SCIENCE & RESEARCH SERIES NO.38

CONSERVATION AND MANAGEMENT OF THE WHITEBAIT FISHERY

by
R.M. McDowall

Published by
Head Office,
Department of Conservation,
P O Box 10-420,
Wellington,
New Zealand

ISSN 0113-3713
ISBN 0-478-01317-5

National Library of New Zealand
Cataloguing-in-Publication data

McDowall, R. M. (Robert Montgomery), 1939-
Conservation and management of the whitebait fishery /
by R.M. McDowall. Wellington [N.Z.] : Head Office, Dept. of Conservation, c1991.
1 v. (Science & research series, 0113-3713 ; no. 38)
Includes bibliographical references.
ISBN 0-478-01317-5
1. Galaxias fisheries--New Zealand. 2. Galaxiidae--New Zealand.
I. New Zealand. Dept. of Conservation. II. Title. III. Series:
Science & research series ; no. 38.
639.27550993 (597.550993)

Keywords: Whitebait, *Galaxias maculatus*, inanga, *G. fasciatus*, banded kokopu, *G. brevipinnis*, koaro, *G. argenteus*, giant kokopu, *G. postvectis*, shortjawed kokopu, fishery, management, life cycles.

CONTENTS

CONSERVATION AND MANAGEMENT
OF THE
WHITEBAIT FISHERY

by

R.M. McDowall[1]

Freshwater Fisheries Centre, Ministry of Agriculture and Fisheries
P.O. Box 8324, Christchurch

ABSTRACT

Five species of *Galaxias* are exploited in the whitebait fishery: *Galaxias maculatus* (inanga), *G. fasciatus* (banded kokopu), *G. brevipinnis* (koaro), *G. argenteus* (giant kokopu), and *G. postvectis* (shortjawed kokopu). The Department of Conservation is involved in both the management of the whitebait fishery, and the conservation of the species. The fishery may exploit species for which there is a conservation concern, so the dual responsibilities of the Department could create conflicts which need to be identified and balanced when the fishery is managed.

The relative abundance of the different species in the fishery varies from place to place and from time to time. This review summarises the history and available information concerning the fishery, and the life cycles of the species involved. Specific attention is paid to gaps in present knowledge and identifying research issues and priorities.

1 INTRODUCTION

Exploitation of the shoals of juvenile galaxiid fishes (family Galaxiidae, *Galaxias* spp.) as they move into New Zealand rivers during the spring has long been a traditional New Zealand fishery, both for Maori and since European settlement of the country. It is popularly known as the whitebait fishery (McDowall 1984).

1.1 Background

The migrations of these small fish were well known to the Maori prior to European colonisation, and some early reports discuss the means that the Maori used both to prepare and preserve whitebait (McDowall 1984, 1990). There are also several early commentaries on European explorers having been provided with meals of whitebait by the Maori (Brunner 1848), and the settlers quickly recognised the culinary value of these small fishes, and became involved in the fishery.

---

[1] **Contract funded by Department of Conservation**

The fishery has for many years been managed by regulations designed both to govern the manner and extent of exploitation of the fish stocks, as well as to control the behaviour of the fishers themselves. Because the fishery is based on the sequential, upstream exploitation of migrating shoals of fish, all fishers are seeking access to the same stocks of fish, and there is a strong likelihood of competitive interactions between fishers who seek the best sites, or may interfere with the fishing of others further upstream. As a result management of the fishers has always been a significant aspect of the regulations.

1.2 Research

Research on the fishery has always lagged somewhat behind its management, partly on account of the difficulties in addressing biological questions of significant importance to the fishery. However, following prolonged comments and complaints during the 1920s, an investment was made by Government in research during the 1930s. This work was focused almost entirely upon identifying the locations and conditions under which inanga (*Galaxias maculatus*) spawning took place (Hefford 1931, 1932, 1933). Further research was initiated in the 1960s. This focused initially upon the natural history of the inanga (McDowall 1968), which was generally regarded, at that time, as the only species involved in the fishery, though some early reports had suggested that this was not the case. This 1960s research confirmed these earlier reports, and showed that five species of *Galaxias* are present in the catches (McDowall 1964, 1984). This added considerable complexity to the management of the fishery, and subsequent research (McDowall and Eldon 1980) addressed questions that related to increasing understanding of the multi-species nature of the fishery. A comprehensive account of whitebait natural history and the whitebait fishery is contained in McDowall (1984).

1.3 This report

This report has been prepared at the request of the Department of Conservation which assumed responsibility for managing the whitebait fishery, as well as for the conservation of native freshwater fishes (including those involved in the fishery), when the Department was established in 1987. The Department solicited a review of issues that relate to both of these responsibilities: management of the fishery, and conservation of the species. Clearly, since the fishery has the potential to exploit species for which there may be conservation concern, these dual responsibilities of the Department create conflicts that need to be identified and balanced when the fishery is managed.

2 SPECIES IN THE FISHERY

Five species of *Galaxias* are exploited in the whitebait fishery. These are
(in approximate order of importance in the catches):
Galaxias maculatus - inanga
Galaxias fasciatus - banded kokopu
Galaxias brevipinnis - koaro
Galaxias argenteus - giant kokopu
Galaxias postvectis - shortjawed kokopu

Confirmation that these species are involved in the fishery comes from the captive rearing of whitebait juveniles of all species through to the fully pigmented subadult stage when identification becomes simple and reliable. Relative abundance of the various species in the fishery varies from place to place and from time to time at any place.

2.1 Identification

Identification of the adults/subadults of these five species of *Galaxias* is relatively simple using normal, macroscopic, adult/subadult characters. There is little scope for confusion and inexperienced naturalists can rapidly learn to distinguish the species in the field.

