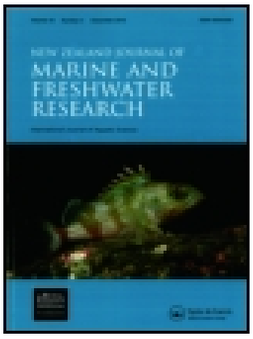

New Zealand Journal of Marine and Freshwater Research

ISSN: 0028-8330 (Print) 1175-8805 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzm20

Growth characteristics, pigmentation, and the identificaton of whitebait *(galaxias* spp., Salmonoidea)

C. S. Woods

To cite this article: C. S. Woods (1968) Growth characteristics, pigmentation, and the identificaton of whitebait *(galaxias* spp., Salmonoidea), New Zealand Journal of Marine and Freshwater Research, 2:2, 162-182, DOI: 10.1080/00288330.1968.9515233

To link to this article: https://doi.org/10.1080/00288330.1968.9515233

Published online: 30 Mar 2010.

GROWTH CHARACTERISTICS, PIGMENTATION, AND THE IDENTIFICATON OF WHITEBAIT (*GALAXIAS* SPP., SALMONOIDEA)

C. S. WOODS*

Department of Zoology, University of Canterbury, New Zealand

(Received for publication 19 June 1967)

SUMMARY

Definitions are given for stages in the development of five species of *Galaxias*, family Galaxiidae, which have marine larvae.

Larvae of *Galaxias maculatus attenuatus* and *G. brevipinnis* are large, and those of *G. fasciatus* relatively small as they enter fresh water from the sea. Development as whitebait involves shrinkage by about 25% in total length; the head length, considered separately, shrinks by about 15%. The ratio of standard length to head length alters from the larval to the adult value before positive growth recommences. These features are probably similar for *G. postvectis* and *G. argenteus*.

Minimum observed pigmentation is described for the late larvae of *G. m. attenuatus, G. brevipinnis,* and *G. fasciatus* and for early whitebait of these and of *G. postvectis* and *G. argenteus*. Subsequent development of melanophores and of colour pattern is described and figured. Large melanophores along the lateral line distinguish early whitebait of *G. m. attenuatus,* but no distinguishing feature of pigmentation has been found in other species until the juvenile pattern is apparent. This pattern is characteristic for each species, and it persists in adult *G. m. attenuatus*. *G. argenteus* has distinct juvenile and adult patterns, the latter being developed in a second, superficial, layer of pigment cells. Adult *G. postvectis* develop a distinctive fin colour pattern unlike other New Zealand *Galaxias;* the superficial pigment layer is without definite pattern. In adult *G. brevipinnis* this layer resembles the persistent juvenile pattern and the two layers combined give a reticulate appearance. In *G. fasciatus* the juvenile pattern persists and develops as the fish grow; the superficial pigment layer is present in adults but is not usually apparent.

Until now positive identification of whitebait has depended on colour pattern. Recently recorded identifications of unpigmented whitebait are shown to be misleading. A key is given for the identification of early and late whitebait using absolute measurements as an important character.

INTRODUCTION

The life history of *Galaxias maculatus attenuatus* (Jenyns) (formerly *G. attenuatus* (Jenyns), see Stokell 1966) is well known to involve a marine larval stage (Phillipps 1930) yet some basic features of its development on return to fresh water have not been recorded. The

* Present address: Department of Zoology, University of Manitoba, Winnipeg, Canada.

present investigation was made in order to distinguish early freshwater stages, the whitebait, of *G. m. attenuatus* and similar stages of related species. Stokell (1955, p. 27) records juvenile *G. brevipinnis* Günther mixed with early whitebait of *G. m. attenuatus* in tidal waters and suggests that the former species might enter the sea. Woods (1963, pp. 29, 32) made the first tentative suggestions that several species, namely, those above and the kokopu (*G. fasciatus* Gray, *G. postvectis* Clarke, and *G. argenteus* (Gmelin)) may each have a whitebait stage. This he defined as the transparent, free-swimming and shoaling stage and commented that the whitebait "probably live downstream from the parent habitat, but it is not yet known if they live in the sea as fry [larvae]". From later deductions (1964, p. 171) he suggested that these species must have marine larvae similar to *G. m. attenuatus*. These views were based on observations of the wide coastal distributions of the adults of these species, absence of larvae in the adult habitats, and other circumstantial evidence. Colour pattern was suggested as the most useful single character for identifying late juveniles. The juvenile and adult markings of *G. argenteus* and of *G. postvectis* were found to be distinct whereas they are similar for the other species. McDowall (1964, 1966) supported these suggestions and recorded having identified each of the above species in the early whitebait stage and (1964) gave descriptions of species other than *G. argenteus* which he described later (1966).

The following account of aspects of growth and pigmentation of species of diadromous *Galaxias* is based largely on material obtained from rivers on the West Coast of the South Island during September 1964, October and November 1965 (Woods 1966), and on late juvenile and adult specimens from this and other localities. The present study has shown that it is possible to recognise several stages in the life histories of these fishes. The division between larval and juvenile stages is made between the marine-living, elongate, transparent fish which probably live a pelagic existence in shoals and the freshwater whitebait stage which follows. On entering fresh water the larvae gradually become pigmented and eventually stouter bodied and, as juveniles, in species other than the neotenous *G. m. attenuatus*, they live a more solitary existence. These uses of "larvae" and "juvenile" are considered to be as intended by Hubbs (1943, p. 260) who gives widely accepted definitions of stages in the life histories of fishes. He defines larvae as "developmental stages well differentiated from the juvenile and intervening between the times of hatching and of transformation . . ." and juvenile as "young essentially similar to adults". The whitebait stage is transitional, and following common usage is here termed juvenile rather than larval. When the shrinkage phenomenon of whitebait, recorded below, is considered it is most probable that the only "transformation" between "well differentiated" stages occurs during the whitebait stage and not earlier in the marine phase as has been assumed. For example, McDowall (1964, p. 60) states that "the larval life and much of the juvenile life is spent in the sea". Stages in the life histories of diadromous *Galaxias* from New Zealand are named and defined as follows.

	Stage	*Definition*
Larva	Larval	Marine growth stage. Little or no pigment. Skeleton not calcified.
Early Juvenile = Whitebait	Early Whitebait	Develops a dorsal and lateral covering of small melanophores. Lateral line melanophores develop. Considerable shrinkage in length occurs; S.L.:H.L.[1] ratio high.
	Late Whitebait	Melanophores increase in density and pattern begins to show. Decrease in length continues. S.L.:H.L. ratio closer to adult value.
	Formative Juvenile	Around a point in time, between shrinkage and positive growth, when growth in length is zero. S.L.:H.L. ratio attains adult value. Some indications of colour pattern. Fish of slender build.
Late Juvenile	Early Immature	Inner pigment layer shows juvenile pattern. Outer pigment layer not present. Large mid-ventral melanophores usually obvious. Fins clear. Body becomes stouter.
	Late Immature	Outer pigment layer is developing[2] but does not mask inner pattern. Mid-ventral melanophores absent.
Adult	Adult	Outer pigment layer fully formed[2]. Some pigment in fins[2].

[1] S.L.:H.L = Standard Length: Head Length.
[2] Does not apply to *G. m. attenuatus*.

