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Short communication

Egg cannibalism by inanga (*Galaxias maculatus*)

RICHARD ALLIBONE*
National Institute of Water and Atmospheric Research Limited
P.O. Box 11 115
Hamilton, New Zealand

*Present address: Biodiversity Recovery Unit, Department of Conservation, P.O. Box 10 420, Wellington, New Zealand. email: rallibone@doc.govt.nz

Abstract Egg cannibalism by inanga (*Galaxias maculatus*) was found to occur immediately after spawning. Spent and immature inanga from a school of 335 fish consumed between 0 and 51 eggs each. As inanga spawning sites are high on the river bank and only accessible on high spring tides, further opportunities for egg predation are limited to when the eggs are re-submerged at hatching on the next suitable spring tides. It is unclear whether the cannibalism observed represents a reduction in short-term reproductive fitness without providing long-term gains.

Keywords Galaxiidae; spawning; predation; *Galaxias maculatus*; egg mortality

INTRODUCTION

Inanga (*Galaxias maculatus* (Jenyns)) is the most common diadromous galaxiid in New Zealand. The species supports a major recreational and commercial fishery, with the juvenile whitebait stage providing the majority of the fish caught in the whitebait fishery. As a species of significant fisheries value, its life cycle has been extensively studied (e.g., Phillipps 1919, 1924; Benzie 1968; McDowall 1968; McDowall & Eldon 1980; Mitchell 1989).

An unusual feature of it biology is its terrestrial spawning behaviour. Spawning aggregations of fish occur in the tidal reaches of rivers and streams. At or just after high spring tides, schools of inanga spawn amongst the temporarily submerged vegetation. As the tide drops, the eggs are left deposited on the soil and root mats and allowed to develop in this damp terrestrial environment until they hatch when next submerged by a high spring tide (McDowall 1968). Other diadromous galaxiids also carry out terrestrial spawning (O'Connor & Koehn 1998; Allibone & Caskey 2000; Charteris 2002), but the reasons for such behaviour are unknown, although avoidance of aquatic egg predators has been suggested (Balon 1981).

In this study egg predation at an inanga spawning site was assessed during spawning.

METHODS

Two known inanga spawning sites on the Waitetuna River, New Zealand (NZMS 260 Raglan R14 841 757) were selected for the study. Both sites were amongst ungrazed long introduced grasses in the upper tidal zone of the river. Inanga, *Gambusia affinis* (mosquito fish), common bully (*Gobiomorphus cotindianus*), and eels (*Anguilla* sp.) were known to inhabit the river and a small drainage ditch connected to the river and were all potential predators of inanga eggs while the nest sites were submerged.

The spawning sites were monitored for 3 days around the peak spring tides in April and May 1999. Extreme high tides in April meant spawning occurred when access to the sites was impossible until well after the potential spawning event. A second spawning event occurred at one of the spawning sites in May, and 335 inanga present in the rank (ungrazed) grass at the spawning site where collected by hand and net as the water retreated. A randomly selected sample of inanga were immediately killed with an anaesthetic overdose. All the other fish were returned alive to the laboratory and placed in an aquarium. The live fish were

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measured and retained for a month in the laboratory before survivors were released back into Waitetuna River. The inanga killed at the spawning sites were weighed, measured, dissected to determine gonad status, and gut contents were examined.

RESULTS

Spawning of inanga was observed on 17 May 1999 and, as the tide dropped, 335 inanga were collected from amongst the rank grass. This spawning site had been used for spawning by inanga the previous month and fully developed eggs were present amongst the long grass. No other fish species were observed amongst the grass at the spawning site. Eels were observed in the drainage channel adjacent to the spawning site and were preying upon adult inanga leaving the spawning site. No gambusia or common bully were observed or caught at the spawning site. The inanga ranged in size from 46 to 124 mm (mean length 72.2 mm, median 67 mm).

Forty-five randomly selected inanga, 18 female and 27 male, were examined for spawning condition and gut contents. Six fish had empty guts and four of these fish were still ripe (one female and three males). The remaining 39 fish all had freshly consumed food items in the gut and only two of these individuals, both male, were ripe. Gonad development in six individuals was at an early stage, indicating that these fish were not actually spawning with the other inanga when they were collected from the spawning site. All the inanga with food items in their guts had recently consumed fish eggs; the number of eggs consumed per individual ranged from 1 to 51. The eggs were round and c. 1 mm in diameter, and all but six appeared in the very early stage of development. Six eggs were eyed and fish embryos were observed in the eggs. Given that the fish were all collected at an inanga spawning site (used for spawning the previous month), that the round shape of the eggs indicated galaxiid rather than bully eggs, and that the eggs showed no sign of digestion, it was concluded the eggs were inanga eggs, most just laid at the spawning site the fish were collected from. The total number of inanga eggs consumed was 723. There was no relationship between fish size or sex and the number of eggs consumed.