Separating the pigmented juveniles is less simple, though with experience, this becomes possible in the field with a high degree of reliability. Separation of the migrating whitebait juveniles is a much tougher proposition, and requires considerable experience, tuition from skilled observers, and attention to small and often highly subjective differences between the species. In particular, it has proved virtually impossible to distinguish the whitebait juveniles of koaro and shortjawed kokopu; this still cannot be achieved with any reliability on the basis of existing information. Problems in the identification of the whitebait of the various species obviously pose significant problems both for proper management of the fishery and for the conservation of the species involved, particularly as the most vulnerable of the species seems to be the shortjawed kokopu, whose whitebait is virtually indistinguishable from that of the much commoner koaro.

Details of the characteristics of the various stages of the five species, and their identification can be found in McDowall (1980, 1984, 1990).

2.2 Life cycles

Fundamental to involvement of these species in the whitebait fishery is the fact that at certain times of the year, their juveniles are migrating out of the sea and into river estuaries, to begin a life of feeding and growing in fresh waters. In summary and generalising, the life histories of these species are believed to be as follows:
Spawning takes place mostly during the late summer through to early winter, in or near fresh waters, and on hatching the tiny larvae (<10 mm) are carried to sea. They live at sea, probably feeding and growing in the marine plankton, for a period of several months, before returning to fresh water as whitebait, at which stage they are subject to exploitation in the whitebait fishery. Those whitebait that escape capture in the fishery, move upstream to increasingly and eventually occupy habitats characteristic of the adults, where they feed and grow to maturity over the next 6-30 months, before spawning. One species in the fishery is an annual species with high mortality after first spawning, but other species take longer to mature and are believed to be multiple spawners. While the above is a summary of the life cycles of all of the species, there are substantial differences in details which, where known, are elaborated later in this report (see Appendix 1).

3 CONSERVATION AND RESEARCH ISSUES

Appendix 1 draws attention to gaps in the specific areas of knowledge concerning the natural history of each of the five species involved in the fishery. These levels of information are summarised diagrammatically in Fig. 1.

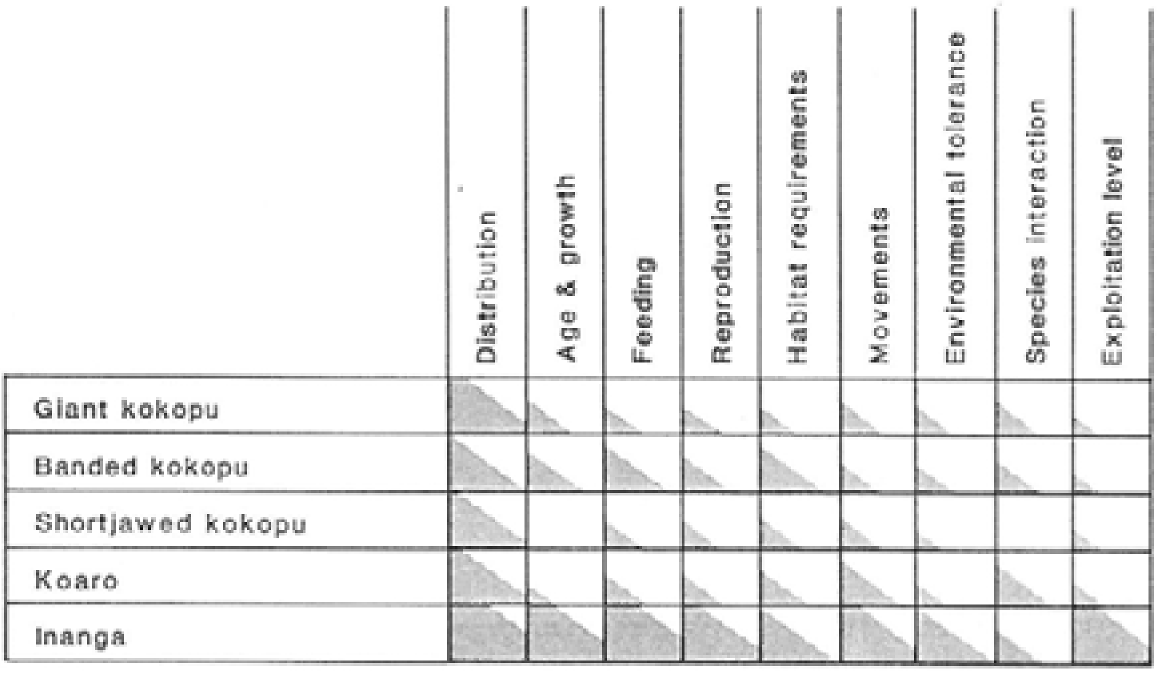


Fig. 1 Diagrammatic representation of the levels of information available on the five species of whitebait.

The general abundance and distributions of virtually all indigenous fishes in New Zealand's fresh waters have declined since the European settlement of the country, and the follow-on effects of that settlement. Deforestation, sedimentation and flooding, wetland drainage, river modifications, river impoundment, water abstraction, and water pollution have all played a role in either extirpating, or reducing the abundance of fishes, including the whitebait species, from habitats that are no longer suitable. In the absence of any information on the former abundance of the whitebait species, it is impossible to provide an objective evaluation of these changes. However, it is obvious that all species have greatly reduced abundance. Huge areas of habitat suitable for their feeding, growth and reproduction have been lost, especially lowland, forested streams and wetlands. In addition it is possible that exploitation has contributed to reduced abundance though there is no evidence that supports this view.

3.1 Conservation status

Overall, it is possible only to provide highly subjective assessments of the conservation status of these species, and such assessments follow.
Inanga - remains very widespread at low elevations and is in some areas abundant.
Banded kokopu - remains quite widespread at low to moderate elevations; however, populations are often small and there are extensive areas where the fish is not found.
Giant kokopu - remains quite widespread in Westland and Southland but is otherwise only locally present and is rarely abundant.
Shortjawed kokopu - is quite widespread in Westland, but otherwise is locally present and there are seldom more than a few fish at any locality, including Westland rivers.
Koaro - sea-migratory populations are widespread in Westland and there are significant populations in some North Island areas (eastern Bay of Plenty, Coromandel, Waikato, Wellington); however, distribution is otherwise patchy and it is rarely common.