SHRINKAGE OF WHITEBAIT

Larval *Galaxias*, and early whitebait with little pigmentation, as described below, are considerably larger than late whitebait of the same species which are beginning to show some pattern. Changes in length have been traced through the whitebait stages and seen to be accompanied by an irreversible increase in the numbers of melanophores. With increase in pigmentation, and therefore with age, there is a decrease in overall length of about 25%, followed by a resumption of positive growth. By the time the initial length has been regained the juvenile pattern is well developed. This phenomenon is linked with a change in the relative size of the head which is proportionately shorter in late larvae than in late juveniles and adults. This change comes about by shrinkage being relatively greater in the trunk and tail (about 30%) than in the head (about 15%). These features are evident from Figs 1–3 which are based on numerous specimens from many samples of *G. m. attenuatus*, *G. brevipinnis*, and *G. fasciatus*. The ratio of L.C.F. (Length to Caudal Fork) to S.L. remains constant for all species during shrinkage, indicating that the caudal fin shrinks in proportion with the rest of the body.

The author has collected only two samples of early whitebait (lightly pigmented) of *G. postvectis* and only one pigmented early whitebait of *G. argenteus* as well as one slightly older specimen. The formative juvenile stage of these two species is not represented in the author's collection, which contains only a few juveniles of these species; the adults are poorly represented in the author's and museum collections. Records from the available material of *G. postvectis* and *G. argenteus* indicate that they have similar growth characteristics to the other species.

All stages of *G. m. attenuatus* can be identified with certainty from the distribution of large melanophores, the position of the pectoral fins, and the small mouth. Other post-marine *Galaxias* larvae and unpigmented whitebait, described below, are divisible into two categories based on size alone. Most large specimens, over about 40 mm S.L. (several thousand) have a short lower jaw and the anal origin is posterior to the dorsal origin; these are readily identifiable as *G. brevipinnis*. Most smaller specimens (several hundreds) have the jaws of about equal length and the anal origin lies below the dorsal origin; these are readily identified as *G. fasciatus*. Two samples, containing rather small whitebait with short lower jaws, are intermediate between *G. brevipinnis* and *G. fasciatus* for the position of the anal fin origin. The amount of shrinkage that had taken place was inferred from the density of pigment which aided in identifying these as *G. postvectis*. *G. argenteus* whitebait were recognised by their large head and low S.L.:H.L. ratio. This ratio has a very wide range for pigmented whitebait, so much so that all other species overlap considerably and it is not useful for separating species. For this reason absolute values of length and head length are employed below.

FIGS 1–5—Relationships between head length and standard length in juveniles of five species of *Galaxias*. A represents late larval dimensions; A–B represents shrinkage during the early whitebait stage; B–C represents shrinkage during the late whitebait stage to the formative juvenile stage, C; C–D represents growth of the late juvenile stage towards adult size. Specimens are figured at natural size (preserved) and the position of each is denoted in each graph by letters. X represents 10 or more specimens with the same head length and standard length values.

Figures 1–3 relate the lengths (S.L.) and head lengths of fish from numerous samples and each figure shows the range of variation observed for one species. Samples of larvae and early whitebait were usually large, and the specimens generally did not differ appreciably in degree of development. But samples of older whitebait usually contained only a few fish and these usually varied greatly in the amount of pigment developed. Thus it has been possible to compare samples of only the earliest stages. Table 1 shows the mean values with standard deviations for standard length and head length for 31 samples of larvae and early whitebait. The standard deviations are similar for the standard length measurements of most samples, but are larger for the sample of larvae and for the most pigmented early whitebait (including samples not tabled).

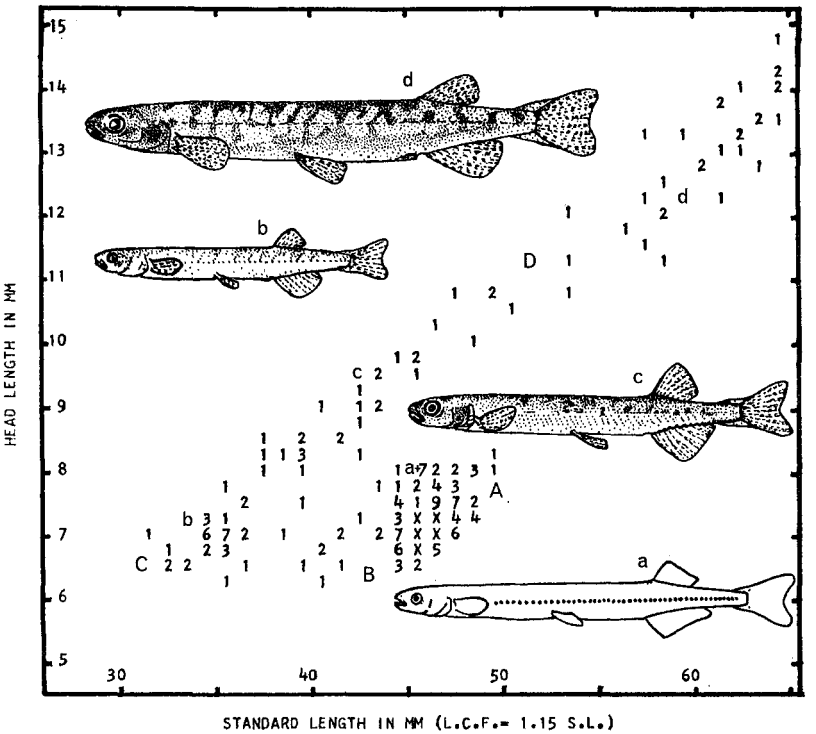

FIG. 1—*Galaxias maculatus attenuatus*. 261 specimens showing negative and positive phases of juvenile growth. (a), (b) and (d) Awarua River, Westland. (c) Awanui River, Northland. See explanation Figs 1–5.

The range of mean S.L. values in Table 1 for *G. m. attenuatus* converts to 52 mm–54 mm L.C.F., which is similar to that recorded by McDowall (1964). He gives 51 mm–54 mm L.C.F. for samples collected at regular intervals throughout the three months of the whitebaiting season in 1963 in the Awarua River, Westland.

In only one large sample did the fish vary in series from late larvae to early whitebait with complete dorsal and lateral pigmentation. This was for *G. brevipinnis* from the Taramakau River on 14 October 1965 (Table 1). Very large runs of whitebait had commenced a few days earlier following a period of several weeks when few whitebait were running. Thus the wide range of development found in this sample is thought to be the result of marine larvae having been attracted to the river mouth and collecting there over a period of weeks. Local whitebaiters maintain that such accumulations do occur and that the shoals may enter the estuary each night. *G. m. attenuatus* in this sample did not show as wide a range of development as *G. brevipinnis*.

