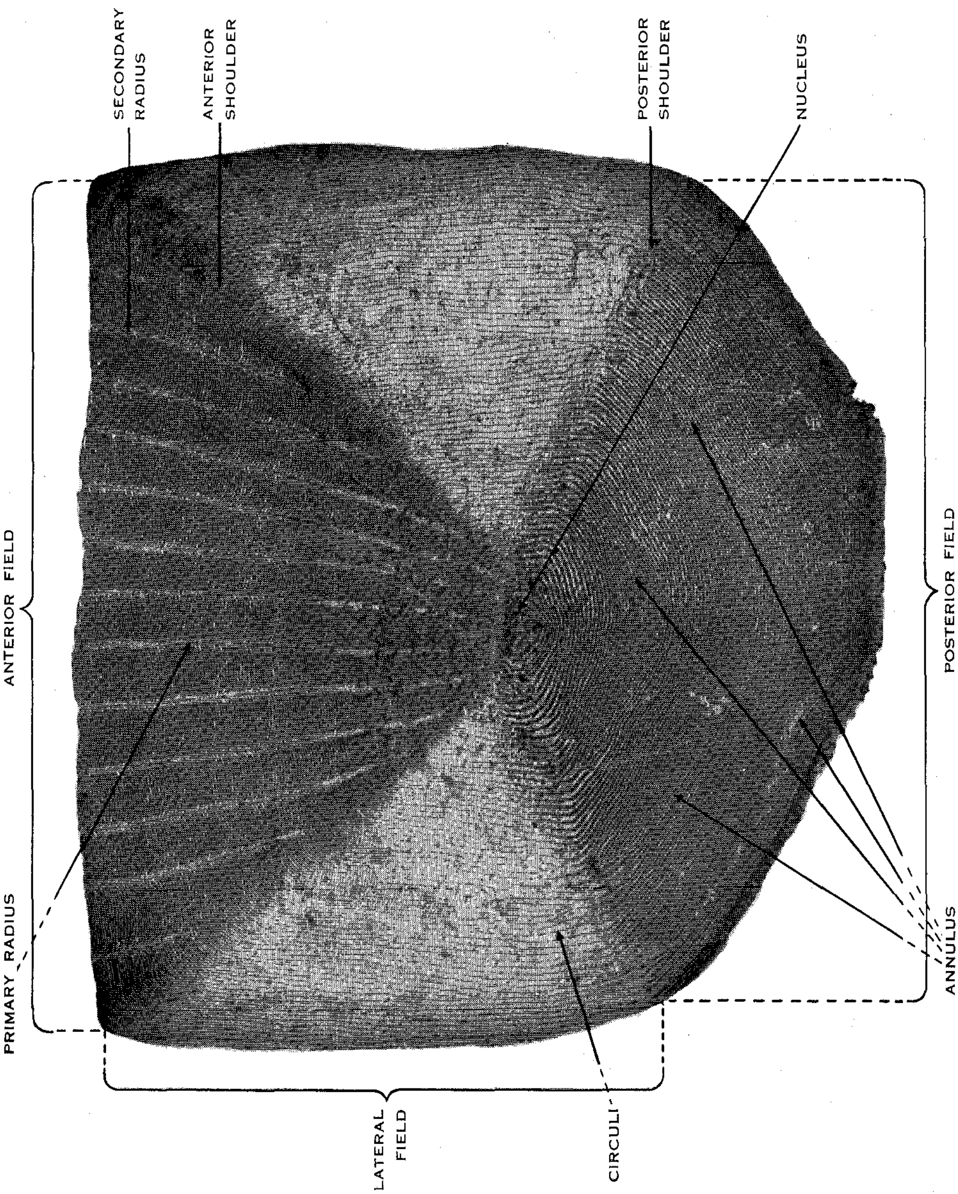
Plate 2

Fig. 1.—Scale X, 17, from a III + fish, 25·2 cm L.C.F., showing double nucleus and displaced mucous canal.

Fig. 2.—Scale VII, 28, from a IV+ fish, 26·2 cm L.C.F., showing irregular granulations.

Fig. 3.—Scale IX, 16, from a III+ fish, 23·0 cm L.C.F., replacement type of granulation.

SCALES OF YELLOW-EYE MULLET



SCALES OF YELLOW-EYE MULLET