3.2 Research and information issues

Information issues relating to Government responsibilities for the whitebait fishery and the species involved in it can be grouped under two headings: the management of the fishery for sustained productivity; and the conservation of the species involved in it.

To some extent these two sets of information overlap, and furthermore, the two goals of managing the fishery and conserving the species could be conflicting. In theory, attaining a goal of sustained productivity should be consistent with conserving the species in it. However, since some species in the fishery make only minor contributions to catch, the viability of their populations is almost incidental to the sustainability of the fishery. Hence maintenance of a sustainable fishery based on one or more common species could jeopardise other, rarer contributing species. With species like shortjawed kokopu and giant kokopu, long term harm to the stocks of the species, within a goal of sustainability of the fishery, is a likely scenario unless particular attention is paid to their conservation needs.

These issues aside, for the moment, the two Government goals of sustainability of the fishery and conservation of the species can be dealt with together since in many respects the information/research needs to meet these Government responsibilities are mostly complementary and rarely in conflict. In the following discussion, where appropriate, attention is drawn to which, if either, of the Government goals has higher significance. If no particular mention is made, then it can be assumed that the information/research need will contribute to both goals with neither having primacy.

3.2.1 Difficulties in identification and separation of juveniles of koaro and shortjawed kokopu.

This is a matter of some significance since the shortjawed kokopu is regarded as threatened, and the level of exploitation in the fishery cannot even be guessed at. It would seem that, at the outset, electrophoretic techniques need to be used to separate fish from whitebait samples. This can be addressed relatively simply by identifying genetic markers that separate the species, or by obtaining samples from the field, taking tissue samples from numbered fish, preserving the fish, and associating genetic markers specific to each species with the preserved fish. Once certain identification is achieved from electrophoresis, an attempt should be made to identify characters by which the two species can be reliably separated (if this is, indeed, possible). This done, there will then be 'voucher' material to determine whether there are consistent and reliable morphological differences between koaro and shortjawed kokopu which can be used for field separation.

The question of identifying whitebait of shortjawed kokopu is an urgent one, on account of the status of the species as a whole.

3.2.2 Escapement from the fishery.

Absolutely nothing is known about levels of escapement from the fishery, either during the periods before and after the fishing season, or during the fishing season itself. In theory, proper management of the fishery cannot be achieved without some understanding of escapement. However, since so little is also known about mortality rates of fish that do escape, about reproductive productivity, about the carrying capacities of the habitats into which the whitebait move to grow and mature, and about mortality of the eggs/larvae/juveniles at sea, there is potentially little use to which information on escapement could be put. Given, also that estimating escapement would be a prodigious and seemingly endless task, and that it would be highly variable with time, place, and river conditions, this does not seem a fruitful line of enquiry, at least at the present.

3.2.3 Spawning migrations of inanga.

Mention is made earlier of the fact that the mature inanga, in upstream (freshwater) habitats, are able to time their downstream spawning migrations so that they coincide with the spring tide, and that this is, as far as presently known, a unique ability in the animal world. Studies of innate rhythms and of cues to which inanga are able to respond would be a very interesting area of enquiry, though its application to management and conservation of the stocks of inanga is not obvious.

3.2.4 Inanga spawning mortality.

Current wisdom is that most post-spawning inanga die, and thus that they reproduce only once. This is an area that needs clarification, and which could have implications for population management, since post-spawning inanga survival in large proportions could make a major contribution to the next season's reproductive productivity.

3.2.5 Conditions for inanga egg development.

The habitats in which inanga spawn are becoming better understood, but very little is known about the conditions under which the eggs develop, and about the factors that effect development and survival to hatching.

3.2.6 Whitebait migration at night.

There are conflicting views about whether or not whitebait migrate at night. All the published data suggest that they do not in any significant numbers. Anecdotal reports suggest that, at least sometimes, they do. This issue has some importance to management of the fishery for two reasons. At present regulations prohibit fishing at night, and this is a fruitless regulation (apart from people-management issues) if the fish don't migrate then. If they do migrate at night, the significance of unlawful fishing at night needs to be determined and decisions made about the need to ensure enforcement of the relevant statute for conservation reasons.

3.2.7 Natural history in fresh water of species involved in the fishery.

The state of knowledge of the natural history of the species while in fresh water is widely variable, but with the exception of inanga, it can fairly be summarised as rudimentary. Reproduction in several species is totally unknown. So little is known that biologically based management of the fishery and its species is impossible. Life history structure, age and longevity, etc., are poorly understood. Even distribution is not thoroughly documented for some species and in some areas.

3.2.8 Life at sea.

For all species involved in the fishery, life at sea is little better than an unexplored 'black box'. It is assumed that the young fish live at sea in the surface plankton, but this is not confirmed. Nothing is known about how they live, what they feed on, how they disperse at sea, or how they navigate back to fresh waters. There is some minimal information from daily growth rings on how long they spend at sea, though this information needs augmentation.

3.2.9 The question of stocks.

Knowledge of which populations the fishery is taking its fish from is fundamental to managing any fishery. In other words, there is a need to understand the nature of the stocks on which the fisheries in various locations depend. Is there a single, large, panmictic stock in the seas around New Zealand; or are there several more or less independent stocks in various parts of our coastal seas; or are there more local stocks? If there are several stocks, to what extent do they mingle, or remain isolated; and how does the productivity of one stock differ from that of another? These are very complex and demanding questions, although there is only a minimal amount of information that could be interpreted as indicating that there are separate stocks in our coastal seas (McDowall and Eldon 1980). This question could be addressed by exploring genetic differences between fish from different parts of the country, using electrophoresis/mtDNA techniques.

Just the identification of whether there is one, or several stocks around our coastlines has profound implications for management. The existence of separate stocks means that local regulations are justifiable; if there is only one stock, local regulations may be worthless.