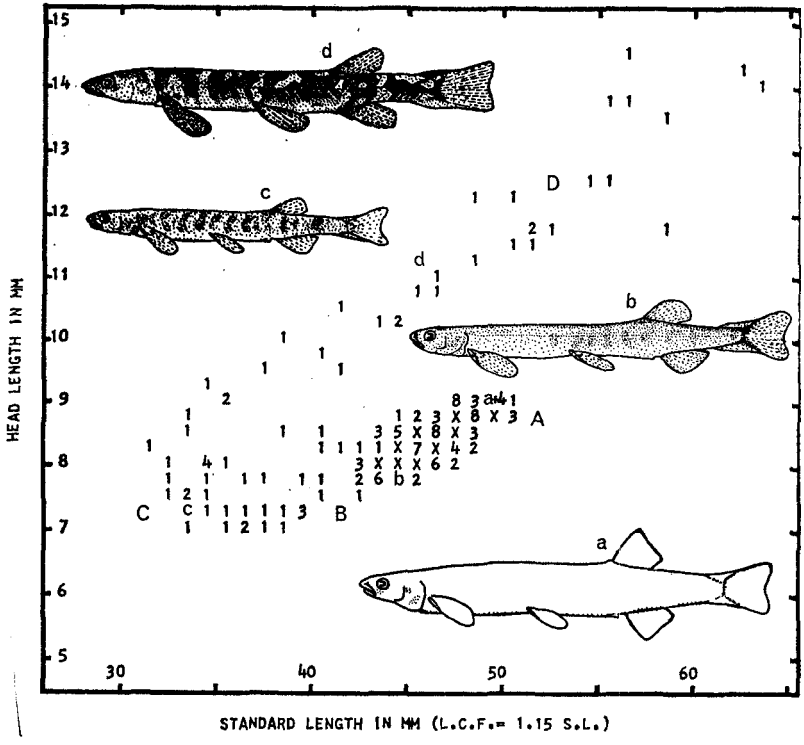

FIG. 2—*Galaxias brevipinnis*. 169 specimens showing negative and positive phases of juvenile growth. (a) Karamea River, Westland. (b) Auckland Island (subantarctic). (c) Day's Bay Stream, Wellington. (d) Owhiro Bay Stream, Wellington. See explanation Figs 1–5.

These observations support the possibility that contact with fresh water, even for short periods, is a necessary stimulus to initiate the whitebait phase.

The relation between shrinkage and increase in pigmentation demonstrated within the Taramakau samples of *G. brevipinnis* has also been traced through the early whitebait stage of *G. m. attenuatus* using individual samples. Further development, from the late whitebait to the early immature juvenile stage when the fish have assumed adult proportions, can be traced in Figs 1–3. The formative juvenile stage is not well represented, but this stage may not be clearly defined in life. The whitebait of the three most common species feed regularly during shrinkage; this has been observed in aquaria. Thus shrinkage is an active, and not a wasting process, although the possibility remains that the amount of shrinkage is not the same for all fish and may be greater in specimens which have made a long upstream migration than in those which have not.

Burnet (1965) caught juvenile *G. m. attenuatus* several miles inland which were smaller, on average, than a sample taken about the same time just above the tidal reaches. To account for this size difference he suggests that it may be smaller fish that move further inland and that they may be smaller because they are from the later part of the whitebait run; he also states that they spend a year longer in fresh water before maturing. Burnet's conclusions could suggest racial differences, but normal shrinkage probably accounts for his observed size differences, and it is here suggested that the late maturity of the fish which have moved further inland is related to environmental factors.

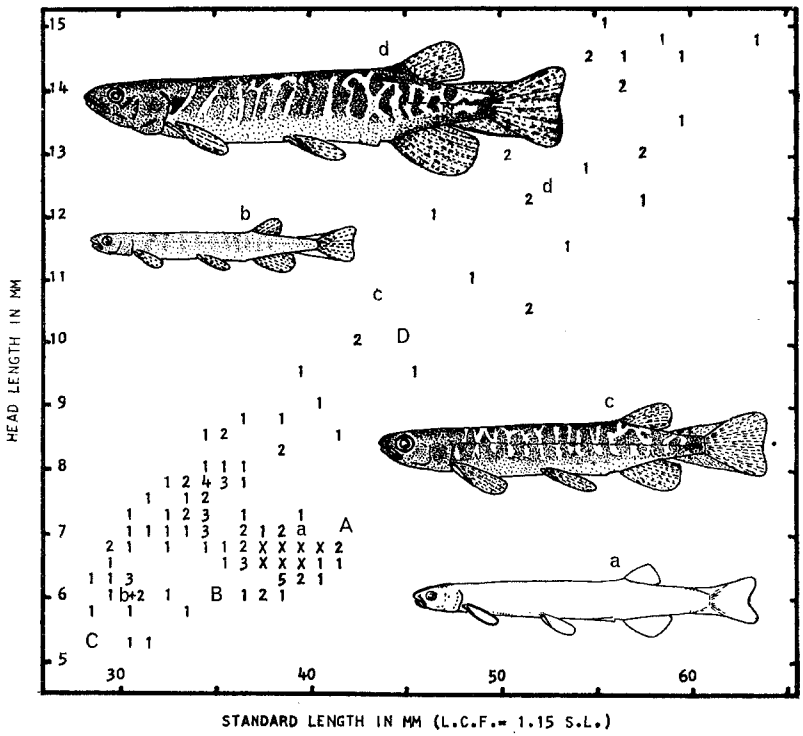

FIG. 3—*Galaxias fasciatus*. 193 specimens showing negative and positive phases of juvenile growth. (a) Karamea River, Westland. (b) Little Barrier Island. (c) Waitati River, Otago. (d) Kaihoka Lakes, Nelson. See explanation Figs 1–5.

The formative juvenile stage requires to be followed for individual fish under a variety of conditions in order to define precisely the phenomenon of shrinkage. However, the general picture is clear. As the rate of shrinkage decreases and is reversed there is an increase in head length and in weight until the fish have body proportions similar

to adults, allowing for slight allometric growth. A similar pattern of development would appear most satisfactorily to link the available specimens of *G. postvectis* and *G. argenteus* as plotted in Figs 4 and 5.

TABLE 1—Range of mean values for standard length and head length for 27 samples of unpigmented whitebait each containing 20–40 specimens, and otherwise for individual samples. All samples are from the West Coast of the South Island. Standard deviations ranged from 1.04 to 1.43 for S.L. and from 0.49 to 1.24 for H.L.

Species	No. of samples	Standard length	Head length
G. m. attenuatus	9 samples	45.0 to 47.1	7.41 to 7.86
G. brevipinnis	20 larvae	48.5 ±1.32 S.D.	8.73 ± 1.14 S.D.
G. brevipinnis	12 samples	44.8 to 46.9	8.18 to 8.51
G. brevipinnis	20 specimens**	42.3 ± 1.31 S.D.	8.28 ± 1.35 S.D.
G. fasciatus	6 samples	36.4 to 37.8	6.52 to 6.69
G. postvectis	12 specimens*	40.3 ± 0.89 S.D.	7.34 ± 1.06 S.D.
G. argenteus	2 specimens**	34.0 and 36.0	8.0

* Specimens have dorsal, and lateral-line pigment.

** Specimens have complete dorsal and lateral covering of melanophores.

Mean L.C.F. = 1.15 S.L. for all samples.

