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Observations on the Fishes of the Family Galaxiidae Part III

By

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PLATE IX

The present paper records some general observations on *Galaxias (G.) truttaceus*, including the discovery of a regular sequence of colour-pattern phases in this species.

Conventions. All dimensions are recorded in millimetres: except in a few instances where ambiguity might arise, the unit of measurement is omitted. Length-classes are designated by their mid-points. Abbreviations used include: LS = standard length; LT = total length; h = width of class-interval; f with numerical suffix = frequency of length-class specified by suffix; $\bar{x}$ = arithmetic mean; Md = median; Mo = mode; Q_1, Q_3 = 1st, 3rd, quartiles; σ = standard deviation, using $(n - 1)$.

Genus **Galaxias** Cuvier, 1817

Galaxias Cuvier, *Règn. Anim.* ed. 1. 11. 1817: 183. Haplotype *Esox truttaceus* Cuvier, 1817

Galaxias (Galaxias) truttaceus (Cuvier, 1817)

Esox truttaceus Cuvier, *Règn. Anim.* ed. 1. 11. 1817: 184.
Galaxias ocellatus McCoy, *Intercol. Exhib. Ess.* 7. 1866: 14.
Galaxias truttaceus Regan, *Proc. Zool. Soc. London.* 1905 (1906). II.: 378: pl. XII. fig. 4 (references).

MATERIAL AND LOCALITIES

Material examined, comprising upwards of 700 specimens, representing 36 Tasmanian and several extralimital localities, falls conveniently into 5 sections noted below. Letters in brackets refer to map (Text-fig. 1): in series marked with an asterisk *G. (G.) truttaceus* occurs in association with *G. (G.) attenuatus* (Jenyns, 1842).

(i) Punchbowl Creek, Launceston (A). 23 series. Series 89*, 8/10/35; 90*, 10/11/35; 91*, 24/11/35; 92*, 15/12/35; 115*, 18/10/36; 117*, 22/11/36; 119*, 31/12/36; 124*, 31/1/37; 125*, 126*, 14/2/37; 129*, 21/3/37; 145*, 24/10/38; 146*, 19/11/38; 151*, 31/12/38; 153, 8/1/39 (E. Chugg); 156*, 29/1/39; 157*, 26/2/39; 158*, 19/3/39; 159*, 26/3/39; 166*, 27/5/39; 167*, 28/5/39; 171*, 16/3/40; 172*, 30/9/40.

(ii) Other Tasmanian Localities (B-Z; a-b; d-k). 59 series. Series 1, no locality, no date (Museum coll.); 4*, Kelso (B), 22/12/33 (R. Slater); 5, Cormiston (C), April 1933 (E. Lumley); 6, Racecourse Creek, Launceston (D), no date (W. Smith); 7, 16, 77*, 87, 105, Saltwater Creek, Low Head (E), April 1933, 19/3/34, 24/4/35, 6/9/35, 24/7/34 (G. Green); 9, Cook's Creek, Adventure Bay, Bruny Island (F), 24/1/34 (V. V. Hickman); 10, 19, 35, 78, various creeks, northern end of Great Lake (G), 8/2/34, 29/3/34, 3/6/34, 1/5/35 (10 N. J. B. Plomley, 78 R. Wigram); 12, Sulphur Creek (H), 15/2/34 (N. Gill); 17*, 34, 43*, 49, 52*, 53*, Cox's Creek, Wynyard (I), 29/3/34, 29/5/34, 24/11/34, 11/12/34, 27/12/34, 27/12/34 (17, 34, 43*, 53 J. Harrison); 18, North Esk at St. Leonards (J), 29/3/34 (A. L. Meston); 24, 65, 66, 96, 97, 130, 154, 169, creeks, drains, lake itself, Great Lake, western shore, near, and south of, Reynold's Neck (K), 2/4/34, 18/2/35, 19/2/35, 27/1/36, 27/1/36, 4/4/37, 23/1/39, 12/2/40 (96, 97, 130, 154 D. Paton, 169 A. Pike); 25, River Brid (L), 4/4/34 (A. L. Meston); 28*, Franklin (M), 26/4/34 (A. B. Gaul); 30, 60 Pyengana (N), 12/5/34, 6/2/35 (30 E. Hookway, 60 H. Le Fevre); 33, Carroll's Creek, Rocky Cape (O), 21/5/34 (A. L. Meston); 38*, 39*, 40*, River Tamar (P), 17/9/34 (whitebait); 41*, Upper Scamander (Q), 18/10/34 (A. E. Elms); 54*, Clayton Rivulet (R), 31/12/34; 71, Tonganah (S), 13/3/35 (K. E. Jackson); 72*, creeks running into Don River (T), 14/3/35 (A. Smith); 86*, creek at Spreyton (U), 1/9/35; 88, creek running into River Pieman (V), 8/3/35 (M. White); 93*, Young Town (W), 28/12/35 (R. Gardam); 95*, creek about 4 miles south of Sorell, West Coast (X), 2/1/36 (A. L. Meston); 99, Snug River (Y), 16/1/36 (P. B. Edwards); 100*, Sassafras Creek, at Pardoe Beach (Z), 17/1/36 (A. L. Meston); 108*, Latrobe (a), 14/9/35 (whitebait); 109*, Big Eel Creek, near Temma (b), 6/2/36 (S. L. Larnach); 110*, Mella (d), 17/4/36 (B. Burnley); 116*, Pedder River (e), 22/1/36 (S. L. Larnach); 118*, Stony Creek, near Swansea (f), 2/12/36 (G. C. McKinlay); 120*, River Pieman, at mouth (g), 23/1/37 (A. L. Meston); 121, River Pieman, at Corinna (h), 23/1/37 (A. L. Meston); 122, Middleton's Creek (i), 24/1/37 (A. L. Meston); 140*, Welcome River (j), 7/1/37 (A. L. Meston); 161*, 163*, Mowbray, Launceston (k), 1/4/39, 17/4/39 (F. Frankcombe).

(iii) Islands of Bass Strait; Victoria. (These localities not included in map, Text-fig. 1). 5 series. Series 32, Currie, King Island, 19/5/34 (M. C. Challis); 59, 69, Clarke Island, 30/1/35, 9/3/35 (A. Maclaine); 68, Yarra River, Abbotsford, Victoria; Lilypilly Gully, National Park, Victoria; creek near Timboon, Victoria; Marat Creek, Pakenham, Victoria (exchange, National Museum, Melbourne); 164, Rhodes' Creek, western side of Mt. Strzelecki, Flinders Island, 16/1/38 (C. Davis).