3.2.10 Impact of fishing mortality on rare species.

Numbers of shortjawed and giant kokopu in freshwater habitats, in particular, are low in many parts of the country. It is possible that fishing mortality is having effects on the stocks of these species, though we have no information on this question. If this is regarded as a matter of real concern, it is possible that regulations could be fine-tuned to minimise the impact of fishing on these species. For example, it is known that in South Westland, at least, whitebait of giant kokopu migrate at the very end of the season, some time in early November. A slightly earlier closure of the fishery could ensure substantially greater escapement of giant kokopu whitebait, perhaps without unduly reducing overall catches. Since nothing is known about the whitebait of the shortjawed kokopu, no such measures are yet possible, which emphasises the importance of developing techniques for identification, and following that, developing knowledge of the seasonal periodicity of shortjawed kokopu whitebait migrations.

3.2.11 Habitats.

Clearly habitats for the species are poorly defined. With the amount of historical change that has occurred to the habitats of the various whitebait species, the whole question of definition and quantification of habitat characteristics must be a matter of profound and primary concern. How is it possible to properly attend to the habitat needs of species when they are undefined? It has been argued that if the vegetative cover surrounding streams and clothing their catchments is retained with no or minimal modification, then the occupants of streams draining these catchments will survive. This is a reasonable, but high risk and only temporary strategy. It should be replaced, as soon as practicable, by a strategy that is based on a real understanding of the stream and catchment conditions which favour these species.

The issue of habitats favoured or required by species has fundamental importance to all aspects of their conservation and management. This applies generally, but is particularly applicable to rarer species such as the giant and shortjawed kokopu. Obtaining reliable information on distribution, presence/absence, quantification of habitats, and levels of abundance is essential to the management of any species, either for fisheries or for conservation. Which of these two responsibilities has priority will differ from species to species. For example, the issue is conservation for giant kokopu and shortjawed kokopu, but is more probably fisheries management for koaro and banded kokopu.

3.2.12 Issues relating to the fishery itself.

The whitebait fishery is a highly dispersed activity, lightly regulated, and very lightly enforced. It has recreational, semi-commercial, and commercial aspects, occurring simultaneously. The fishers are numerous, highly mobile, and often erratic in their involvement. In essence, it is the nearest thing New Zealand has to a ‘peasant fishery'.

At present, information on production from the fishery is totally lacking. In the recent past it has been sparse, and throughout the history of the fishery it has been inadequate and unreliable. In short, managers of the fishery have never had much idea how much fish was caught. There has never been any ability to relate catches to populations, to estimate the impact of fishing on the stocks, or any of the other, fundamental parameters/measures that would be required if the fishery was to be managed on sound, biologically based principles. Management has always been a hit and miss, ad hoc affair. It has to be recognised that without a vast investment in research and management oversight, none of these problems is going to be overcome. It should not be expected that the fishery will in the foreseeable future be managed on biological principles. Given, however, that a fishery has survived under seemingly heavy pressure for 150 years or so, it would seem that, unlike the Tasmanian whitebait fishery (another, though related species; Blackburn 1950), the New Zealand fishery is robust and can withstand the sorts of pressures that have been applied. The records that exist show that the fishery has always fluctuated wildly; there are some seasons in which catches have risen, and some in which they have fallen. Rises and falls have persisted over a long time period, so it would seem that the fishery is not being consistently and seriously overexploited, otherwise there would be continuous decline. This provides some confidence that, despite its totally ad hoc manner, the approach used in the past for managing the fishery has not been totally at variance with the needs of the stocks.

It is said that for many parts of New Zealand there has been a long-term decline in the amount of whitebait entering rivers, and this is unarguable. However, it is certainly a matter of opinion how extensive that decline has been. Frequent, stories are told about using whitebait for garden manure and for feeding fowls. No doubt this sometimes took place, but these stories have become repetitious, and in some instances have become legends that have little direct connection with times and places mentioned. Nevertheless, it is accepted that once there were many more whitebait in some rivers than there are now.

There can be no doubt that a major contributor to declines in abundance of whitebait in virtually all rivers has been habitat deterioration. This has resulted from deforestation, wetland drainage, sedimentation, channelisation, pollution, impoundment, water abstraction, etc. If it is accepted that this is so, there is no way of quantifying the relative impacts of habitat deterioration and fishing on the stocks.

3.2.13 Barriers to migration.
Having migratory habits, the five whitebait species need to be able to move upstream and downstream in river systems, not just to and from the sea at river mouths. Some species must also travel long distances up river systems. Upstream distances exceeding 200 km, and reaching elevations of more than 1000 m are known for koaro and others. Dams, impoundments, weirs, flood gates, and all such obstructions to water flows are major impediments to whitebait stocks.

3.2.14 The impacts of eel fishing.
Several species of whitebait, but particularly the inanga and giant kokopu, share habitats with eels, in wetlands, lowland lakes and lagoons, streams, and the like. It is known that at some times eel fishers catch significant numbers of kokopu. Their fate in the hands of eel fishers is far from secure, quite apart from mortalities/damage ensuing from being held for substantial periods in set fyke nets, often shared with large and numerous eels.
This is not a major point, but it is one that should not be ignored. It is a research issue insofar as the numbers of kokopu taken, and the mortalities caused are unknown. Otherwise it is an education/regulation/enforcement issue that needs attention to minimise damage.

3.2.15 Impacts of exotic species.
There are frequent allegations, largely unsupported by data, that introduced trout, particularly brown trout, have had harmful impacts on various of the whitebait species. This has been attributed to predation of whitebait by estuarine/sea-roving brown trout at river mouths, and by competition in the adult habitats (McDowall 1990). It is time this question was addressed with more objectivity, and studied in natural habitats. This is only possible if there are enough significant populations of whitebait species and trout still coexisting, otherwise some experimental studies could be carried out.

