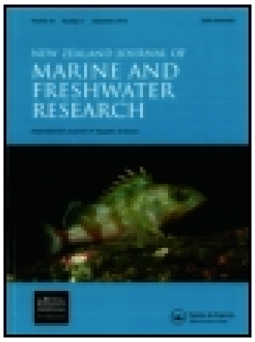

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Deposition of *Galaxias fasciatus* eggs with *Galaxias maculatus* eggs at a tidal site

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Abstract While measuring egg distribution of the intertidally spawning galaxiid fish, *Galaxias maculatus*, some noticeably larger eggs (1.86–2.2 mm diam.) were seen. In common with the smaller *G. maculatus* eggs (1.18–1.5 mm diam.), these eggs peaked in abundance at 300 mm above normal water level. The two sizes of eggs were distributed differently along a 1 m length of stream bank. A sample of the larger eggs was hatched and reared in the laboratory. They proved to be the eggs of *Galaxias fasciatus*, a forest-stream dwelling species not normally found as adults in the intertidal zone.

Keywords *Galaxias fasciatus*; *Galaxias maculatus*; spawning behaviour; terrestrial fish egg incubation

INTRODUCTION

Fish that lay eggs above normal water levels gain guaranteed protection from aquatic predators (Tewksbury & Conover 1987). Such egg-laying behaviour has been recorded for several Galaxiidae (a southern hemisphere family of Salmoniformes): *Neochanna apoda* (black mudfish) was found to scatter adhesive eggs above normal water level in an aquarium (Eldon 1971); field studies found that larvae of this fish appear soon after a rise in water level (Eldon 1978). Diadromous *Galaxias maculatus* (inanga) spawn among intertidal vegetation (Benzie 1968b); land-locked populations of *G. maculatus* rely on flooding to provide the necessary water level fluctuations (Pollard 1971).

Galaxias fasciatus (banded kokopu) was observed spawning at the delta of a small flooding forest stream (Mitchell & Penlington 1982); eggs were found deposited ≥ 0.5 m above normal water level beneath *Carex geminata* plants and hatched in the laboratory after 30 days. Newly hatched larvae are swept down stream during flooding (Ots & Eldon 1975) and return to freshwater as 40–45 mm juveniles after some 4 months growth in the sea.

Unlike *G. maculatus* (the common whitebait), juvenile *G. fasciatus* are a relatively uncommon component of the New Zealand whitebait catch (McDowall & Eldon 1980; Stancliff et al. 1988). Adults are most abundant in small streams where catchments remain enclosed by native forest (McDowall 1970; they are not normally found in estuarine or tidal reaches of New Zealand rivers.

This note reports the occurrence of intertidal egg deposition by *G. fasciatus* and discusses implications of this egg-laying behaviour.

METHODS

As part of field work to describe the spawning ecology of *G. maculatus*, a series of transects was laid to estimate egg distribution and abundance in the intertidal zone of the Waiotane Stream, a small stream draining into Ohiwa Harbour, Bay of Plenty (38°00′S, 177°03′E). On 13 June 1986, I noticed that some eggs were larger than the surrounding *G. maculatus* eggs. Under 30× magnification it was confirmed that they were developing fish eggs.

A sample of 42 *G. maculatus* eggs and 42 larger eggs was then collected from the site, measured to the nearest 0.01 mm diam. using a binocular microscope with a graticule eyepiece, and the size-frequency determined.

Normal water levels and levels at peak spring tides were measured at the spawning site, as was

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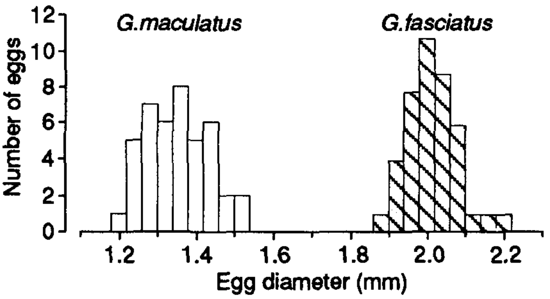

Fig. 1 Size-frequency distribution of *G. fasciatus* and *G. maculatus* eggs.

