Environment Waikato Technical Report 2001/11

The Diversity and Distribution of Freshwater Fish and their Habitat in the Major Rivers of the Waikato Region

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Acknowledgements

This report is the sum of the considerable number of publications and reports produced by other authors on all aspects of the freshwater fish and fish habitats of the Waikato Region.

It is hoped that the distribution maps and appended annotated bibliography of those "contributing" publications will serve as a good starting point for any future work and decisions on the management of the Region's freshwater fishery.

Thanks to Andrew Taylor of Environment Waikato for his assistance with the distribution maps and in editing, Megan Graeme for her work on the annotated bibliography included with this report and to Grant Barnes, also of Environment Waikato for his comments and assistance in editing the draft.

Frontispiece: Male redfinned bully *(Gobiomorphus huttoni).* Photo by Leif Pigott.

Line Drawings by Sonia Frimmel – "What' the story?" (Not to be copied or reproduced without written authorisation from Environment Waikato)

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1 Introduction

1.1 Intended Use of this Report

This report is intended to give a brief overview of the fisheries of the major rivers in the Waikato Region (Figure1). It includes a brief commentary on the state of the fishery in each river, the species present, the threats to them, and offers some guidance on possible methods to reduce or remove those threats and thereby enhance the fishery.

For the sake of those readers interested in a more in depth consideration of the fishery or a specific aspect of it, the report includes an annotated bibliography of reports and publications relevant to the Waikato Region's freshwater fishery (Appendix 2). Also included as Appendix 1 are regional distribution maps for each freshwater fish species. These maps were generated from the New Zealand Freshwater Fish Data Base in April 2001 and, with some additions from unpublished surveys, represent the state of knowledge as to their distribution at the time this report was completed.

1.2 Fish Fauna Of the Waikato Region

The freshwater fish fauna of New Zealand consists of fifty-six species. Thirty-five of these species are indigenous of which most are endemic[1], and the remaining 21 species are introduced. Within the Waikato Region there are 22 species of indigenous and 14 species of introduced freshwater fish (Table 1).

At least eighteen of our indigenous freshwater fish are diadromous[2] species who move between freshwater and marine environments at various stages of their lifecycle. This movement between habitats is often, but not always, obligatory (e.g. koaro) and is required for completion of the lifecycle (McDowall, 1990). Their diadromous lifecycle provides these species with some protection from small scale disturbances in local areas as it allows for rapid re-colonisation of areas which may have been de-populated by an event such as a landslide or a large flood. However, it also makes these species particularly vulnerable to loss of access to either spawning or adult habitat as a result of in-stream barriers or reductions in water quality in the lower reaches of streams and rivers.

[1] Endemic – native and restricted to a given area (in this case New Zealand)
[2] Diadromous – fish that migrate between freshwater and saltwater