(iv) Tank Series. Numerous specimens from various localities (most important, Punchbowl Creek, Launceston, and Great Lake) have been kept alive in observation tanks over a period of about five years.

(v) Overseas Museums Material. Material in the collection of the National Museum, Melbourne; Australian Museum, Sydney; British Museum (Natural History), London; Muséum National d'Histoire Naturelle, Paris; Museum für Naturkunde, Berlin; and a number of Museums in U.S.A. has also been examined.

DISTRIBUTION: ABUNDANCE

(a) General. Tasmania, including Bruny Island (Series 9), King Island (Johnston, 1888; Series 32), Clarke Island (Scott, 1936*a*; Series 59, 69), Flinders Island (Series 164), Victoria. McCulloch (1915) incidentally mentions South Australia: this State is not included in the Check-list (McCulloch, 1929), and I can find no other published record for it. The British Museum (Natural History) has seven specimens, of which there appears to be no published account, labelled

'New South Wales: Stead'. Not known from New Zealand: it has been shown (Scott, 1936*a*) that the designation by McCulloch (1929, p. 48) of New Zealand as type-locality is an error.

(b) Tasmania. Most rivers and streams (Text-fig. 1); common in Great Lake. No authentic data available regarding far South-West, or Lake St. Clair. Not included in upwards of 200 Galaxiids examined from Cradle Valley district.

(c) Abundance. In Tasmania *G. (G.) truttaceus* ranks next in abundance to *G. (G.) attenuatus*. Mack (1936) has noted it occupies a similar position in Victoria.

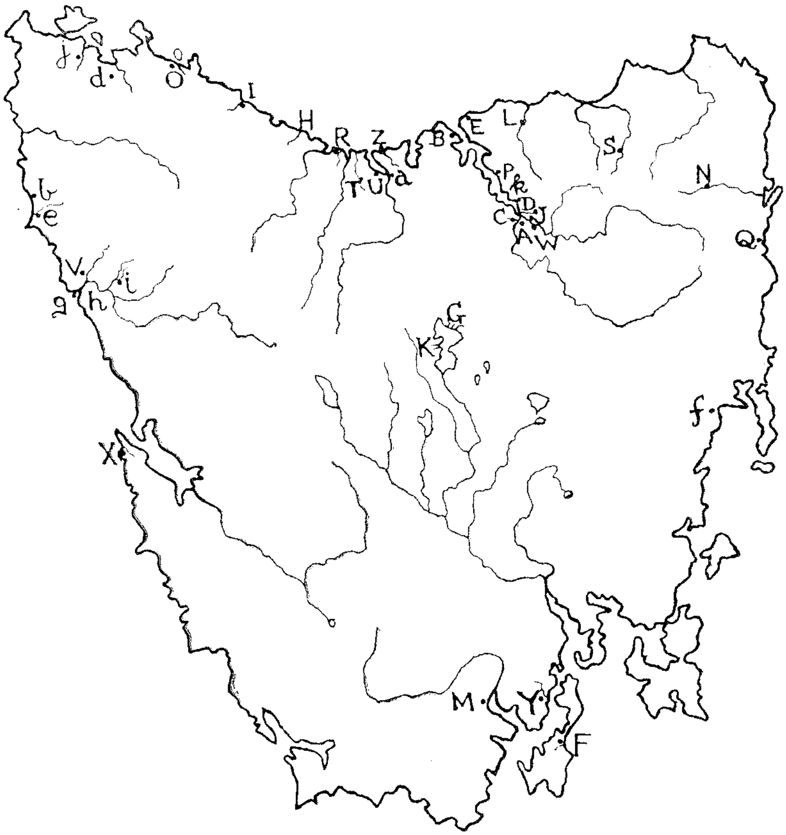

FIG. 1.—Sketch map of Tasmanian localities of material examined. For reference-letters see text.

SALINITY TOLERANCE

(a) Salinity Tolerance. All information available in the literature would indicate that in Tasmania *G. (G.) truttaceus* is confined to the Central Plateau, and fresh water of inland creeks and upper reaches of rivers. Thus Johnston (1883, p. 130) observes 'Abundant in most of our freshwater streams, but not descending to brackish water like *G. attenuatus*'; and Lord and Scott (1924, p. 23) expressly state it 'does not occur in the lower reaches and brackish estuaries,

where its place is taken by the 'Jollytail' [*i.e.*, *G. (G.) attenuatus*]. Actually, I find, *G. (G.) truttaceus* descends right to the beach-line: indeed, some observations made at Stanley in October, 1935, though unverified by the actual collection of material, strongly suggest it may upon occasion enter the sea on the falling tide.

Records from salt or highly brackish water include: Kelso (Series 4); Salt-water Creek, Low Head (7, 16, 77*, 87, 105); Sulphur Creek, about 300 yards from the sea (12); Upper Scamander (41*); Clayton Rivulet, below railway, at upper limit of beach (54*); brackish creek, Clarke Island, Bass Strait, 200-300 yards from sea (69); Sassafras Creek, Pardoe Beach, close to mouth, at a point to which the high tide backs up (100*); mouth of River Pieman (120*): (asterisk indicates presence in sample of *G. (G.) attenuatus*).

In several cases the available material affords information regarding the occurrence of the fish at widely separated points in the same waterway. Thus Series 120, 121, 122, collected within two days, provide examples from mouth of River Pieman (associated with *G. (G.) attenuatus*); the Pieman at Corinna (about 14 miles from sea by water), where water is still tidal, somewhat brackish; and from Middleton's Creek (fresh water), a tributary of the Savage, itself a tributary of the Pieman, into which it empties a mile or so below Corinna: further, Series 88 provides specimens from a creek draining into the Pieman some 7 miles from the coast. Again, in the River Tamar, samples are available from several localities between the mouth and Launceston, some forty miles inland; and, further *G. (G.) truttaceus* is traceable along lengthy stretches of the North Esk and South Esk, by whose confluence the Tamar is formed.

(b) Salinity Gradient. With the abandonment of the conception, hitherto held, that *G. (G.) truttaceus* and *G. (G.) attenuatus* are essentially inland and coastal species, respectively, overlapping and mingling in an intermediate region lying between the upper limits of tidal influence and the foot of the Central Plateau, the question naturally arises as to whether, in Tasmania, the former species exhibits any marked salinity gradient at all. Data bearing on this problem is set out in Table I.