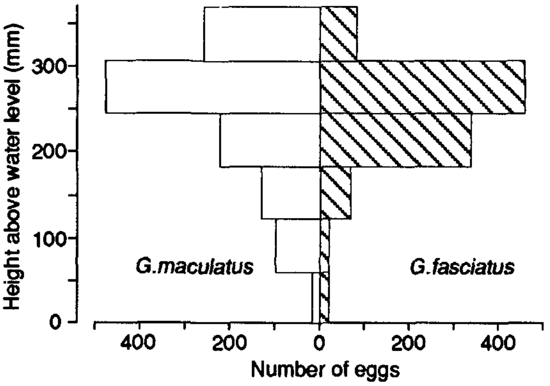

Fig. 2 Vertical distribution of eggs of *G. fasciatus* and *G. maculatus* above low-tide water level.

salinity using a hand refractometer. A block of 60 continuous 0.01 m^2 quadrats, 10 long × 6 high centred on the egg find, was used to estimate egg density. The 10 rows of quadrats were run up the stream bank from normal water level to where eggs could no longer be found. Vegetation was carefully parted, removed when necessary, and all eggs seen within each quadrat were counted. In each quadrat, eggs were visually sized as large (>1.8 mm diam.) or small (<1.6 mm diam.).

A sample of large eggs on a turf was returned to the laboratory on 18 June 1986 and kept in a plastic bag at room temperature (6–12°C). The turf was regularly dampened and air exchanged within the bag. Eggs were examined at 7-day intervals under 30× magnification to determine the stage of development. After 14 days, embryos were fully developed (Benzie 1968a). Hatching then occurred when fresh water (14°C) was flooded over the eggs. Newly hatched larvae were transferred to 60-litre sea water aquaria and reared (Mitchell 1989) until metamorphosis into the juvenile stage occurred. Juveniles were then transferred to freshwater aquaria and reared until 9 months old, large enough for positive identification using the criteria of McDowall (1970).

RESULTS

Two separate groups of eggs, with no overlap in size, were recorded for the site (Fig. 1). Superficially both types of eggs were clear, spherical, and smooth-surfaced.

When found, all eggs were at a similar developmental stage with pigmentation of the optic cups visible but before guanine deposition had begun (Stage 16: Benzie 1968a). The section of stream where eggs were found was tidal, being subject to a rise in water level on all spring tides. However, upstream sea water penetration was never closer than 25 m from the site, even at peak spring tides. As a result of previous draglining, the stream bank was straight and sloped steeply into the water. The highest quadrat in which eggs occurred was 60 cm up the bank and 37 cm vertically above water level at low tide. This level was covered by tidal freshwater for only 3–5 days each month. The area had last been covered by the tide 17 days before eggs were found on 13 June. Bankside vegetation consisted of a mixture of grasses and herbs, dominated by *Festuca arundinacea*, *Agropyron repens*, *Carex geminata*, and *Ranunculus repens*.

Vertical distributions of both types of egg were similar with peaks of abundance between 25–30 cm vertically above low tide water level (Fig. 2). However, the eggs of each species were independently clustered with most larger eggs found within a 20 × 40 cm^2 area of bank. *G. maculatus* eggs were also clustered, but peak numbers were found some 40 cm away (Fig. 3). A total of 1023 large eggs and 1243 *G. maculatus* eggs were counted within 0.6 m^2 of bank.

Newly hatched larvae from the larger eggs appeared to be galaxiids (Fig. 4) although larger (9.0 mm TL) than *G. maculatus* (7.0 mm TL, Benzie 1968b). After a period of growth in sea water, metamorphosis into the freshwater stage (marked by superficial melanocytes, development of the spleen, and settling to the tank bottom) was complete within 4 months. Nine months from hatching pigmentation was sufficiently developed for identification as *G. fasciatus* (Fig. 5).