3.2.16 Tangata whenua/Treaty of Waitangi issues.

Maori are promised free and unrestrained access to their fisheries under the Treaty. Historical documents show that Maori traditionally harvested virtually all of the species involved in the whitebait fishery, and at virtually all life history stages. Maori continue to be involved in the whitebait fishery, largely complying with the regulations under which the present fishery is managed. However, there is evidence that some Maori continue to have an interest in harvesting other life history stages of the whitebait species. For example, the downstream-migrating, mature-to-ripe adults of the inanga were highly favoured by the old-time Maori, as they were then very rich and fat, occurred in vast numbers, and were good to eat. In some areas there may be continued interest in this fishery, which is quite lawful under existing freshwater fisheries regulations so long as the fish are being taken to eat, rather than sell. There is no evidence that the adults of the other species in the fishery are still taken by Maori, but this, too, would be quite lawful. When adult fish are taken for human consumption, there are implications for both managing the whitebait fishery and conserving the species involved.

4 RESEARCH ISSUES AND PRIORITIES

Research issues need to be assessed according to criteria such as practicability, urgency and threats to the populations, costs, likelihood of useful management results being obtained, and ultimate value for management.

Lack of information on any of the points discussed can be addressed by research. However, the various criteria listed above all need to be taken into account in decision-making. It is beyond the scope of this report to make such decisions, but it is appropriate that attention be directed towards some of the issues that have been raised. Determination of research priorities is essentially an issue for discussion between managers and researchers. It is necessary to establish the right balance between what information is most urgently needed to meet the needs of the fishery and species conservation, and what is practicable, given availability of resources and the difficulties involved in various research projects.

5 REFERENCES

Blackburn, M. 1950. The Tasmanian whitebait, *Lovettia sealii*, and the whitebait fishery. *Australian Journal of Marine and Freshwater Research* 1(2): 155-198.

Brunner, T. 1848. *Journal of an expedition to explore the interior of the Middle Island of New Zealand.* Examiner, Nelson. 17 pp.

Burnet, A.M.R. 1965. Observations on the spawning migrations of *galaxias attenuatus* (Jenyns). *N.Z. Journal of Science* 8(1): 79-87.

Cadwallader, P.L. 1976. Breeding biology of a non-diadromous galaxiid, *Galaxias vulgaris* Stokell, in a New Zealand river. *Journal of Fish Biology* 8(1): 157-177.

Hanchet, S.M. 1990. Effects of land use on the distribution and abundance of fish in tributaries of the Waikato River in the Hakarimata Range. *N.Z. Journal of Marine and Freshwater Research* 24: 159-171.

Hefford, A.E. 1931. Whitebait. *N.Z. Marine Department Annual Report on Fisheries* 1931: 14, 16-17.

Hefford, A.E. 1932. Whitebait investigation. *N.Z. Marine Department Annual Report on Fisheries* 1932: 13-15.

Hefford, A.E. 1933. Whitebait. *N.Z. Marine Department Annual Report on Fisheries* 1933: 13-14.

Hopkins, C.L. 1979a. Age-related growth characteristics of *Galaxias fasciatus* Gray (Salmoniformes: Galaxiidae). *N.Z. Journal of Marine and Freshwater Research* 13(1): 39-46.

Hopkins, C.L. 1979b. Reproduction of *Galaxias fasciatus* Gray (Salmoniformes: Galaxiidae). *N.Z. Journal of Marine and Freshwater Research* 13(2): 225-230.

Jellyman, D.J. 1979. Observations on the biology of the giant kokopu, *Galaxias argenteus* (Gmelin, 1789). *Mauri Ora* 7: 53-61.

McDowall, R.M. 1964. A consideration of the question "What are whitebait?" *Tuatara* 12(3): 134-146.

McDowall, R.M. 1968. *Galaxias maculatus* (Jenyns) - the New Zealand whitebait. *N.Z. Marine Department Fisheries Research Bulletin* 2: 1-84.

McDowall, R.M. 1980. A synoptic checklist of the freshwater fishes of New Zealand.
N.Z. Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication 16: 1-67.

McDowall, R.M. 1984. *The New Zealand whitebait book*. Reed, Wellington. 210 pp.

McDowall, R.M. 1990. *New Zealand freshwater fishes: a natural history and guide*. Heinemann-Reed, Auckland. 553 pp.

McDowall, R.M. and Eldon, G.A. 1980. The ecology of whitebait migrations (Galaxiidae: *Galaxias* spp.). *N.Z. Ministry of Agriculture and Fisheries, Fisheries Research Bulletin* 20: 1-171.

McDowall, R.M., Robertson, D.A. and Saito, R. 1975. Occurrence of galaxiid larvae and juveniles in the sea. *N.Z. Journal of Marine and Freshwater Research* 9(1): 1-11.

Main, M.R. and Lyon, G.L. 1988. Contributions of terrestrial prey to the diet of banded kokopu (*Galaxias fasciatus* Gray) (Pisces: Galaxiidae) in South Westland, New Zealand. *Verhandlungen de Internationale Vereinigung fur theoretische und angewandte Limnologie* 23: 1785-1789.

Main, M.R. and Winterbourn, M.J. 1987. Diet and feeding of koaro (*Galaxias brevipinnis*) in forested, South Westland streams. *Mauri Ora* 14: 77-86.

Main, M.R., Nicoll, G.J. and Eldon, G.A. 1985. Distribution and biology of freshwater fishes in the Cook River to Paringa River area, South Westland. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Reports* 60-1-142.

Mitchell, C.P. and Eldon, G.A. [1991] *How to locate and protect whitebait spawning grounds*. Freshwater Fisheries Centre, MAF Fisheries, [Christchurch]. 49 pp.

Mitchell, C.P. and Penlington, B.P. 1982. Spawning of *Galaxias fasciatus* Gray (Salmoniformes: Galaxiidae). *N.Z. Journal of Marine and Freshwater Research* 16(1): 131-133.

Ots, J-P. and Eldon, G.A. 1975. Downstream movement of fry of *Galaxias fasciatus* Gray. *N.Z. Journal of Marine and Freshwater Research* 9(1): 97-99.

Sagar, P.M. and Eldon, G.A. 1983. Food and feeding of small fish in the Rakaia River, New Zealand. *N.Z. Journal of Marine and Freshwater Research* 17: 213-226.