PIGMENTATION OF LARVAE AND JUVENILES

LATE LARVAE AND "UNPIGMENTED" WHITEBAIT

Late larvae of *G. brevipinnis* and *G. fasciatus* caught in river estuaries show only a few, typically four, melanophores on the occiput and some in the cranium and opercular regions, and the eyes are fully pigmented. Other melanophores which are present internally but which cannot be seen through the white opaque flesh of preserved specimens are not recorded here. The minimum pigmentation pattern of early whitebait of these species is as above, and additional pigment has been laid down on the lips, along the bases of the unpaired fins, and dorsally and ventrally on the caudal peduncle. *G. m. attenuatus* larvae and early whitebait are both similar to the above species, but in addition they always have a conspicuous row of large, lateral-line melanophores and at least one melanophore is present just anterior to the dorsal origin (Figs 1a and 6). Other species lack these, and when their lateral line does become pigmented the melanophores are small and not readily discernible. McDowall (1964, fig. 1; 1965, fig. 1a and texts) did not recognise this difference, yet his identifications are based on colour pattern, and this is a most obvious diagnostic character separating the late larvae and early whitebait of *G. m. attenuatus* from those of other New Zealand Galaxiidae. *G. brevipinnis* and *G. fasciatus* always have, and *G. postvectis* and *G. argenteus* probably have, a double row of large melanophores extending ventrally in unbroken lines from the isthmus to the anus. In specimens of *G. m. attenuatus*

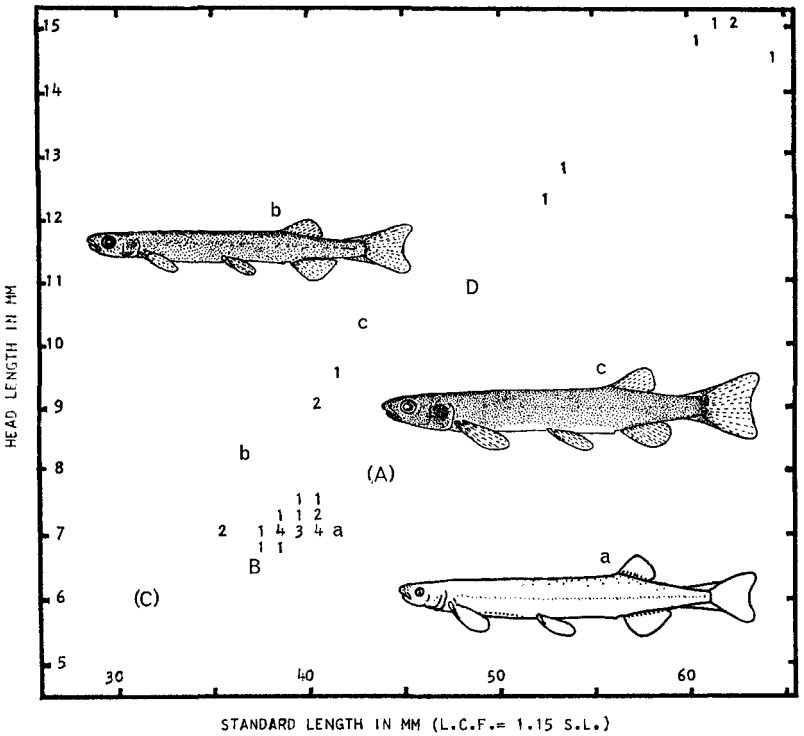

FIG. 4—*Galaxias postvectis*. 35 specimens showing negative and positive phases of juvenile growth. (a) Orowaiti River, Westland. (b) Waikanae River, Wellington. (c) Serpentine Creek, Westland. Positions of A and C are extrapolations using data in Figs 1–3. See explanation Figs 1–5.

which have minimum pigment elsewhere, similar ventral rows are developed only anteriorly, but with increase in pigmentation dorsally these ventral rows either extend to the anus or recur only around the ventral fins or anus.

WHITEBAIT STAGE

Development of pattern from the minimal pigmentation commences with the appearance of melanophores on the dorsal trunk. In *G. m. attenuatus* these are large and conspicuous, and as their number increases anteriad they can appear to form a double row. Usually less than one hundred form before they are replaced by much smaller melanophores which develop to cover a wide area of the dorsal surface. The density of these increases and they progressively extend onto the lateral surface, outlining the myotomes. A few large dorsal melanophores lying anterior to the dorsal fin are retained for life. In

G. fasciatus some large irregularly spaced melanophores may develop dorsally, or along the lateral line but these are never deeply pigmented. Otherwise, in all species very small melanophores appear on the dorsal surface and along the lateral line and these increase to cover the sides. The head and dorsal surfaces are the most deeply pigmented at all stages while the ventral surface remains largely or completely free from small melanophores. Xanthophores, guanophores, and other chromatophores also appear during the development of these fishes.

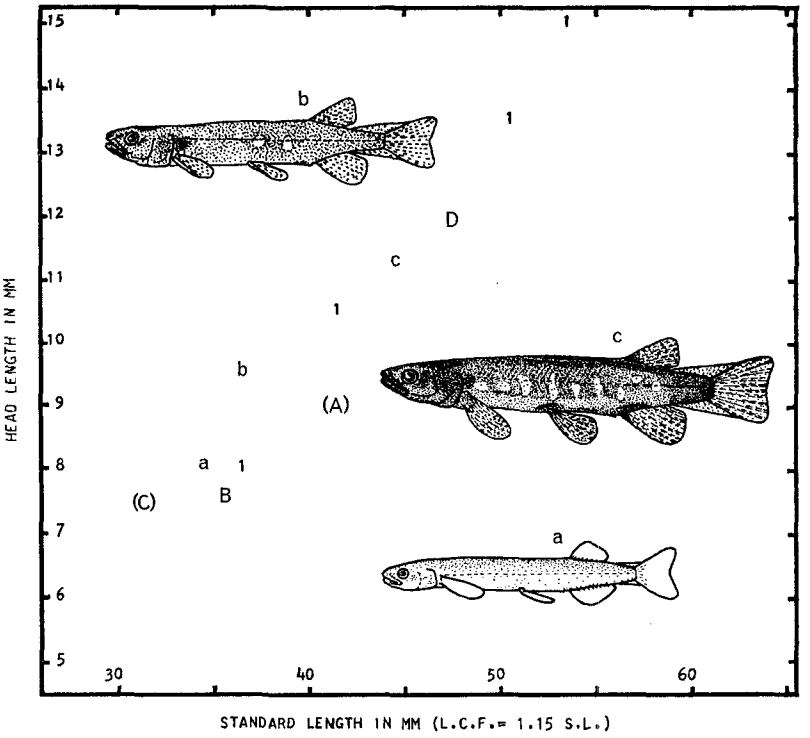

FIG. 5—*Galaxias argenteus*. 7 specimens showing juvenile growth. (a) Serpentine Creek, Westland. (b) Tributary of Lake Brunner, Westland. (c) Horokiwi Stream, Wellington. Positions of A and C are extrapolations using data in Figs 1–3. See explanation Figs 1–5.

COLOUR PATTERN IN LATE JUVENILES AND ADULTS

The layer of pigment which has developed in the whitebait stage differentiates into a characteristic late juvenile pattern by localised expansion or contraction of pigment in the melanophores rather than by uneven addition of chromatophores, except as described below for

G. argenteus. This pattern is the same as the adult pattern for *G. m. attenuatus* and contributes largely to the adult appearance in *G. fasciatus* and to a lesser extent in *G. brevipinnis*. The pigment described above is developed in the subcutis. Late immature fish develop a superficial cutaneous layer of pigment (absent in *G. m. attenuatus*); this may or may not develop a pattern. These pigmented layers are unaffected by scales, which do not develop in any species of *Galaxias*.