TABLE I

G. (G.) TRUTTACEUS - G. (G.) ATTENUATUS: FREQUENCY RATIO IN WATERS OF VARYING SALINITY

Salinity-category		No. of Localities	No. of Series	Number of Specimens				
				G. (G.) truttaceus	*G. (G.) attenuatus*	Total	Average No. in Sample	*G. (G.) truttaceus* %
Salt or highly brackish		5	5	45	60	105	21	42·9
Moderately brackish		3	6	28	117	145	24	19·3
Fresh	(*a*) Punchbowl Creek	1	19	202	640	842	44	24·0
	(*b*) Other Localities	9	9	24	90	114	23	21·1
	(*c*) Total	10	28	226	730	956	35	25·2

An analysis of samples (16 localities, 20 series, 192 specimens) of *G. (G.) truttaceus* from localities in which *G. (G.) attenuatus* occurs (*e.g.*, Great Lake series excluded), but unassociated, as collected, with that species, yields the following additional data: salt or highly brackish water, 2 localities, 3 series, 39 specimens, average number per sample 13; moderately brackish water, 6, 8, 73, 9; fresh water, 8, 9, 80, 9.

While the information recorded in Table I, not being based on material collected expressly in relation to the present problem (note, *e.g.*, disregard of seasons, possible tendency of some collectors to concentrate on one particular species, &c.), does not provide rigorously random sampling on which to base a proper quantitative analysis (*e.g.*, a satisfactory computation of Forbes' coefficient of association), nevertheless, it does appear generally decidedly unfavourable to an assumption of an inverse correlation in this species between frequency and salinity.

(c) Experimental Evidence. That *G. (G.) truttaceus* behaves, under laboratory conditions, as a euryhaline form has been demonstrated by a number of experiments in which fish have been brought from fresh to (artificial) sea-water—average analysis of Dittmar (1884)— and *vice versa*, without suffering any serious disturbance of metabolism, or exhibiting any marked changes of behaviour, other than temporarily enhanced general liveliness and quickened respiratory rhythm on being subjected to an abrupt increase in salinity. These trials have varied in severity from, on the one hand, starting with tap-water, a regular increase in salinity of 3·5 gm per 1000 gm on each of 10 successive days, to, on the other hand, direct transference from tap-water to sea-water of salinity 35 gm per 1000 gm: in no instance has the fish manifested any noteworthy symptom of distress.

ASSOCIATION WITH G. (G.) ATTENUATUS

(i) General. That *G. (G.) truttaceus* forms a consocies with *G. (G.) attenuatus* over the whole ecological range of the latter species is sufficiently established by the facts recorded above. In many localities the two species are found occupying the same pool: in captivity they share a tank in complete community.

(ii) Whitebait. It has been shown (Scott, 1936*b*) that young individuals of *G. (G.) truttaceus* and *G. (G.) attenuatus* form a minor constituent of Tasmanian 'whitebait', in which they are associated with the haplochitonid *Lovettia sealii* (Johnston)—the 'whitebait' of New Zealand largely consists (Clarke, 1899; Phillipps, 1919) of *inanga*, or *G. (G.) attenuatus* fry. Schools of whitebait, often comprising an almost incredible number of individuals, appear in Northern Tasmanian rivers and in the Derwent in Spring.

It is generally accepted that the Galaxiidae are a group of Salmonoids of marine origin, related to the Osmeridae (Regan, 1906, 1913), which, like the Northern circumpolar Salmonidae, are establishing themselves in fresh water; and it is well established (Hutton, 1896; Clarke, 1899; Best, 1903; Whitely, 1935) that in New Zealand *G. (G.) attenuatus* descends to the sea periodically to spawn. The presence of *G. (G.) truttaceus*, as fry, in whitebait, and observations on its occurrence in Punchbowl Creek noted below suggest that this species is not improbably facultatively catadromous, and that, when not confined in landlocked waters, it may retain the presumably primitive spawning habit of the family.

(iii) Punchbowl Creek. In Punchbowl Creek, Launceston, *G. (G.) truttaceus* and *G. (G.) attenuatus* commonly occur together, with the latter species present in greater abundance. It is, however, worthy of note that over the period 6/2/34-7/10/35 the whole catch of 12 series, comprising 310 specimens, from this locality consisted exclusively of *G. (G.) attenuatus*. While experience has shown that *G.*

(G.) truttaceus, except when young, is more wary of the trap employed in these investigations (for description, see Scott, 1938, p. 116)—with adult fish, it is quite customary, in a pool containing, say, twenty *G. (G.) attenuatus* and ten *G. (G.) truttaceus*, to trap fifteen of the former species without securing one specimen of the latter—it seems probable these results are to be interpretated as indicative of the failure in 1934 of the normal vernal immigration of *G. (G.) truttaceus* discussed below. In Punchbowl Creek the great majority of specimens, apart from fry, are only of moderate size (LS 60-75): large individuals are unusual, but I have measured examples up to LS 150.

Association With Other Galaxiids

In Tasmania *G. (G.) truttaceus* probably occurs associated with all our local Galaxiidae. Its association with the following species has been established: *G. (G.) attenuatus (vide supra)*, *G. (G.) auratus* (Great Lake, *fide* Johnston), *G. (G.) parkeri* (Great Lake, Snug River), *G. (G.) scopus* (Clarke Island, Bass Strait, in same series as holotype): it is recorded from the type-locality of *G. (G.) weedoni* (River Mersey), *Saxilaga (S.) anguilliformis* (Cox's Creek, Wynyard). I have no authentic records of it in association with *Paragalaxias shannonensis* (known only from type-locality, Shannon River), *Saxilaga (S.) cleaveri* (based on unique holotype, found in eucalyptus stump, West Ulverstone), *G. (G.) johnstoni* (known only from four specimens, creek, near Nive River), *G. (G.) affinis* (type-locality Lake St. Clair): further investigations will, however, probably establish it as an associate of these four forms.

Vernal Juvenile Migration

(a) General. The occurrence of *G. (G.) truttaceus* in whitebait, and the appearance of fry in Punchbowl Creek have already been noted: the latter migration is discussed below.