Saxton, B.A., Rowe, D.K. and Stancliff, A.G. 1987. Species composition and relative importance of whitebait fisheries in 13 Bay of Plenty rivers. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report* 79: 1-63.

APPENDIX 1 - Summary of Biological Knowledge

Understanding of the life histories, habitat requirements, feeding habits, migratory patterns and other details of the five species varies greatly. Existing knowledge is summarised below for each species, with annotations.

1 Inanga -*Galaxias maculatus*

Knowledge of the biology of the inanga far exceeds that of any other species in the fishery. A review of the natural history of this whitebait species is presented in Fig. 2.

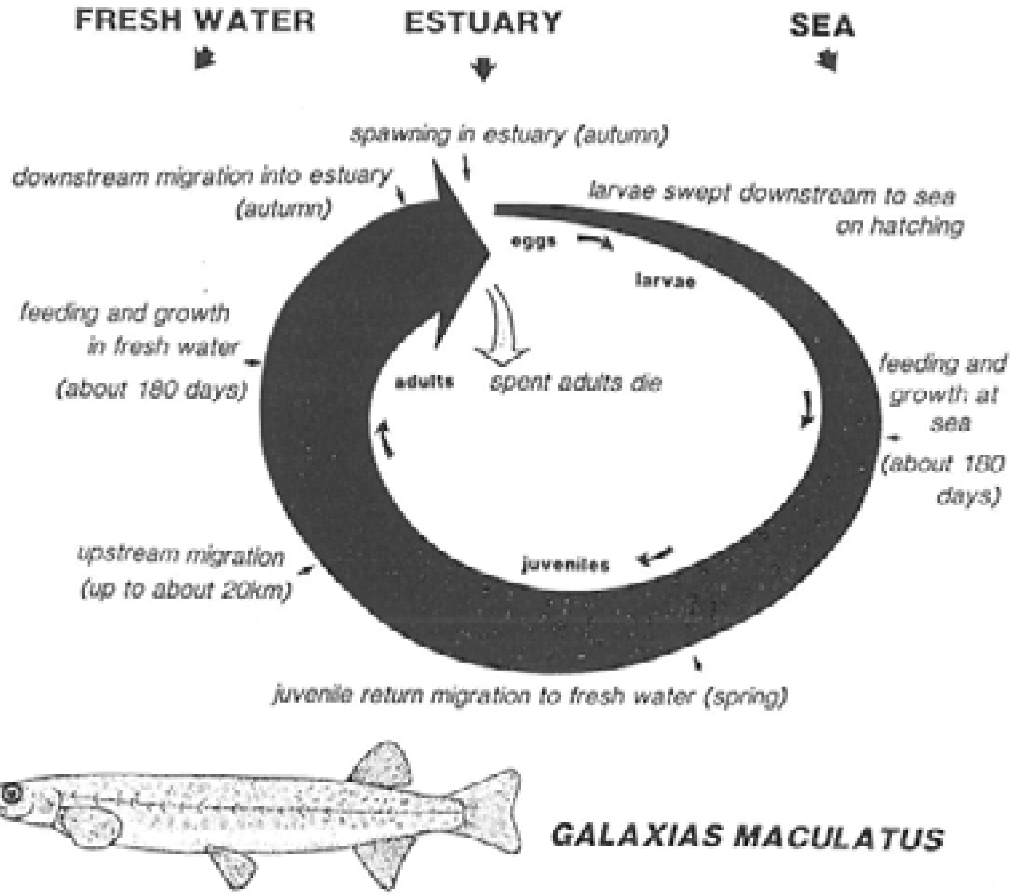
The mature to ripe adults of the inanga migrate downstream from lowland-river habitats and into estuaries to spawn. These migrations are timed to coincide roughly with the full and new moon spring tides, mostly during the late summer through autumn to early winter, though some spawning has been recorded in most months of the year. How the fish are able to discern the impending spring tides from their upstream and non-tidal habitats, is unknown, and these migrations are one of very few confirmed instances of a freshwater animal carrying out lunar/tidal migrations.

Spawning takes place on normally supra-tidal, marginal, estuarine vegetation when this is inundated during the spring tides. Dense shoals penetrate this vegetation and spawning is a communal activity amongst the vegetation. After spawning, it is believed that most spent adults die, though it appears that some may recover to spawn a second time. Once the tide recedes the eggs are left in moist air amongst the marginal vegetation, where they develop over the next two or more weeks (depending on temperature), and when fully developed, they hatch on the next set of spring tides that re-inundates them with water.

There is some understanding of the factors that affect the location of spawning grounds and what triggers the actual spawning itself (McDowall 1990, Mitchell and Eldon 1991). Very little is known about factors that contribute to egg mortality.

When they hatch, the larvae are washed out to sea, where they feed and grow in the surface marine plankton for approximately 6 months. Apart from a few samples of inanga larvae taken at sea (McDowall *et al.* 1975), nothing is known about the life of the fish there. This includes dispersal and geographical distribution, distribution in the water column in the seas around New Zealand, mortalities, feeding, growth rates, and migratory pathways followed and cues used during the return to fresh water.

The slender transparent juveniles return to fresh waters mostly during the spring, roughly from early July through late November, though freshly-run whitebait juveniles of the inanga have been found in rivers in every month of the year (McDowall 1968). Given that some spawning takes place in most months, the long migrating season is predictable. The juveniles enter virtually all freshwater streams and rivers around the New Zealand coastline, from the larger rivers to the smallest creeks that do no more than seep across beach sands or gravels.