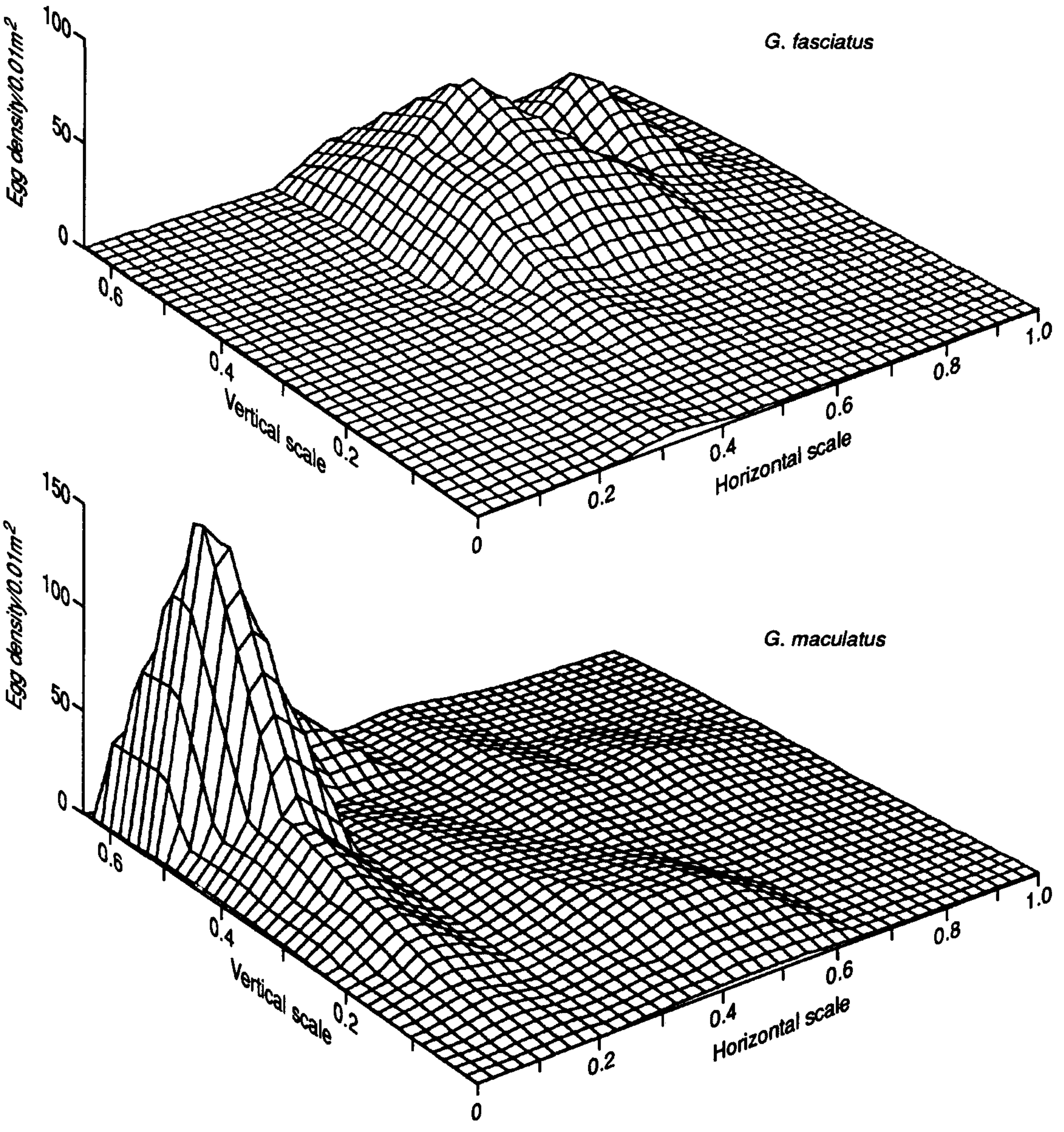

Fig. 3 Density of *G. fasciatus* (top) and *G. maculatus* eggs (bottom) within 0.01 m^2 quadrats over a 1.0 m long × 0.6 m high section of stream bank.