An estimate of the total number of eggs consumed by the 335 inanga captured was calculated:

Estimate of eggs consumed = (Fish collected/Fish analysed for gut) × number of eggs eaten
= (335/45) × 723
= 5382 eggs

The 290 inanga whose gut contents were not sampled were kept for over a month in the laboratory and no mortality occurred. All fish were very active feeders, rapidly consuming all food items (tube worms, *Daphnia*, and stream insects) offered.

DISCUSSION

The results present two interesting points: (1) inanga readily cannibalise their eggs; and (2) no other fish species present was taking advantage of this feeding opportunity. Eels were preying upon the spent inanga as they returned to deeper water, but common bully and gambusia that were present in the area were not collected or observed at the spawning site while the area was submerged. Given that gambusia are often noted to be egg predators, the terrestrial spawning habit of inanga (and other galaxiids) may place their eggs out of the foraging range of gambusia. The other fish species present may also find the shallow receding tidal water an unsuitable foraging habitat and therefore the inanga eggs are safe from other aquatic predators.

The percentage spawned eggs consumed by the inanga appears to be a small percentage of the eggs actually spawned. Fecundity of individual inanga has been estimated to range from 175 to 13 500 eggs (length 43–135 mm, McDowall 1968) and the number of eggs laid by this spawning school would have been in the millions. Given that mortality of the early life history stages (egg to post-whitebait stage) of most fish is high (Kalmer 1992) the overall impact of the cannibalism should be minimal. The predation rate is also constrained by the tidal nature of the spawning sites. The sites are only submerged on spring tides for a few hours 2 or 3 days a month. Egg predation opportunities for aquatic predators are therefore limited to the time around inanga spawning and hatching.

Of considerable interest is the fact that inanga prey upon their own eggs. Egg cannibalism itself is not uncommon and has been reported in other galaxiids (e.g., koaro (Kusabs & Swales 1991; O'Connor & Koehn 1998) and flathead galaxias (Allibone & Townsend 1997)). As a rule, inanga are considered to be an annual species with mortality after spawning probably being in the high 90% range

(McDowall 1968). The spawning strategy of inanga also suggests that the eggs are being deposited away from aquatic predators and yet if this is the strategy, then cannibalism would appear to be counter productive.

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REFERENCES

Allibone, R. M.; Caskey, D. 2000: Timing and habitat of koaro (*Galaxias brevipinnis*) spawning in streams draining Mt Taranaki, New Zealand. *New Zealand Journal of Marine and Freshwater Research 34*: 593–595.

Allibone R. M.; Townsend C. R. 1998: A comparative dietary analysis of a recently described fish species complex (Galaxiidae) in a New Zealand river. *New Zealand Journal of Marine and Freshwater Research 32*: 351–361.

Balon E. K. 1981: Additions and amendments to the classification of reproductive styles in fishes. *Environmental Biology of Fishes 6*: 377–389.

Benzie, V. 1968: Some ecological aspects of the spawning behaviour and early development of the common whitebait. *Proceedings of the New Zealand Ecological Society 15*: 31–39.

Charteris, S. C. 2002: Spawning, egg development and recruitment of diadromous galaxiids in Taranaki, New Zealand. Unpublished MSc thesis, Massey University, Palmerston North, New Zealand. 89 p.

Kamler E. 1992: Early life history of fish: an energetics approach. London, Chapman & Hall.

Kusabs, I. A.; Swales, S. 1991: Diet and food resource partitioning in koaro, *Galaxias brevipinnis* (Günther), and juvenile rainbow trout, *Oncorhynchus mykiss* (Richardson), in two Taupo streams. *New Zealand Journal of Marine and Freshwater Research 25*: 317–325.

McDowall, R. M. 1968: *Galaxias maculatus* (Jenyns), the New Zealand whitebait. *Fisheries Research Bulletin 2*. Wellington, New Zealand Marine Department. 84 p.

McDowall, R. M.; Eldon, G. A. 1980: The ecology of whitebait migration (Galaxiidae *Galaxias* spp.). *Fisheries Research Bulletin 20*. Wellington, New Zealand Ministry of Agriculture and Fisheries. 171 p.

Mitchell, C. P. 1989: Laboratory culture of *Galaxias maculatus* and potential applications. *New Zealand Journal of Marine and Freshwater Research 23*: 325–336.

O'Connor, W. G.; Koehn, J. D. 1998: Spawning of the broad-finned galaxias *Galaxias brevipinnis* Günther (Pisces: Galaxiidae) in coastal streams of southeastern Australia. *Ecology of Freshwater Fish 7*: 95–100.

Phillipps, W. J. 1919: Life cycle of the fish *Galaxias attenuatus*. *Australian Zoologist 1*: 211–213.

Phillipps, W. J. 1924: The New Zealand minnow. *New Zealand Journal of Science and Technology 7*: 117–119.