(b) Periodicity. Series taken in Punchbowl Creek between February, 1934 and October, 1935 contained no specimens. In the early part of the summer of 1935-6, however, with the immigration into the Creek of *G. (G.) attenuatus* fry (this migration has been studied in a previous paper; Scott, 1938), there came also an invasion of juvenile *G. (G.) truttaceus*, which penetrated in large numbers into the second, or *Larnoo*, section (for ecological divisions of Creek see Scott, 1938, p. 116, footnote), and, in diminished numbers, to the upper limit of the third. Analysis of the four series 89-92, 8th October - 15th December, 1935, *Larnoo* section, shows that of 51, 17, 73, 88 specimens of mixed *G. (G.) attenuatus* and *G. (G.) truttaceus* 18, 7, 18, 38, an average of 35%, were the latter species: the great majority were juvenile (only exceptions, 2 specimens of Series 89, of LT 68·5, 87·0). Further observations in this section were rendered impracticable by the sudden and almost complete drying-up of the Creek, resulting in a heavy mortality, in which *G. (G.) truttaceus* suffered proportionally much more severely than *G. (G.) attenuatus*, a score or more individuals often being found lying in a square yard on the bed of a dried-up pool in which the failure of the stream had trapped them.

Samples from the *Larnoo* section on 27th September, 1936 (Series 113) and 4th October (Series 114) consisted exclusively of large examples of *G. (G.) attenuatus*, and an inspection made on 11th October showed that the juvenile immigration for the year still had not then begun, the influx taking place between the last-mentioned date and 18th October. *G. (G.) truttaceus* was present this year in decidedly smaller proportion than in the preceding year, Series 115, 117, 119 (October, November, December, 1936) consisting of 69, 83, 20 specimens, of which 4, 4, 4 were *G. (G.) truttaceus*, an average of 7%. This percentage was virtually maintained during the first quarter of the next year, Series 124-126, 129, taken between 31st January and 21st March, 1937, comprising in all 156 specimens, of which 9 were *G. (G.) truttaceus*.

No observations were made in the spring of 1937. In 1938 the immigration had occurred by 24th October, a sample on that date containing 18 *G. (G.) attenuatus* and 11 *G. (G.) truttaceus*. Series 146, 151, taken in November and December, contained 11 (20%) and 8 (17%) of *G. (G.) truttaceus*, an average for the last three months of 1938 of 23%. Five samples in the first five months of 1939 consisted of 143 fish, of which 13 (9%) were *G. (G.) truttaceus*.

The vernal immigration of 1939 was not recorded. A sample of upwards of 50 fish on 30th September, 1940 (Series 172) included 2 early arrivals of the 1940 class of *G. (G.) attenuatus*: a week later, the main body had arrived, a sample of 47 from the *Queechy* section containing 37 juveniles. This year the *G. (G.) truttaceus* element was small, Series 172 including only a few specimens, Series 173 none.

It is thus established that there commonly occurs in Punchbowl Creek an extensive immigration of juvenile *G. (G.) truttaceus*, in company with *G. (G.) attenuatus* fry, the main body of fish arriving in late September - early October. A possible secondary invasion in February - March is noted below.

(b) Metrical Characters. The standard length of 10 samples (trapped) of juvenile *G. (G.) truttaceus* population in Punchbowl Creek in October - December 1935, 1936, 1938 is specified in Table II.

Table II shows the vernal immigrant population is essentially a juvenile one, having $\bar{x}_{LS}$ about 47, and modal LS-class 45·5 ($h = 1$).

The data afford no clear evidence regarding growth during the three months under review. It is possible secondary minor waves of invasion may occur, especially since frequency polygons for *G. (G.) attenuatus* in Punchbowl Creek exhibit (Scott, 1938) a primary mode in LS-class 45 ($h = 10$), and a secondary mode in LS-class 35 ($h = 10$), apparently indicative of a second juvenile invasion of that species in February - March. In this connexion, analysis of LS specifications of samples collected in the early months of the year (not included in Table II) yields two noteworthy facts: first, in 1937 (no data for 1936) the smallest specimen of *G. (G.) truttaceus* secured in these investigations (LS 37·8) was obtained on 14th February, $\bar{x}_{LS}$ of the whole sample taken on that date being 40·2, decidedly less than $\bar{x}_{LS}$ for samples (Series 124, 129) in January and March; secondly, in 1939 (no data for 1938) a sample (Series 158) in March (one specimen only) had LS 46·5, compared with $\bar{x}_{LS}$ 50·4, 53·7, 56·0, 48·9 for samples (Series 156, 157, 166, 167) collected in January, February, May (2 samples in May).

With $h = 1$, LS distribution of the 130 specimens in Table II is; $(f_{41\cdot5})$ - $(f_{57\cdot2})$ = 6, 7, 10, 13, 19, 15, 10, 10, 11, 8, 8, 2, 2, 4, 2, 1, 2.

(c) Non-Metrical Characters. On arrival in Punchbowl Creek, some individuals still exhibit a furrow with double raised flanking walls locating the region of absorption of the yolk-sac, and, slightly dorsad of this depression, a subspherical vascular plexus, clearly visible through the transparent body-wall as a red spot.

Pigmentation is little developed. In 1935, October specimens exhibited Colour-Phase A (see **Colour-Phases**, below); on 11th November 5 out of 7 had advanced to middle and late subphases of Phase B; on 24th November a sample of 18 included

TABLE II

GALAXIAS (G.) TRUTTACEUS: STANDARD LENGTH SPECIFICATION OF JUVENILE POPULATION IMMIGRANT INTO PUNCHBOWL CREEK, LAUNCESTON, OCTOBER, NOVEMBER, DECEMBER, 1935, 1936, 1938

Year	Series No.		No. of Specimens	Min.	Max.	$\bar{x}$	Mode (1)	Q	Md	Q_3	σ
1935	89	8/10/35	16 (2)	45·0	57·5	46·99	46·5 [4]	44·7	46·2	48·6	4·21
	90	10/11/35	7	43·8	54·5	48·97	.... (3)	46·0	49·0	51·0	3·46
	91	24/11/35	18	43·0	55·1	48·38	45·5 [3]	45·5	47·7	51·4	4·26
	92	15/12/35	38	41·2	57·7	45·29	44·5 [7]	43·1	44·7	46·4	3·33
Totals and Means, 1935	4 Series	8/10/35–15/12/35	79	41·2	57·7	46·66	.... (4)	44·0	45·8	49·0	4·12
1936	115	18/10/36	4	45·6	51·6	47·95	47·5 [2]	46·3	47·8	49·6	2·57
	117	22/11/36	4	46·1	53·8	49·28	46·5 [2]	46·4	48·8	52·1	2·56
	119	31/12/36	4	48·8	51·6	50·23	.... (3)	49·4	50·3	51·1	1·61
Totals and Means, 1936	3 Series	18/10/36–31/12/36	12	45·6	53·8	49·15	.... (5)	46·9	49·9	51·1	2·57
1938	145	24/10/38	11	45·7	52·8	49·27	48·5 [3]	47·8	48·6	51·1	2·31
	146	19/11/38	20	42·2	55·8	45·95	45·5 [6]	44·0	45·2	46·8	3·16
	151	31/12/38	8	42·4	56·0	49·00	48·5 [2]	46·9	49·0	51·0	4·37
Totals and Means, 1938	3 Series	24/10/38–31/12/38	39	42·2	56·0	47·51	45·5 [8]	45·0	47·1	50·0	3·44
Totals and Means, 1935, 1936, 1938	10 Series	Oct.-Dec., 1935-6-8	130	41·2	57·7	47·15	45·5 [19]	44·6	46·4	49·4	3·71