G. m. attenuatus

Adult *G. m. attenuatus* are less densely pigmented than any other New Zealand species of *Galaxias*. The greatest concentration of pigment is present dorsally while the dorso-lateral surfaces and caudal region have a dark mottling on a light ground. A more or less sharp

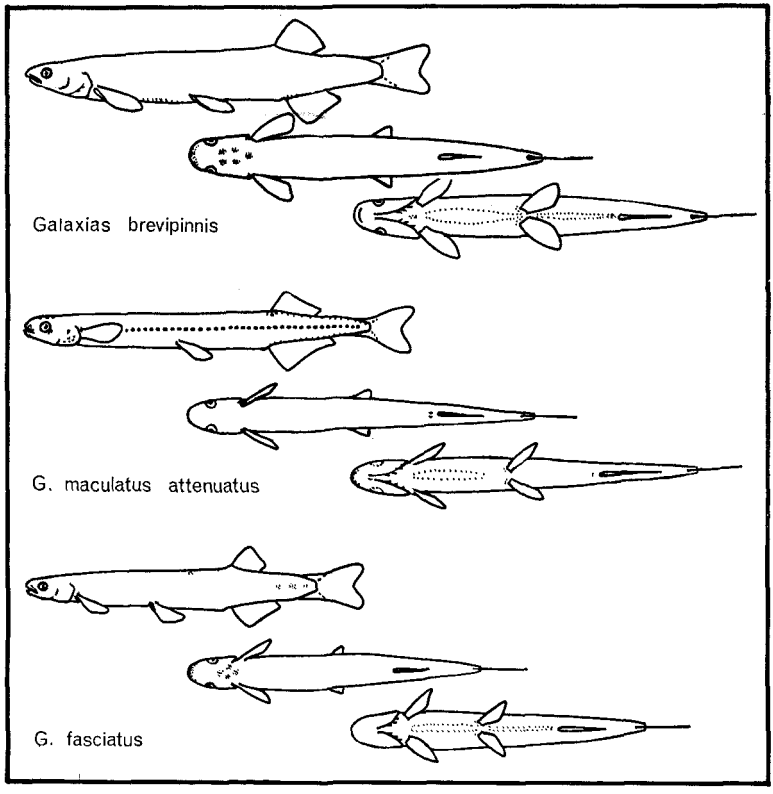

FIG. 6—Immediate post-larval or early whitebait stage of three species of *Galaxias*. Lateral, dorsal and ventral aspects are figured at natural size to show relative sizes, proportions and minimal pigmentation.

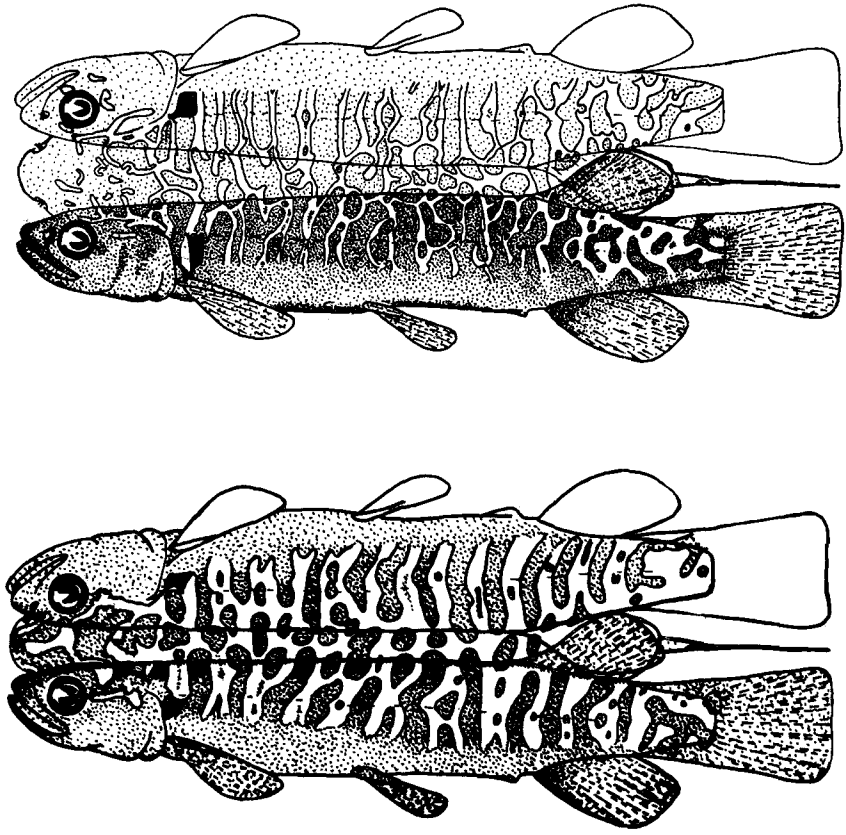

FIG. 7—*Galaxias fasciatus* showing (a) typical broken and (b) clearly formed patterns. Upper, 95 mm L.C.F.; Lower, 105 mm L.C.F., Kaihoka Lakes, Nelson.

discontinuity occurs at the lateral line below which the pigment is less intense and the pattern grades into a nacreous belly. The fins are not pigmented. In life the muscle is translucent but expansion and contraction of pigment in the chromatophores, which interrupts reflections from the guanine in the iridocytes, may cause the fish to appear pale and transparent, or dark. The muscle is white on fixation and only the expanded melanophores contribute to the pattern.

The adult pattern of *G. m. attenuatus* is not comparable to that of most other species of Galaxiidae in that all the melanophores are developed in the subcutis and none in the cutaneous layer. However, of many hundreds of specimens examined for the presence of superficial melanophores, only one, the largest specimen examined (Fig. 8) is unique in the author's collection in having a few melanophores pre-dorsally in this layer.

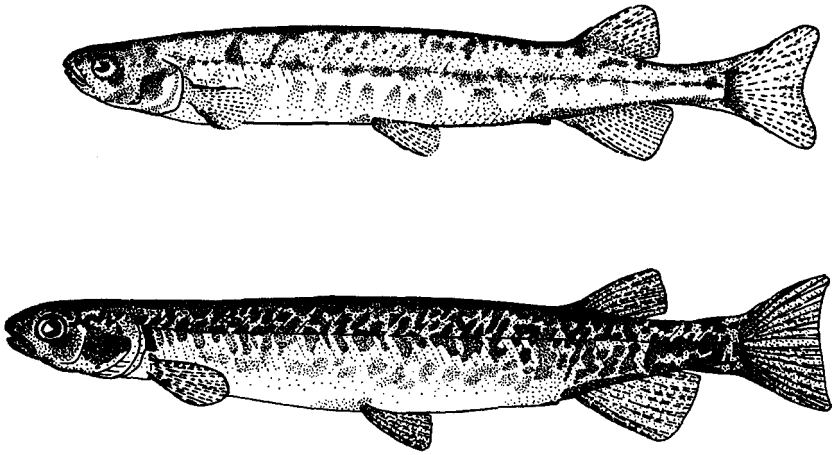

FIG. 8—*Galaxias maculatus attenuatus*. Adults. Upper, 87 mm L.C.F., Waitati River, Otago. Lower, 150 mm L.C.F., Day's Bay Pond, Wellington.

G. brevipinnis

G. brevipinnis is heavily pigmented from the formative juvenile stage and the pattern frequently follows the myotomes but is typically irregular, and individuals from the same sample vary greatly from having a bold to a finely formed pattern. The superficial layer of pigment develops a similar pattern and with increase in size of the fish, which is usually accompanied by dissection of the unpigmented areas, the interplay of the two layers gives a highly reticulate appearance. The fleshy fin bases carry some pattern and chromatophores invade the fins along the rays. (See Figs 2 and 9.)

G. fasciatus

The colour pattern of late juvenile and adult *G. fasciatus* is due to localised contraction or expansion of pigment in the melanophores belonging to the subcutis. The appearance is best interpreted as being of pale vertical stripes breaking a dark ground. The number of stripes between the pectoral and the dorsal origins of 115 specimens have the following frequencies—two specimens with nine stripes, 18 with 10, 40 with 11, 37 with 12, and 18 with 13 stripes. Although typically irregular, especially on the tail where the colour contrast is greatest, the pattern has a very definite form. The dark ground is dissected into areas each surrounded by a halo such that each pale stripe is effectively double and bifurcates dorsally to surround a smaller dark area. This is shown in Fig. 7 for a "typical" and a particularly well patterned specimen. With increase in size the light

stripes become divided along their length by dark pigment and the original dark areas may be broken by the appearance of thin pale stripes; this is usually most developed anteriorly. (See Figs 3 and 10.)