DISCUSSION

Adult *G. fasciatus* had never been caught at this spawning site, although eight fish species representing a typical upper estuarine fauna were routinely caught over a 5-month autumn–winter period of fortnightly hand-net sampling for *G. maculatus*. This indicates that *G. fasciatus* migrated down stream before spawning. Such migration may be common for the diadromous galaxiids. Burnet (1965) described lunar mediated pre-spawning downstream migration for *G. maculatus*. Humphries (1989) observed an attempted downstream movement for a prespawning diadromous stock of *Galaxias truttaceus* (spotted

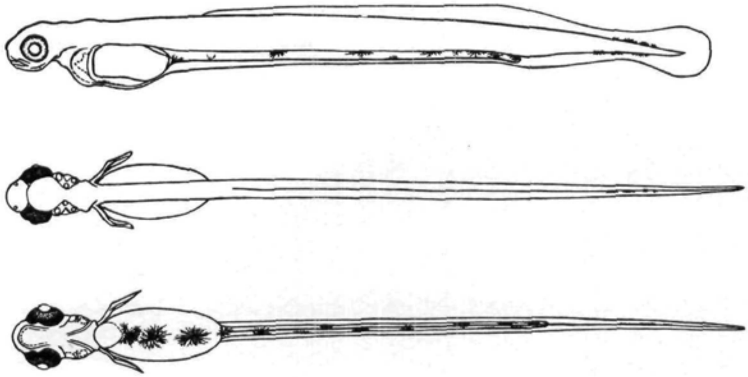

Fig. 4 Newly hatched larvae of *G. fasciatus*, 9 mm TL.

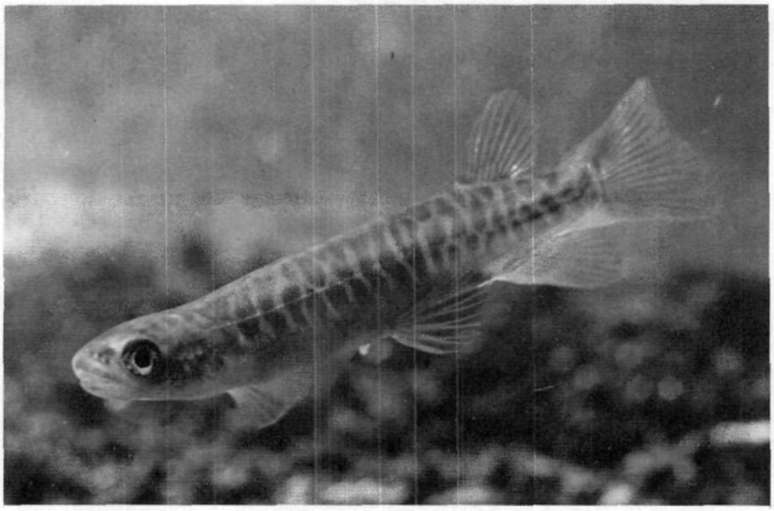

Fig. 5 Nine-month-old tank-reared *G. fasciatus* grown from eggs collected from the Waiotane Stream 18 June 1986 (Photo: R Strickland).

galaxias). I have caught a running ripe female *Galaxias argenteus* (giant kokopu) in a saltwater, tidal drain. Eel fishermen can make large catches of this normally uncommon species in early winter, implying that these fish are then migrating.

However, this spawning at a tidal site con-flicts with knowledge that the adult distribution of *G. fasciatus* is centered on small forest streams. It seems improbable that all the inland populations of *G. fasciatus* would migrate to an estuary to spawn. Although this is essentially a lowland species, many populations of *G. fasciatus* are found above waterfalls and rapids scaled by upstream migrating juveniles (McDowall 1978). Adults may spawn for several years (Hopkins 1979) implying repeat migrations. The large size of eggs of this and the other whitebait species, in comparison with *G. maculatus* (all near 2 mm diam., whereas *G. maculatus* is 1 mm: McDowall 1970), could be linked to the need to provide substantial yolk reserves while the larvae are carried long distances down stream (Ward et al. 1989). Landlocked populations of *G. fasciatus* also occur where obviously non-tidal reservoirs and lakes provide egg laying sites and larval habitat (McDowall 1970).

It can be concluded that *G. fasciatus* is versatile in terms of spawning site requirements (within perhaps a basic requirement for repeated water level fluctuations). Use of either tidal fluctuations or flooding may be general for all the diadromous galaxiids. McDowall (1988) classified the diadromous New Zealand galaxiids as amphidromous, with one exception, *G. maculatus*. This species he considered marginally catadromous because of its migration to an estuarine spawning site. Further evidence for spawn-ing in tidal areas for *G. fasciatus* or the other diadro-mous galaxiids may also require a shift in their classifi-cation from amphidromous to marginally catadromous.

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