(1) Mode with $h = 1$; figures in brackets denote number of cases.
(2) Two specimens of LS 61·2, 75·5, clearly belonging to previous year-class, omitted from Table.
(3) With $h = 1$, no mode.
(4) With $h = 1$, plurimodal: 44·5, 45·5, 46·5 classes each with 10 cases.
(5) With $h = 1$, plurimadol: 46·5, 47·5, 50·5, 51·5 classes each with 2 cases.

several individuals in Interphase B C. In 1936-7, October arrivals were in Phase A, reaching B by late November, Interphase BC in January and February, and Phase C in March. In 1938, 10 of 11 specimens taken on 24th October were in Interphase AB, one individual being in subphase Bd; of 20 fish on 19th November, 17 were in late, 1 in middle, 1 in early Phase B, while one individual had arrived at Phase C. Samples of the 1938 class collected in January, February, March, 1939 were in Phase B, Interphase B C, Phase C: of 9 specimens in May (Series 166, 167 pooled) 1 was in advanced Interphase B C, the rest in Phase C.

VARIATION OF COLOUR-PATTERN WITH GROWTH: COLOUR VARIETIES

(a) General. Our knowledge of colour-pattern in the Galaxiidae is scanty. Of possible differences associated with sex, season, locality we know virtually, or literally, nothing: of individual variation as much as, but no more than, the systematist records in the compilation of his specific diagnoses. Colour-varieties in *G. (G.) truttaceus*, long known, are discussed in subsection (*d*) below. In a previous paper (Scott, 1936*a*, p. 94) some tentative associations of colour-pattern types (spots, bars, blotches) with other diagnostic features have been made in the characterization of what appear to be species-groups. Variations of colour-pattern with age have been the subject of references, more or less incidental in character, by Clarke (1899), *G. (G.) kokopu*; Regan (1906), *G. (G.) lynx*, *G. (G.) weedoni* (Lake Laura specimens); McCulloch (1915), *G. (G.) attenuatus*; Eigenmann (1924), *G. (G.) maculatus*, *G. (G.) globiceps*; Scott (1936*a*), *G. (G.) parkeri*; Whitley and Phillipps (1939) *G. (G.) argenteus*: in general, these observations have been concerned with a progressive increase in extent, and at times in complexity, of pigment-deposition (Clarke, however, notes markings on body of *G. (G.) kokopu* are relatively larger in young).

Though the genotype of *Galaxias* has now been known to science for nearly a century and a quarter, the fact that it manifests a regular sequence of changes in colour-pattern appears hitherto entirely to have escaped notice. So far as I can ascertain, references in the literature to colour-markings on the body of this species are consistently confined to mention of the annulated dark spots regularly, and the dark post-pectoral bar or bars usually, present in the adult—*e.g.*, " readily recognized by the trout-like black spots on the sides of the body " (Mack, 1936): note, also, McCoy's (1866) significant synonymic specific name *ocellatus*. The present investigations show that *G. (G.) truttaceus* exhibits a series of successive colour-pattern phases almost as marked as, and presenting at least a superficial resemblance to, that encountered in certain Salmonidae.

My attention was first drawn to this circumstance by the receipt, in March, 1934, of specimens of what, judged from the colour-pattern alone, would naturally be taken for an undescribed species. Subsequent investigation revealed the presence of a strikingly barred, wholly unspotted phase of *G. (G.) truttaceus* in Punchbowl Creek: the complete pattern-sequence has since been thoroughly established by systematic collecting in this locality, supplemented by the keeping of this species under observation in fish-tanks continuously over a period of several years.

(b) Colour-Phases. Three phases, two interphases, and about ten subphases may be recognized. While clearly chronologically successive, the subphases manifest some overlapping (particularly in samples from different localities, and, to some extent, in different year-classes) when regarded as a direct function of size, LS min. of one phase in one series being sometimes exceeded by LS max. of preceding phase in another sample: *cf.* observations by Eigenmann (1924, p. 50) on variation in duration of retention of unspotted juvenile condition in *G. (G.) maculatus*. Marked differences in bodily proportion (subsection (*c*)) characterize the primary phases. The following analysis, based primarily on Punchbowl Creek material, is confined to macroscopic features: microscopic aspects of the changes involved are of interest, and worthy of detailed study.

Phase A: Unornamented Stage. (The term 'unornamented', not strictly accurate, conveniently connotes complete absence of body-bars and large spots consistently present in succeeding phases). In very young, presumably immediately post-larval specimens (Plate IX, Fig. 2) the body is transparent: ornamentation is confined to the caudal fin, and comprises, first, a highly characteristic vertical dark, almost black basal bar, commonly about $\frac{1}{8}$-$\frac{1}{6}$ eye-diameter in width; secondly, a series of 6-10 proconcave dark arcs covering most of the fin (often better developed at a somewhat later stage). In whitebait samples the caudal bar may be in two (united) halves, each with a convex posterior margin.

The pre-pigmentation stage in Galaxiids has been recorded for *G. (G.) maculatus* by Eigenmann (1924): for *G. (G.) attenuatus* by McCulloch (1915), Scott (1938); see also speculation by Regan (1906) as to the possibility of *G. (G.) gracillimus* being a larval form of this species. The presence in very young *G. (G.) truttaceus* of a patterned caudal fin lends support to a suggestion (Scott, 1938, p. 121) that this feature may well be a primitive family character, enjoying brief ontogenetic manifestation. It should be noted that the extensive proximal caudal bar of *G. (G.) truttaceus* is entirely absent in *G. (G.) attentuatus*.

Individuals in Phase A occur among whitebait, and in recently arrived vernal influxes in Punchbowl Creek. They are commonly of LS 43 $\pm$ 5, but unornamented individuals of LS>52 occasionally occur.