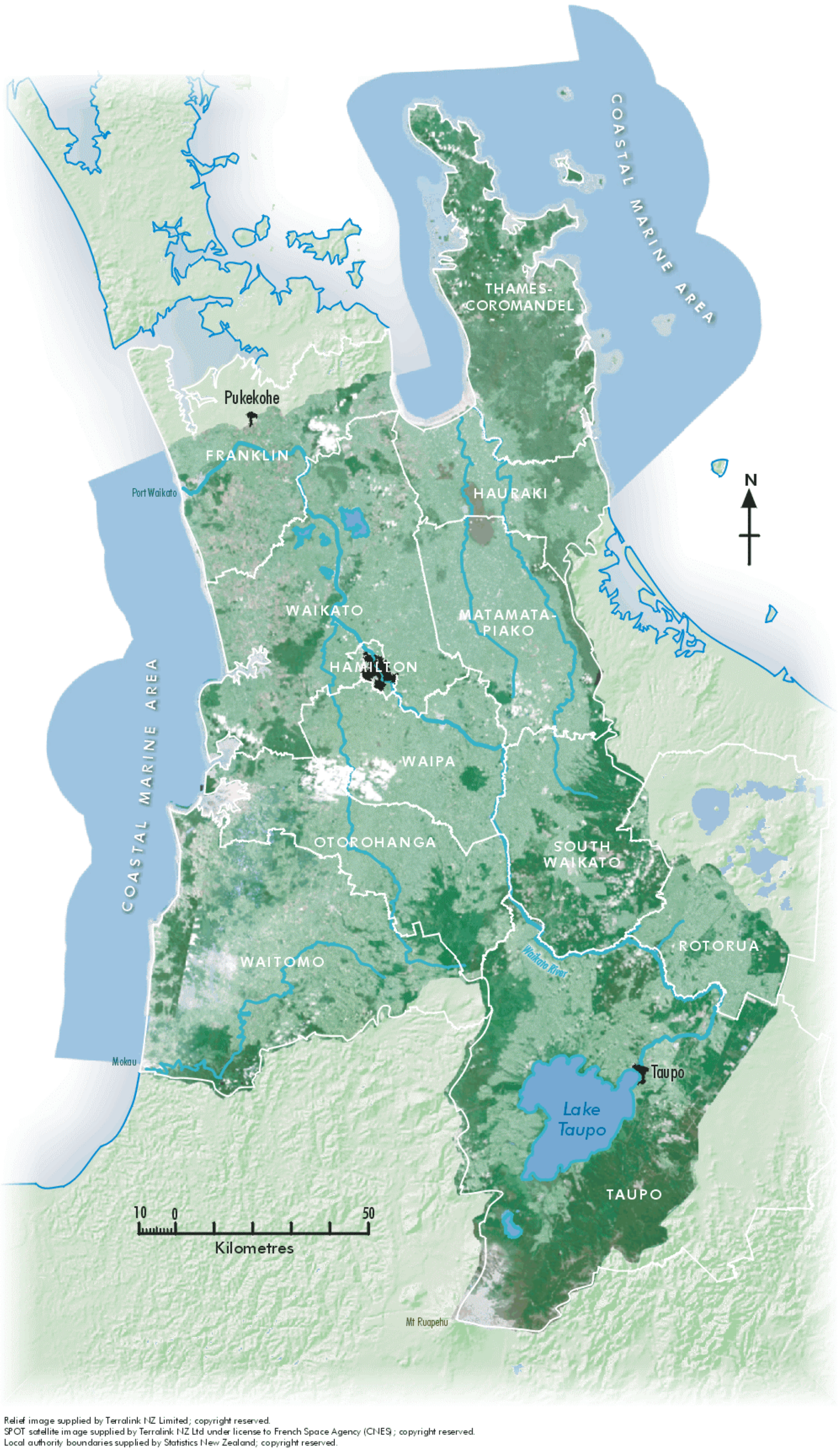


Figure 1: The Waikato Region

Table 1: Freshwater Fish of the Waikato Region.

Common Name (Maori Name)	Scientific Name
NATIVE FISH	
Yelloweyed mullet (Aua)	*Aldrichetta forsteri*
Shortfinned eel (Hao)	*Anguilla australis*
Longfinned eel (Kuwharuwharu)	*Anguilla dieffenbachii*
Australian longfinned eel	*Anguilla reinhardtii*
Torrentfish (Papamoko)	*Cheimarrichthys fosteri*
Giant kokopu (Kokopu)	*Galaxias argenteus*
Koaro	*Galaxias brevipinnis*
Dwarf galaxias	*Galaxias divergens*
Banded kokopu (Para)	*Galaxias fasciatus*
Inanga	*Galaxias maculatus*
Shortjawed kokopu	*Galaxias postvectis*
Lamprey (Piharau)	*Geotria australis*
Black mudfish	*Neochanna diversus*
Giant bully	*Gobiomorphus gobioides*
Upland bully	*Gobiomorphus breviceps*
Common bully (Pako)	*Gobiomorphus cotidianus*
Bluegill bully	*Gobiomorphus hubbsi*
Redfinned bully	*Gobiomorphus huttoni*
Cran's bully	*Gobiomorphus basalis*
Grey mullet (Kanae)	*Mugil cephalus*
Common smelt (Ngaoire)	*Retropinna retropinna*
Black flounder	*Rhombosolea retiaria*
INTRODUCED FISH	
Catfish	*Ameiurus nebulosus*
Goldfish	*Carassius auratus*
Grass carp	*Ctenopharyngodon idella*
Koi carp	*Cyprinus carpio*
Mosquitofish	*Gambusia affinis*
Rainbow trout	*Onchorhynchus mykiss*
Perch	*Perca fluviatilis*
Sailfin molly	*Poecilia latipinna*
Guppy	*Poecilia reticulata*
Brown trout	*Salmo trutta*
Brook char	*Salvelinus fontinalis*
Rudd	*Scardinius erythropthalmus*
Tench	*Tinca tinca*
Swordtail	*Xiphophorus helleri*
CRUSTACEA	
Freshwater crayfish (Koura)	*Paranephrops planifrons*
Shrimp (Patiki)	*Paratya curvirostris*