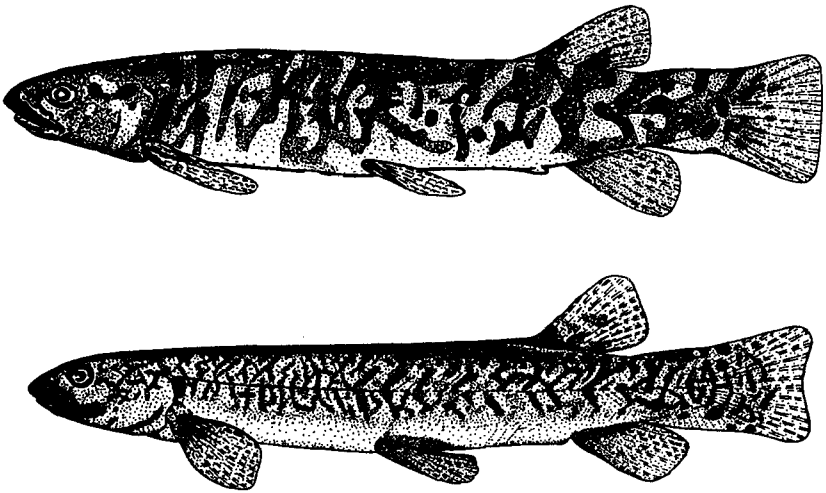

FIG. 9—*Galaxias brevipinnis*. Adults. Upper, 112 mm L.C.F., Waikanae River, Wellington. Lower, 158 mm L.C.F.,Wanganui River, near National Park.

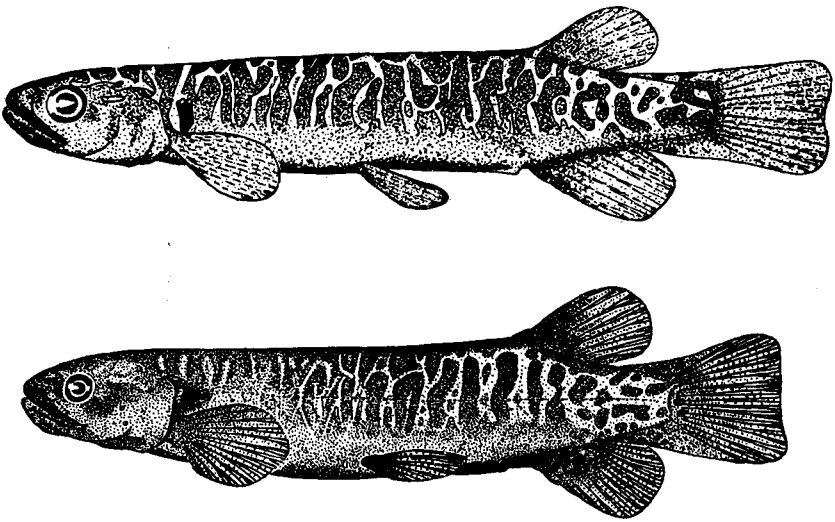

FIG. 10—*Galaxias fasciatus*. Adults. Upper, early immature stage, 80 mm L.C.F., Lower, 175 mm L.C.F., Waitati River, Otago.

On one occasion in the field the author observed an adult specimen of *G. fasciatus* with a broad, dark, lateral stripe extending between the pectoral and caudal fin bases. This was again observed on specimens of this species in aquaria. The stripe may appear and disappear several times within a few hours and is assumed to be of importance in the behaviour of the species. It is probably produced in the superficial layer which otherwise affects the whole area of the fish uniformly. Overall changes in this layer will allow the fish to adapt its colour tone to the local conditions within a short span of time. Similar long term adjustments to the environment are probably due largely to the deep layer. The general pattern does not change noticeably when fish are placed in aquaria, but fish from open streams tend to have broader pale areas in the basic pattern than fish from bush streams with dense cover.

G. postvectis

The first pattern to form consists of about a dozen dusky vertical stripes which are irregular and ill-defined. These persist in fish up to about 100 mm L.C.F. (late immature fish) and are not easily visible in larger specimens. Adults can have a sparse scatter of indistinct spots, mostly above the lateral line. The most obvious adult feature is an unusual and characteristic fin pattern. Dark pigment, in melanophores, spreads between the fin rays and eventually forms a dark fringe to the distal margins of all the fins, including the pectorals. A similar dark fringe in the fins of *G. truttaceus* of Australia and Tasmania suggests a very close relationship with *G. postvectis*. A similar close relationship probably exists between *G. fasciatus* and the Australian *G. coxii*. (See Figs 4 and 11.)

G. argenteus

The distinctive late juvenile pattern of *G. argenteus* (visible up to about 80–100 mm L.C.F.) is similar to that of *G. fasciatus* in having pale vertical stripes, but they are fewer in number (7–9) pre-dorsally and are simple unpaired features that rarely bifurcate and seldom extend onto the dorsal surface. This pattern, as for *G. fasciatus*, is contained in the subcutis, but it differs from all other species in that the light areas have a reduced density of melanophores (see Figs 5 and 12). This difference is probably associated with the permanence of this pattern which is retained for life. Late immature specimens develop a much fragmented pattern of light dots, streaks, and crescents on a dark ground in the superficial layer of pigment. While this is developing it may permit the juvenile pattern to be seen also (Fig. 12, middle) and is more obviously a double pattern than the more irregular patterns of *G. brevipinnis*. Fig. 13 summarises several aspects of pattern for the five species.

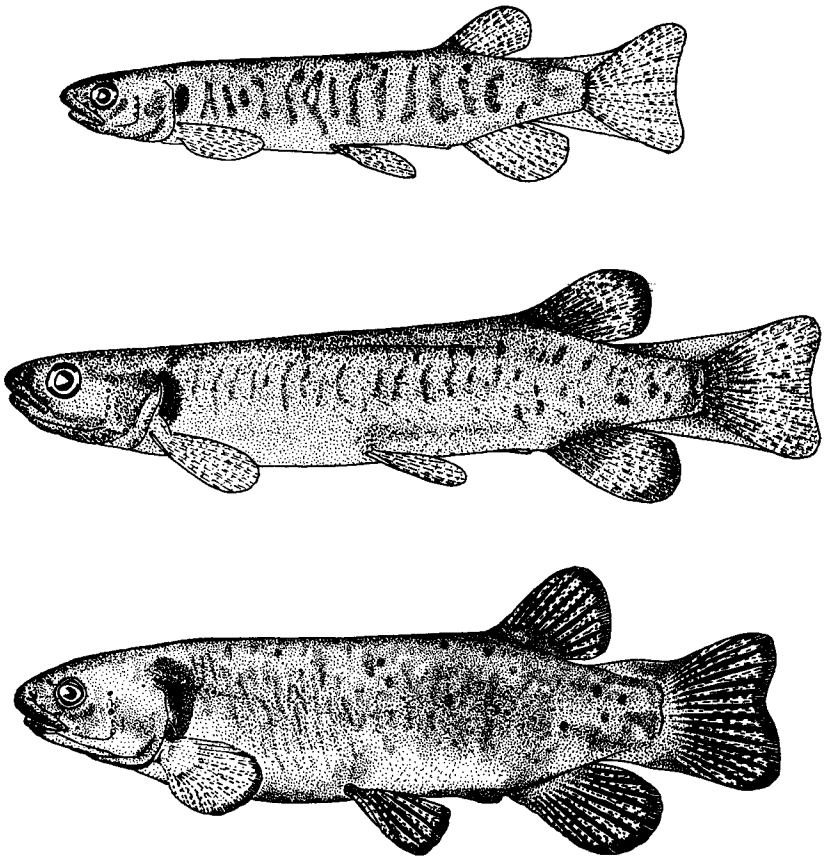

FIG. 11—*Galaxias postvectis.* Upper, early immature stage, 80 mm L.C.F., Waikanae River, Wellington. Middle, late immature stage, 128 mm L.C.F., Day's Bay Stream, Wellington. Lower, adult, 245 mm L.C.F., Waikanae River, Wellington.