Interphase AB: Preliminary Pigmentation Stage. The interesting early stages of somatic pigmentation are predominantly microscopic; macroscopically they result in a slight decrease in transparency (especially above mediolateral line), quite evident in preserved material, barely noticeable in life; and in the first pigmentary outlining of the myomeres. Basal caudal bar conspicuous; caudal arc-pattern usually most apparent in this stage (Fig. 3). Punchbowl Creek examples have been taken in late October.

Phase B: Barred Stage. In the course of this stage the young fish gradually develops a series of forwardly directed chevrons or subvertical bars (angulation frequently markedly more acute posteriorly) that lend it an appearance strikingly at variance with that of the adult. Bars, which are most prominent in Cox's Creek specimens (Fig. 16), commonly number 12-15: on the average, in Punchbowl Creek and Cox's Creek material bars are rather narrower than, in Great Lake specimens about one-half as wide as, their interspaces.

The normal schedule of bar-development appears to be as follows. *Subphase Ba* (Fig. 4): upper halves only of chevrons extending progressively from head to level of pelvic origin. *Subphase Bb* (Fig. 5): the same, continued to level of vent. *Subphase Bc* (Fig. 6): head-pelvic interspace with chevrons complete; pelvic-anal interspace with half-bars above mediolateral line; postanal region bare. *Subphase Bd* (Fig. 7): chevrons complete to level of base of anal fin; postanal region bare. *Subphase Be* (Fig. 8): upper halves of bars now developed on caudal peduncle. *Subphase Bf* (Fig. 9): complete series of chevrons or bars from behind head to base of caudal.

Occasional departures from the normal programme include: *(i)* appearance of two or three full chevrons prior to complete development of superolateral series of half-bars (Fig. 17); *(ii)* omission of Subphase Be, with Bd passing directly into Bf. In general, however, the sequence follows a well-marked course involving, first, the preanal region, with progressive development caudad of half-bars, then of complete bars; secondly, the postanal region, with similar succession.

Basal caudal bar now less conspicuous; caudal fin pattern normally almost, or wholly, lost; blackish oblique suborbital streak and dark upper labial marking, characteristic specific characters of adult *G. (G.) truttaceus*, begin to appear.

Fish exhibiting Colour-Phase B are commonly of LS 45 ± 3, with recorded extremes of 37·8 and 56·7 (Punchbowl Creek); 50 ± 4 (Cox's Creek); 45 ± 3 (Great Lake). Punchbowl Creek individuals normally exhibit this colour-stage in November (exceptionally, as early as late October, as late as January); Cox's Creek specimens were taken in March, November, December; examples are included in Great Lake series collected in January, March.

Interphase BC: Barred-Spotted Stage. Shortly after establishment of Subphase Bf, there sets in a progress of disintegration of chevrons and bars into subvertical linear series of spots. This process proceeds in the reverse direction from bar-formation, becoming initiated on the caudal peduncle, and extending gradually (at times somewhat irregularly) cephalad: again in contrast to the sequence of events encountered in Phase B, the superolateral and inferolateral regions of the body are here involved contemporaneously (occasionally an odd bar or two becomes discrete first in its superior moity). Three subphases may conveniently be recognized. *Subphase BCa* (Fig. 10): caudal peduncle with rows of spots; rest of body with bars. *Subphase BCb* (Fig. 11): region caudad of about mid-point of pelvic-anal interspace with rows of spots; region anterior to this barred: commonly, the anterior two (or three) bars that will constitute the adult shoulder-markings now broaden and darken, and, in individuals destined to develop them, the yellow bands between these emphasized anterior bars become more or less pronounced. *Subphase BCc* (Fig. 12): as in BCb, but with tendency towards the breaking-up of one or two bars at, or in advance of, level of pelvic, bars posterior to this still remaining intact.

Basal caudal bar much diminished in width and intensity; suborbital streak and upper labial marking fully developed; dusky tips to pelvic, dorsal, and anal, if present in adult, begin to appear.

Punchbowl Creek specimens in Interphase BC, though occasionally present in late November, do not become common till December or January: they are the characteristic form in February samples, and may exceptionally be taken as late as May. Modal LS 49 ± 3 (Punchbowl Creek): Cox's Creek and Great Lake examples of about the same size were taken in March.

Phase C: Spotted Stage. While the stage immediately following Subphase BCc finds the colour-pattern composed entirely of spots (save for permanent post-pectoral bars), adult marking is not yet achieved, Phase C comprising three subphases. *Subphase Ca* (Fig. 13): subvertical bars of subphase Bf wholly resolved into rows of smallish spots. *Subphase Cb* (Fig. 14): regular spot-pattern suffers disruption; linear arrangement of spots, though invariably lost first on caudal peduncle, and persisting longest in head-pelvic interspace, manifests only a general tendency towards progressive disintegration cephalad, frequently occurring discontinuously; concurrently with assumption of random spotting (which involves reduction in frequency, increase in dimensions, of spots) there generally occurs a movement towards the differentiation of the larger spots often present below part, or whole, of dorsal profile, these specialized spots being usually the first to become annulated. *Subphase Cc* (Fig. 15): the normal adult colour-pattern, with scattered large spots, of which many, usually most, are ocellated.

In Punchbowl Creek, fish arriving as fry in October attain the final colour-pattern by about March, or April (exceptionally not till May or even later).

The probable partial correlation of extent of shoulder-markings with age is discussed in subsection (*d*) below.

(c) Metrical Characters of Colour-Phases. Table III exhibits variation, in the three primary colour-phases, of twelve diagnostic body-ratios and fin-ratios: entries for Phase A are based on Series 115 (4 specimens); B, Series 17, 49, 53, 54 (8); C, Series 33, part (10).

TABLE III

GALAXIAS (G.) TRUTTACEUS: VARIATION OF 12 BODY-RATIOS AND FIN-RATIOS IN THE THREE PRIMARY COLOUR-PHASES.