Table 2: Distribution of Freshwater fish in the Waikato Region.

Species	River System or Catchment									
	Waikato	Mokau	Waitoa/ Piako	Waipa	Waihou	Tongariro / Taupo	Coromandel streams	Tairua	Marakopa	Awakino
Yellow-eyed mullet	#	#	#		#		#	#	#	#
Short-finned eel	#	#	#	#	#		#	#	#	#
Long-finned eel	#	#	#	#	#		#	#	#	#
Australian eel	#			?						
Torrentfish	#	#	#	#	#		#	#	#	#
Giant kokopu	#	#		#			#	#		#
Koaro	#	#		#	#	#	#	#		#
Dwarf galaxias					#					
Banded kokopu	#	#	#	#	#		#	#	#	#
Inanga	#	#	#	#	#		#	#	#	#
Shortjawed kokopu	#	#		#	#		#	#		
Lamprey	#	#		#			#	#	#	
Black mudfish	#	#	#	#						
Giant bully	#						#	#		
Upland bully		#								
Common bully	#	#	#	#	#	#	#	#	#	#
Bluegill bully		#					#			#
Redfinned bully	#	#		#	#		#	#	#	#
Crans bully	#		#	#	#		#			
Grey mullet	#		#							
Common smelt	#	#	#	#	#	#	#	#	#	#
Catfish	#		#		#	#				
Goldfish	#		#	#						
Grass carp	#									
Koi carp	#		#	#	#					
Gambusia	#		#	#	#		#			
Rainbow trout	#	#		#	#	#	#	#		#
Perch	#				#					
Sailfin molly	#					#				
Guppy	#									
Brown trout	#	#		#	#	#	#		#	#
Brook char						#				
Rudd	#		#	#	#					
Tench	#				#					

1.2.1 Native Species

Yelloweyed mullet (*Aldrichetta forsteri*)

Primarily a marine species, it can often be seen in shallow bays and estuaries and will penetrate up rivers with flat gradients to the extent of the tidal influence. This fish species is commonly caught by children of all ages from wharves throughout New Zealand.

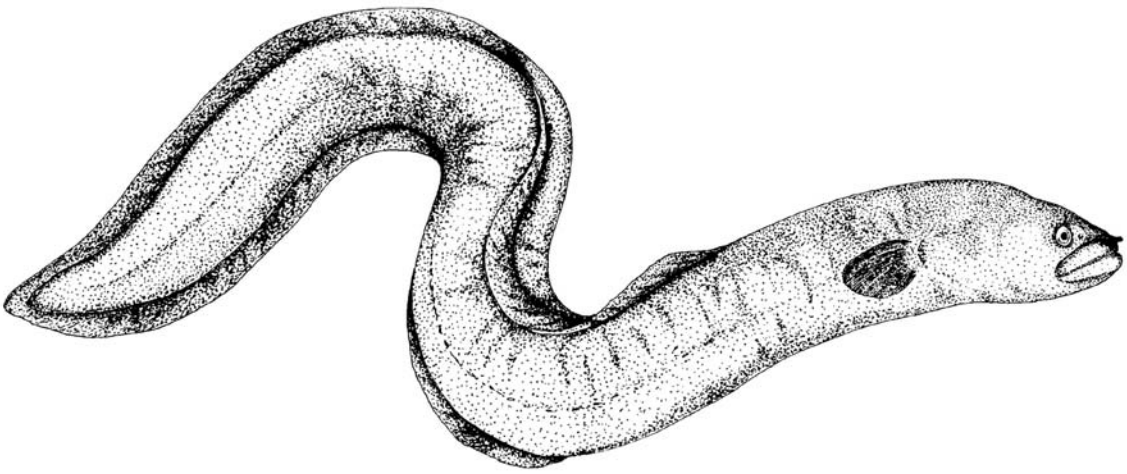
Shortfinned eel (*Anguilla australis*) and Longfinned eel (*A. dieffenbachii*)