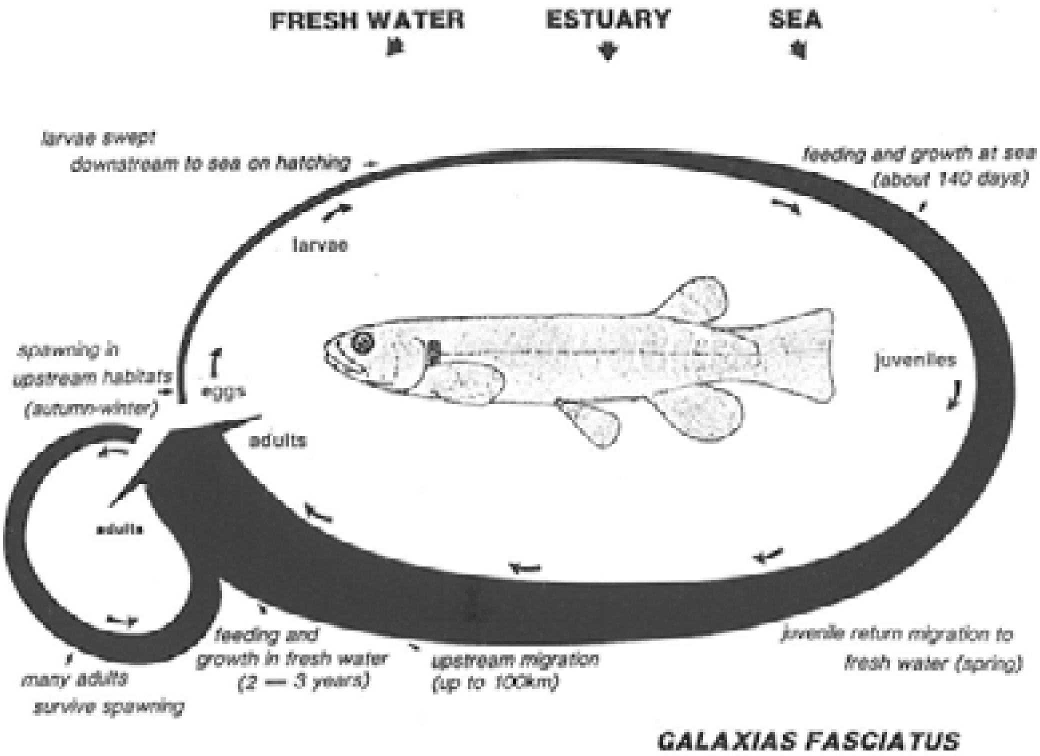


Fig. 2 The life histories of inanga (*Galaxias maculatus*) and banded kokopu (*G. fasciatus*) each depicted as a cycle between fresh water and marine habitats.

Migrations are affected by a series of variables. Apart from their seasonal distribution, on a shorter time scale, major migrations appear to follow flood events in rivers, and this is interpreted as a response to increased outflows of fresh water which attract the shoals of fish. Migration from the sea is nearly exclusively during daylight hours, though assertions of night migrations need evaluation. Most fish movements take place on the rising tide during the day, though there are exceptions to this generalisation, only some of which can easily be explained. In general, movements are related to the flow variations discharging from rivers.

It is during these migrations from the sea that the whitebait juveniles are the target of the fishery. Those fish that escape capture (escapement rates are unknown and bound to be highly variable), move on upstream and the inanga whitebait penetrate all available lowland habitats to which access is not hindered by excessively fast flows, falls, and other impediments. In general the distribution of the inanga is distinctly lowland and close to the coast, though distance penetrated inland depends, of course, on topography and river gradient.

Though there is probably a good generalised understanding of the habitats occupied by inanga during growth from the whitebait stage to adulthood, there is minimal quantified information on habitats. Inanga are generalised, opportunistic carnivores, and feed on a very diverse array of small invertebrate animals which may be taken at the surface, in the water column, or from the benthos.

Growth is rapid, and in most populations, most individuals attain sexual maturity over the spring and summer following their entry to fresh water, and they thus mature during the following autumn at an age of about one year. Growth rates and size at maturity vary greatly, and mature fish at age one may be only 60-70 mm long, but may exceed 100 mm. A small proportion of the populations, and possibly more at upstream sites than downstream ones, may delay maturity until age two, and an even smaller fraction until age three; late maturers are all female (Burnet 1965). Fecundity varies greatly, both with growth rates (i.e., it is proportional to size), but it also seems to vary between habitats, and what causes this variation is unknown. As noted above in discussion of spawning, it is likely that spawning mortality at first maturity is high, making the life cycle essentially an annual one.

Little is known about mortality rates during growth and maturation in fresh waters, or about the factors that contribute to these mortalities.

Landlocked stocks: Few landlocked stocks of inanga are known from New Zealand, though they are common in other lands.

2 Banded kokopu -*Galaxias fasciatus*

The banded kokopu is, in general though not always, the second commonest species in the whitebait fishery. By comparison with the inanga, knowledge of the natural history of the banded kokopu is very meagre. In essence, in their structural patterns, the life cycles of the two species are similar, but from what is known, details differ extensively.

A review of the natural history of this whitebait species is presented in Fig. 2.

Spawning of banded kokopu has been observed just once, and occurred during June, when the fish were found to be spawning in forest litter at the margins of a small stream during a flood (Mitchell and Penlington 1982). That this was not an aberrant situation is indicated from the fact that banded kokopu hatched from forest litter taken in May from the margins of another stream in which banded kokopu were known to be breeding (from studies of sexual maturity of the populations - Hopkins 1979b). Thus, as in inanga, it appears that the eggs are deposited in situations that are normally above water levels and the eggs develop in humid atmosphere and not in water. From analysis of maturation of fish, a spawning period during late autumn and winter has been inferred (Hopkins 1979b). It is not known whether there are any significant migrations by banded kokopu from rearing habitats to spawning sites. Virtually nothing is known of spawning behaviour, choice of spawning sites, egg mortalities, or development rates of the eggs.

When the eggs are fully developed, it appears that they hatch during spates in the spawning streams that re-inundate the marginal litter, and the larvae are washed downstream (Ots and Eldon 1975); a movement to sea is assumed from the fact that the larvae/juveniles are not known from fresh waters and the juveniles are found to migrate back from the sea during the spring. Absolutely nothing is known about the life of banded kokopu at sea.