Dimension or Ratio	Colour-Phase	Min.	Max.	$\bar{x}$	σ
Standard length, LS, in mm.	A	45·6	51·6	47·95	2·573
	B	51·0	59·0	54·34	2·777
	C	98·1	109·1	102·66	4·623
Head in LS	A	5·7	6·3	5·90	0·283
	B	4·5	5·0	4·76	0·173
	C	4·8	5·1	4·99	0·477
Depth in LS	A	7·5	8·6	8·20	0·496
	B	5·6	7·6	6·63	0·549
	C	4·3	5·4	4·91	0·324
Eye in head	A	3·5	3·6	3·55	0·058
	B	3·8	4·4	4·04	0·230
	C	4·4	5·4	4·92	0·405
Eye in snout	A	0·9	1·0	0·95	0·064
	B	1·2	1·0	1·13	0·075
	C	1·2	1·5	1·32	0·105
Eye in interorbital width	A	1·2	1·5	1·35	0·141
	B	1·5	1·7	1·58	0·925
	C	2·0	2·5	2·18	0·200
Length of caudal peduncle in LS	A	6·9	7·0	6·98	0·577
	B	6·7	8·9	7·71	0·694
	C	8·3	9·9	8·94	0·498
Depth of caudal peduncle in its length	A	1·8	2·0	1·90	0·082
	B	1·3	1·7	1·45	0·165
	C	1·3	1·4	1·35	0·075
Length to pelvic fin in LS	A	2·11	2·14	2·12	0·0153
	B	1·95	2·02	1·99	0·0229
	C	1·82	1·98	1·89	0·0054
Length to dorsal fin in LS	A	1·43	1·49	1·46	0·0271
	B	1·40	1·47	1·42	0·0332
	C	1·35	1·38	1·38	0·0167
Length of pectoral fin in pectoral-pelvic interval	A	2·4	2·7	2·48	0·141
	B	1·8	2·1	2·01	0·105
	C	1·8	2·1	1·92	0·120
Length of pelvic fin in pelvic-anal interval	A	2·2	2·3	2·25	0·082
	B	1·6	2·1	1·91	0·015
	C	1·6	1·9	1·78	0·100
Combined base of dorsal and anal fins in LS	A	3·8	4·2	3·98	0·208
	B	3·8	4·2	3·97	0·141
	C	4·2	4·9	4·54	0·691

Table III shows: *(i)* points of origin of dorsal and pelvic constitute important morphological landmark, subject, in a given length-class, to little individual variation: *(ii)* with increase in LS, relative length of head appears, on present data, first to decrease, then slightly to increase; results are perhaps exceptional, normal course probably being a progressive decrease: *(iii)* with increasing LS eye becomes smaller, relative to head, snout, interorbital width; body grows deeper; caudal peduncle becomes deeper, also shorter relative to LS; lengths to dorsal and pelvic origins increase; combined bases of vertical fins become relatively smaller; lengths of pectoral and pelvic, relative to fin-interspaces, increase: *(iv)* except that of combined bases of vertical fins, in which there is no significant difference on average between Colour-Phases A and B, all changes noted in *(iii)* are clearly progressive, and ratios yield distinctive figures for each colour-phase.

(d) Colour Varieties. Johnston (1883, p. 131) states: 'There are two or three varieties: Var. *a*.—In the North Esk, without the three characteristic cross-bars upon the shoulder. Var. *b*, Mountain Trout.—Without spots or bars; head more depressed. Colour, grey, with beautiful iridescent specks of green and gold. Mount Wellington. Var. *c*.—A red-finned variety, found in streams at Gould's Country'. Regan (1906, p. 379) admits: 'A. *Forma typica*, with 2 or 3 dark vertical bars above the pectoral and with the dorsal, anal, and ventral fins blackish at the tip [all his specimens from Tasmania]: B. Variety without bars above the pectoral, with the fins uniformly pale' two specimens from Moorabool River, Victoria [Johnston's reference to Tasmanian examples without bars above pectoral noted].

Examination of the present material yields the following results. *(i) General Body-Colour:* greyish, greyish green, pale green, dark green, yellowish green, yellow, yellowish pink, greyish purple, and other tints; some West Coast specimens (*e.g.*, Series 88, 120) very dark purplish, almost black. *(ii) Pectoral:* usually colourless, but may be greyish or greenish, becoming somewhat lighter or somewhat darker distally; not tipped with black. *(iii) Dorsal and Anal:* virtually colourless; almost colourless proximally, faintly dusky distally (common); pale brownish proximally, becoming nearly colourless or darkening almost to black distally; yellowish, with or without black margins (common); successively from base, about one-fourth olivaceous or pale yellowish, five-eighths bright reddish orange or brownish red, one-tenth black, one-fortieth pale ashen (a common succession). *(iv) Shoulder-Bar:* number and extent of bars may vary on two sides of same individual; bars at times absent, but if so, shoulder-region usually bears one or more dark blotches larger than general body-spots; bar usually margined, anteriorly, posteriorly, or both, with area lighter or brighter than general body-colour, this area frequently being, in small specimens sulphur-yellow—there is some evidence to suggest number and distinctness of bars vary with age, Punchbowl Creek specimens of LS 50-60 usually having two prominent bars with conspicuous sulphur-yellow interspace (whole pattern quite apparent in living fish several yards away in water), larger individuals often showing only a single bar; in many series bars are more numerous, relatively larger, and better defined in small than in large fish; in Great Lake material of fair size there is commonly one bar (often relatively smaller in larger specimens), or none, and, in the majority of cases, a moderate or smallish blotch above superior angle of operculum. *(v) Dark Suborbital Streak:* constantly present. *(vi) Upper Lip:* regularly dark. *(vii) Ocellated Spots:* the development of the ocellus, which does not always involve all body-spots, appears to be largly a function of age. *(viii) Spots on Head:* two or three dark spots on operculum, one or two on preoperculum, sometimes present: body-spots extending on to dorsal surface of head only exceptionally. *(ix) Gold-specking:* quantity present varies considerably; characteristically much more pronounced in material from high altitudes.

While further investigation on colour varieties is needed, these facts suggest the following observations. *(i)* There exists no sharp line of demarcation between Regan's A (= Johnston's Var. *a* from North Esk) and Regan's B—thus, we find examples with shoulder-bars and pale fins (Series 86), and with black-tipped fins, and no well-defined shoulder-bar (Series 118)—nevertheless, it remains true that specimens with fins uniformly pale, or with slight distal duskiness in pelvic, dorsal, anal usually, though not invariably, have the post-pectoral bars reduced to blotches, considerably, or occasionally but slightly, larger than ordinary body-spots: such a form occurs not only in the North Esk (where it is associated with other varieties), but in many widely separated localities, including the Central Plateau, where it is common. *(ii)* Johnston's Var. *c*: specimens with red, black-tipped fins (body usually yellowish or pinkish) are apparently common (Series 30, 60; Pyengana) near Johnston's locality, but are by no means confined to this district (*cf.* Series 99, 110). *(iii)* Of Johnston's Var. *b* (the term 'Mountain Trout', applied by Johnston to this form, is now used indiscriminately for all forms of *G. (G.) truttaceus*, wherever found; often, indeed, also for other species of *Galaxias*) no specimens appear to exist in Museums, nor have I been able otherwise to secure any: while, in the absence of material, surmise only is possible, I am much inclined to believe this reference to an unspotted form relates to another species altogether, possibly *G. (G.) affinis*, which seems to agree reasonably well with Johnston's brief description.