IDENTIFICATION

Late larval and early juvenile *G. m. attenuatus, G. brevipinnis,* and *G. fasciatus* migrate upstream in estuaries in mixed shoals, mostly from September to November. The samples of *G. postvectis,* recorded above, were caught moving upstream in shoals with *G. m. attenuatus. G. argenteus* is present at the same stage of development, and at the same time, in the same rivers as these species and almost certainly shoals with them. Numerically, the proportions of species found together vary widely from day to day, and from year to year in the one river and

between rivers on the same day, and all species are widely distributed (Woods 1964). The problems of initial separation and identification of whitebait are therefore not aided by any complete segregation in seasonal or geographic availability of specimens of each species. Observed relative abundance of adults is unlikely to parallel closely that of their whitebait. But in the rarity of adult *G. postvectis* and *G. argenteus* in all regions, and in the abundance of other species in Westland and of *G. fasciatus* in Northland, these proportions are maintained in the whitebait, as identified.

Specimens of early whitebait and all later stages stain satisfactorily with alizarin dye after being cleared in 3% KOH solution. McDowall

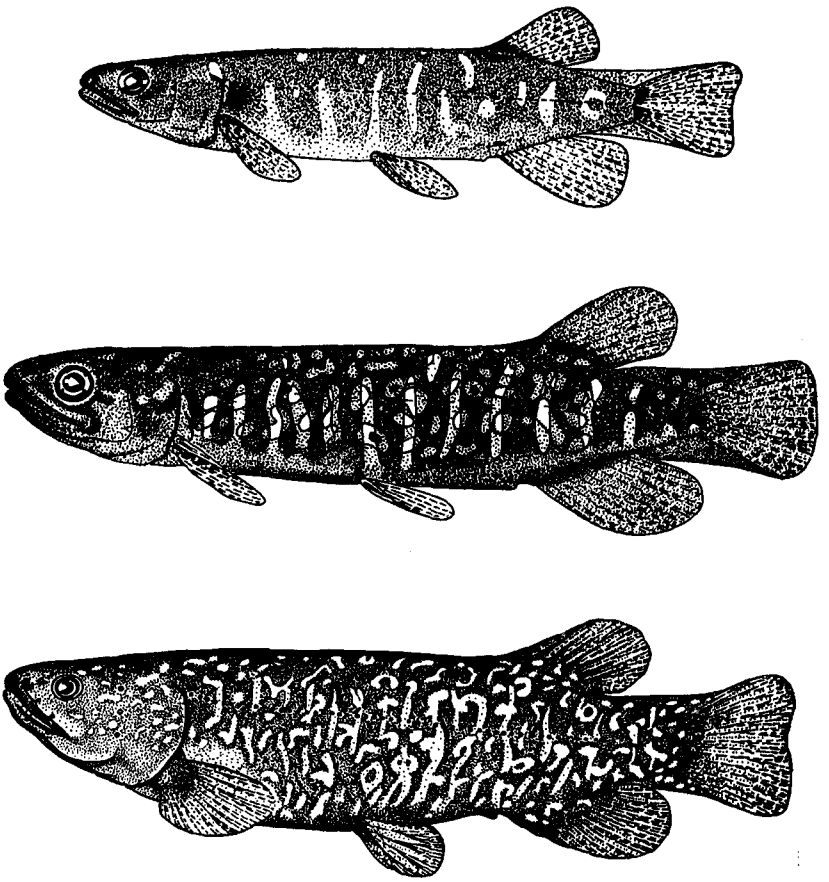

FIG. 12—*Galaxias argenteus*. Upper, early immature stage, 85 mm L.C.F., tributary stream, Pauatahanui, Wellington. Middle, late immature stage, 127 mm L.C.F., Hutt River, Wellington. Lower, adult, 294 mm L.C.F., Butterfly Creek, Wellington.

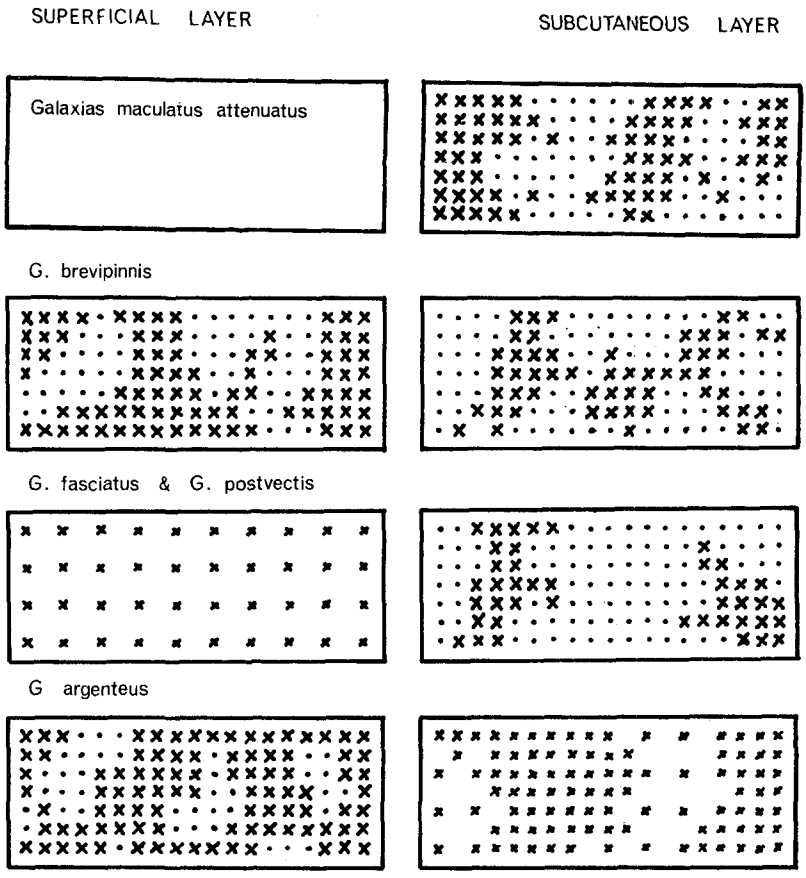

FIG. 13—Diagrammatic representation of pattern due to melanophores in the superficial and subcutaneous layers of five species of *Galaxias*.

(1964) records using this technique to obtain fin ray and vertebral counts for all his material. The skeletons of larvae discussed above were not sufficiently calcified to accept this dye and are probably the youngest specimens to be described.