A return migration of banded kokopu whitebait juveniles takes place during the spring, at which time they are about 95-120 days old, and the juveniles join the shoals of other species in the whitebait migrations and thus in the whitebait fishery. A spawning season in the late autumn-winter can be inferred by back-calculating from known-age at migration. Banded kokopu migrations tend to occur rather later in the spring than some other species (October onwards). They also tend to be rather more selective in the types of rivers they enter, and numbers entering turbid, spring-fed rivers, or migrating during floods in the rivers are relatively low. Banded kokopu whitebait have been observed to favour cool, tannin-stained and low pH streams typical of low elevation forest swamps and Eldon 1980). Inland penetration is vigorous, and banded kokopu whitebait and juveniles are known to climb substantial falls.

General observations of habitats occupied show that banded kokopu typically inhabit small, forest-enclosed streams, where there is plentiful instream cover and where they occupy the small pools. They seem to be largely, though by no means exclusively, nocturnal, and they feed extensively on both terrestrial and aquatic foods, depending on their availability. The contribution of terrestrial foods is notably high (Main and Lyon 1988). Though habitats occupied are generally understood, there is minimal quantified information on habitats. The presence of forest cover is considered to be a prerequisite for large populations of banded kokopu (Hanchet 1990).

Age at maturity is either two (most males) or older, and longevity may reach nine or more years; males predominate in the populations at young ages, but females at older ages, so that there is clearly differential mortality of the sexes (Hopkins 1979a). These data show that females, particularly, as well as many males, survive first spawning to re-mature and spawn again in subsequent years.

Landlocked stocks: Stocks of banded kokopu are known from a small number of lakes.

3 Giant kokopu -*Galaxias argenteus*

The giant kokopu is a minor contributor to the whitebait catches. Even less is known of the natural history of the giant kokopu, though its close resemblance to the banded kokopu suggests similarities in life cycle.

Spawning in the giant kokopu has not been observed; there is a little anecdotal evidence to suggest that there may be spawning migrations, but this is unproven. That the larvae go to sea is inferred from the return migrations of whitebait juveniles from the sea in the late spring, typically during November. At this time they are about 120 days old, and a spawning season during the winter can be inferred by back-calculating data on age at migration (McDowall, R.M., Mitchell, C.P. and Brothers, E.B. pers. com.)[2]. Those that escape capture in the fishery invade low elevation, heavily-vegetated swamplands and larger streams in forest, typically in situations where there is extensive instream cover (overhanging banks, flax clumps, logs, etc.). Favoured habitats are not quantified. Giant kokopu are also thought to be largely nocturnal, and feed on a wide variety of terrestrial and aquatic foods; terrestrial foods appear to be of high importance, though data are few (Jellyman 1979, Main *et al*. 1985, Main and Lyon 1988). Age at maturity is unknown, but likely to be 2-4 years or more; longevity is high, with suggestions of fish exceeding 15 years; repeat spawning almost certainly occurs. Nothing more is known.

Landlocked stocks: Giant kokopu are known from lakes in Westland and Southland.

4 Shortjawed kokopu -*Galaxias postvectis*

The shortjawed kokopu is regarded as rare in the whitebait fishery, though the inability to separate its juvenile from that of the koaro makes a rigorous evaluation difficult. Judging by the rarity of the adults, its contribution to the fishery must be minor. The natural history of the shortjawed kokopu is virtually undescribed.

Nothing is known about spawning movements, or spawning itself though mature to ripe fish are encountered during late autumn and winter. As with other species, a movement to sea by larvae is inferred from their absence in fresh water and the return of the whitebait juveniles from sea during the spring along with the whitebait of other sea-migratory species. Nothing is known of the periodicity of migrations or the types of rivers chosen by the whitebait; those young that escape capture in the fishery

---

[2]A paper is in preparation entitled: Age at migration from the sea of juvenile *Galaxias* in New Zealand (Pisces: Galaxiidae). The authors intend to submit it to the *Australian Journal of Marine and Freshwater Research*.

presumably move upstream into adult habitats, and from their distribution above falls and other barriers it is evident that shortjawed kokopu are adept at climbing.

The typical habitat for the species is heavy cover in small, forest-covered streams at lower to moderate elevations, often a substantial distance from the sea. Habitat characteristics are unquantified. From the size attained, and from data for banded kokopu, it appears that shortjawed kokopu delay maturation to perhaps age two to four, and that fish survive first spawning to mature and spawn again in subsequent years. Terrestrial animals may comprise a large proportion of shortjawed kokopu foods (Main *et al*. 1985, Main and Lyon 1988), but data are few.

Landlocked stocks: No such populations are known.

5 Koaro -*Galaxias brevipinnis*

The koaro is the third most abundant contributor to the whitebait fishery in most areas, though occasionally is second in abundance, and may even be the most abundant species in some situations (Saxton *et al*. 1987). Little is known about its natural history. Spawning of the koaro is undescribed, though similarities between koaro and common river galaxias (*Galaxias vulgaris* - Cadwallader 1976) might suggest that koaro spawn under boulders in rapidly flowing streams close to typical adult habitats. The return of huge shoals of koaro whitebait from the sea indicates that the larvae of the species go to sea on hatching.

Migration is early in the spring, largely preceding that of banded kokopu, and koaro whitebait are found to favour turbid, snow-fed rivers, to migrate earlier in floods than other species, and to avoid the low pH, tannin-stained waters favoured by banded kokopu. Age at migration is about 120-140 days, and spawning during autumn-winter can be inferred from this age. Inland penetration by koaro whitebait is intensive, the fish being adept at climbing high falls. Typical habitats are small to moderate, fast-flowing and bouldery/gravel streams typically within a dense forest canopy. The fish are cryptic and are typically found within boulder cover in the stream rapids. Habitat data are not quantified. The size attained by koaro suggest that maturity is delayed to two to four years of age, and that the fish survive first spawning to mature and spawn again. Koaro feed largely on stream invertebrates though terrestrial animals are also included in the diet (McDowall and Eldon 1980, Sagar and Eldon 1983, Main and Winterbourn 1987).

Landlocked stocks: Koaro are common in the cool higher elevation lakes of the central North Island and the mountains of the South Island.