Both of these species of eel can be found widely throughout the Waikato Region in most rivers and streams. However, the shortfinned eel is generally not as aggressive a swimmer as the longfinned eel and is more commonly found in lowland streams, wetlands and lagoons. The longfinned eel tends to be more common in headwater streams and bush catchments and it grows to a larger size than its shortfinned counterpart. Historically, the longfinned eel was more widespread and was the dominant predator in the swamps and lowland streams of the region where shotfinned eels are now more common.

Unfortunately, their large size and aggressive nature have made longfinned eels an easy and desirable target for commercial harvest and their numbers have been severely reduced in lowland waterways (Jellyman, 2000).

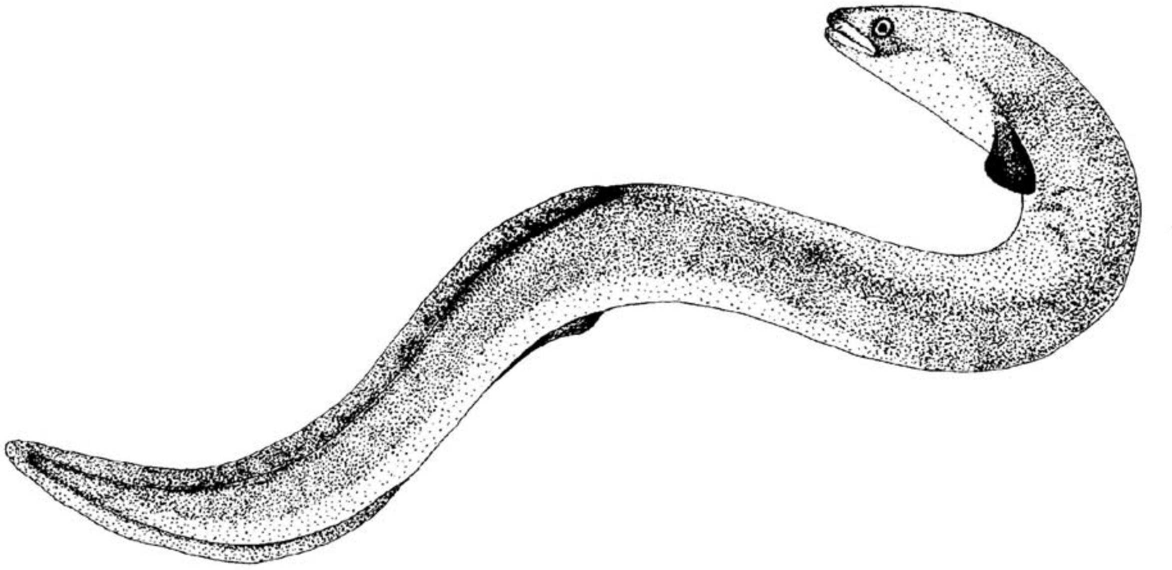
Both species are catadromous[3] with the adults, when mature (which may be up to an age of 80+), migrating to sea to spawn (somewhere in the Western Pacific Ocean). Upon hatching the larval eels (leptocephali) drift back to New Zealand on ocean currents re-entering our rivers and streams in early spring as glass eels approximately eighteen months later.