Identification of juvenile *Galaxias* has until now been based largely on colour pattern. "Colour pattern has been found to distinguish these fishes down to about 36 mm F.L. when pattern first appears" (Woods 1964, p. 171). McDowall (1966, p. 12) reared some fish "until pigmentation patterns indicated the species present" and records that "eleven fish survived until they were identifiable". The large lateral line melanophores of *G. m. attenuatus* (Fig. 6) are diagnostic at the larval and whitebait stages, but other species cannot be distinguished by colour pattern until at least the formative juvenile stage.

Some features of value in distinguishing early whitebait can be derived from the adult condition. These are the relative lengths of the jaws and the relative positions of the origins of the dorsal and anal fins, as first used by McDowall (1964). Some of these characters have now been traced through the complete juvenile stage and are characteristic at all stages. They are the short lower jaw, pointed snout, and rearward anal origin (Figs 2, 6, and 9) of *G. brevipinnis* as compared with the equal jaws, blunt heads, and opposing dorsal and anal fin origins of *G. m. attenuatus* and *G. fasciatus*. Such characters are therefore unlikely to alter between adults and early juveniles of *G. postvectis* or in *G. argenteus*. In these characters adult *G. postvectis* approach the condition of *G. brevipinnis*, whereas *G. argenteus* is similar to *G. fasciatus*.

Woods (1964, p. 171) records that "characters used in the literature to define the three species of Kokopu all overlap between species, and/or are not able to be used with certainty on juveniles". This applies to the fin ray and vertebral counts of all five species as is clear from the ranges of meristic characters recorded by McDowall (1964, p. 142). The total numbers of specimens of adult and late juveniles of *G. postvectis* and *G. argenteus* which can be positively identified, and are available from collections, are too few to permit reliable comparisons of mean values of these characters with whitebait material which is to be identified. Meristic characters, therefore, are not used in this account and as employed by McDowall (1964) can give a misleading impression of accuracy in species identification.

Morphometric proportions alter sufficiently during development of the whitebait to preclude their use for identification except for the head in length value of *G. argenteus* (see above). The conclusion from the present study is that it is necessary to use absolute lengths and head lengths of whitebait, with regard to the amount of pigment present, in order to make accurate identifications of all five species. A further complication could arise if geographic variation were found in size; this is not apparent to any significant extent in the author's material where most large samples are from one area, and this factor remains to be investigated. McDowall (1964) records that his material of non-*G. m. attenuatus* whitebait ranged from 41 to 50 mm L.C.F. and his data for *G. m. attenuatus* are 51 to 54 mm (present data 52 to 54 mm) L.C.F. Otherwise his only length data are for figured specimens and these are shorter than mean lengths for present material by 12% for *G. brevipinnis*, 5% for *G. fasciatus*, and 9% for *G. postvectis*. His length data (1966) for *G. argenteus* (50 to 54 mm) are about 30% longer than his earlier size record of *G. postvectis*, whereas the author's material indicates that as early whitebait these two species are of similar length. McDowall (1964, 1966) does not mention the shrinkage phenomenon in whitebait.

The following key has been constructed from the data already presented for identification of whitebait. Absolute length measurements are used, and along with these other characters become more useful. Although sample means will be more useful the following key should

prove accurate for individual specimens. It is so designed that for borderline cases it will continue to redirect the user so that relevant questions will be repeated. If further inspection of the specimen does not lead to changes, e.g. in the measurements that have been applied to the key, then the specimen should be compared with positively identified material of the alternatives which are indicated by the key, and with Figs 1–5. All measurements used in this account are from specimens in 40% isopropyl alcohol after fixation in 4% formaldehyde.

KEY TO THE IDENTIFICATION OF DIADROMOUS *Galaxias* WHITEBAIT

1	Dorsal surface lightly pigmented or unpigmented (use numeric characters only)	2
	Dorsal and lateral surface noticeably dark, little pattern, slender (use alphabetic characters only)	A
2	With large melanophores along the full length of the lateral line .... *G. m. attenuatus*	
	Lateral line completely lacking in melanophores or only a few posteriorly or melanophores very small	3
3, B	With noticeably shorter lower jaw and low snout profile	4, C
	With jaws about equal and blunt snout	7, F
4, C	With anal origin below middle of dorsal fin base	5, D
	With anal origin about level with or only slightly behind dorsal origin	6, E
5	Greater than 44 mm S.L. and 8.0 mm H.L. *G. brevipinnis*	
	Less than above measurements, relatively stout build *G. postvectis* ?	6, (7)
6	Less than 42 mm S.L. and 7.7 mm H.L. but above 7.0 mm H.L. .... *G. postvectis*	
	Greater than above specifications, relatively slender build *G. brevipinnis* ?	5, (7)
7	Head length less than 7.0 mm; may have a few large, pale melanophores pre-dorsally and/or along lateral line. *G. fasciatus*	(2)
	Head length more than 8.0 mm .... *G. argenteus*	
A	A few large melanophores just anterior to the dorsal fin in all specimens; pectoral fins placed laterally; mouth small .... *G. m. attenuatus*	
	Up to a few large pale melanophores pre-dorsally, usually none; pectoral fins placed low; mouth large	B
D	Greater than 7.0 mm H.L.; may have some pattern *G. brevipinnis*	
	Less than 6.7 mm H.L. .... *G. postvectis* ?	E (C)
E	Less than 6.5 mm H.L. .... *G. postvectis*	
	Greater than 6.5 mm H.L. .... *G. brevipinnis* ?	D (F)
F	H.L. less than 6.5 mm, may have some body pattern *G. fasciatus*	
	H.L. greater than 7.0 mm. No body pattern *G. argenteus*	

ACKNOWLEDGMENTS

The writer wishes to thank Professor G. A. Knox and Dr R. S. Bigelow for reading the manuscript, Mr J. G. Penniket of the Canterbury Museum, Christchurch, for discussion, and Dr V. Benzie for discussion on the use of the term larva. Financial support and the use of some specimens from the New Zealand Marine Department are gratefully acknowledged.

REFERENCES

BURNET, A. M. R. 1965: Observations on the spawning migrations of *Galaxias attenuatus* (Jenyns). *N.Z. Jl Sci. 8 (1):* 79–87, 4 figs., 2 tbls.

HUBBS, C. L. 1943: Terminology of early stages of fishes. *Copeia 1943 (4):* 260.

MCDOWALL, R. M. 1964: A consideration of the question "What are Whitebait?" *Tuatara 12 (3):* 134–46, 4 figs.

———1966: Further observations on *Galaxias* whitebait and their relation to the distribution of the Galaxiidae. *Tuatara 14 (1):* 12–18, 2 figs.

PHILLIPPS, W. J. 1930: *N.Z. Marine Dep. Ann. Rep.* Wellington.

STOKELL, G. 1955: "Freshwater Fishes of New Zealand." Simpson and Williams, Christchurch. 145 pp., 42 pl.

———1966: A preliminary investigation of the systematics of some Tasmanian *Galaxias. Trans. R. Soc. Tas. 100:* 73–9.

WOODS, C. S. 1963: "Native and Introduced Freshwater Fishes." Reed, Wellington, 64 pp., 45 figs.

———1964: Fisheries aspects of the Tongariro power development project. *N.Z. Marine Dep. Fish. Tech. Rep. No. 10,* Govt. Printer, Wellington. 214 pp., 73 figs and diags, 56 tbls.

———1966: Species composition of whitebait (*Galaxias* spp.). *Rec. Canterbury [N.Z.] Mus. 8 (2):* 177–9, 1 tbl.