Spawning

(a) General. There is no published information on the spawning habits of *G. (G.) truttaceus*. As already suggested, it seems not unlikely that, where circumstances permit, this species migrates to brackish water, possibly even to the sea, to spawn. It is noteworthy that fish with ripe ova are not infrequently secured (Series 33, 77, 110) in localities at, or near, the coast.

(b) Number and Size of Ova. Before extrusion, the ova are discharged, as in the Salmonidae, into the abdominal cavity. In a specimen of LS 113 (Series 33) there were counted 5643 ova, of modal diameter (in formalin) of 1·0-1·3 mm.

(c) Spawning Season. Specimens with the abdomen markedly distended with masses of ripe ova are taken in April and May. Fish have been stripped, in several seasons, in both these months; but attempts to hatch ova have hitherto proved unsuccessful.

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PLATE IX

Galaxias (G.) truttaceus Cuvier: COLOUR-PATTERN PHASES

Except in the case of Fig. 14, which represents a specimen from Cox's Creek, Wynyard, the normal sequence of colour-pattern phases (Figs. 2-15) is illustrated by fish from Punchbowl Creek, Launceston. For dates of collection of various Series see text.

For the sake of clearness, the pectoral fin is omitted: details of the remaining fins, other than colour-pattern (where present), are not shown.

Colour-Phase A: Unornamented Stage

FIG. 2.—Series 115.

Interphase AB: Preliminary Pigmentation Stage

FIG. 3.—Series 145.

Colour-Phase B: Barred Stage

FIG. 4.—Subphase Ba. Series 145.
FIG. 5.—Subphase Bb. Series 90.
FIG. 6.—Subphase Bc. Series 91.
FIG. 7.—Subphase Bd. Series 90.
FIG. 8.—Subphase Be. Series 91.
FIG. 9.—Subphase Bf. Series 146.

Interphase BC: Barred-Spotted Stage.

FIG. 10.—Subphase BCa. Series 92.
FIG. 11.—Subphase BCb. Series 92.
FIG. 12.—Subphase BCc. Series 45.

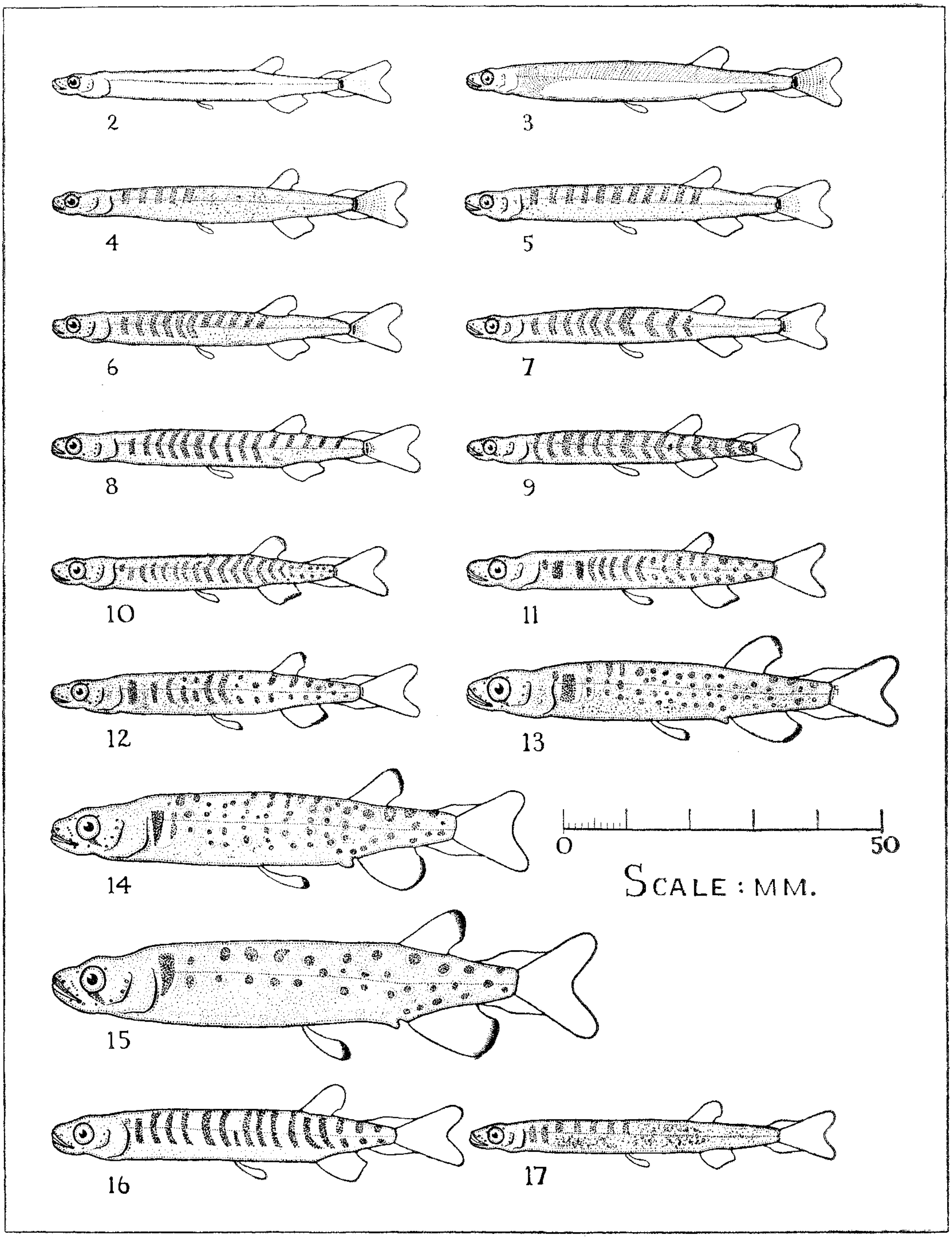
Colour-Phase C: Spotted Stage

FIG. 13.—Series 156.
FIG. 14.—Series 34.
FIG. 15.—Series 166.

Variations

FIG. 16.—Specimen from Cox's Creek, Wynyard, showing greater distinctness of barring than that characteristic of Punchbowl Creek specimens. Series 17.

FIG. 17.—Occasional departure from normal sequence, involving formation of some entire bars prior to complete development of superolateral series of half-bars. Series 91.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