Juvenile eels (elvers) are well known for their ability to climb up almost vertical surfaces and have been seen climbing large structures such as the Karapiro and Arapuni dams on the Waikato River.



Longfinned eel (migrant)

[3] Catadromous - a diadromous species in which the adult moves from freshwater to the sea in order to spawn .



Shortfinned eel

Australian longfinned eel (*Anguilla reinhardtii*)

This species of eel, which is common on the south east coast of Australia and Tasmania, is presumed to have arrived in New Zealand (possibly in the last 20 - 30 years) by natural means. It has a similar life history to that of the short and longfinned eels. However, current records indicate that its distribution is limited to the North Island and is found throughout the Waikato Region.

The Australian longfin has conspicuous black blotches all over its body except on its belly. This is the easiest way of distinguishing it from the New Zealand longfin. The Australian Longfinned eel occupies the same habitat type as both the New Zealand eel species, however, they have been present in New Zealand waters for some time and do not appear to have significantly impacted upon either species although no studies have been undertaken to confirm this.

Torrentfish (*Cheimarrichthys fosteri*)

The torrentfish is widely distributed throughout the Waikato Region and can generally be found in riffle sections of large open gravel and boulder streams amongst the spaces between the gravel and boulders. Torrentfish are diadromous (amphidromous[4]), with the mature adults presumably spawning in spring and the larvae drifting out to sea after hatching. During the summer juvenile torrentfish about 40mm long can be seen migrating upstream from the sea. Torrentfish are known to migrate large distances both upstream and downstream throughout their life cycle. They are however, not good climbers and consequently, their distribution is likely to be seriously limited by the presence of physical barriers to upstream migration. As a general rule the largest and most inland fish are females while males tend to be located lower down in the catchment.

Giant kokopu (*Galaxias argenteus*)

The Giant kokopu is one of the largest native freshwater fishes growing to a length of up to 600mm and 2.5 kilograms although fish of this size are rarely captured (McDowell, 1980). Giant kokopu are relatively rare and are most commonly found in small streams and lowland wetlands where abundant cover is available. These diadromous fish are one of the five galaxiid species which, in their juvenile form, are collectively known as whitebait. They are thought to spawn in freshwater at the start of Autumn (although their specific spawning requirements are not known). Larvae hatch several weeks after on high stream flows and

[4] Amphidromous – a diadromous species in which movement between the sea and freshwater is not necessarily for spawning purposes.

drift out to sea where they grow into the juveniles which migrate back into freshwater during spring and early summer.

Giant kokopu are distributed throughout the Waikato region but are rarely found at high elevations or further than 150km inland. Giant kokopu can establish land-locked populations.

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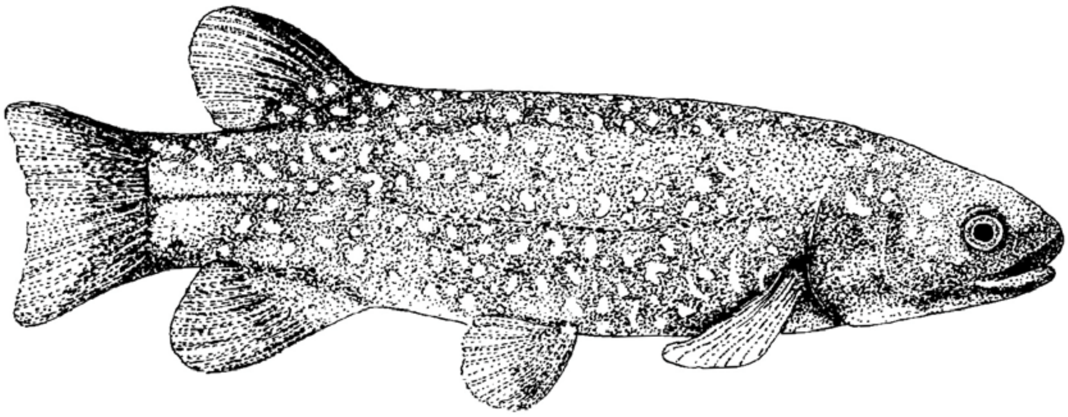
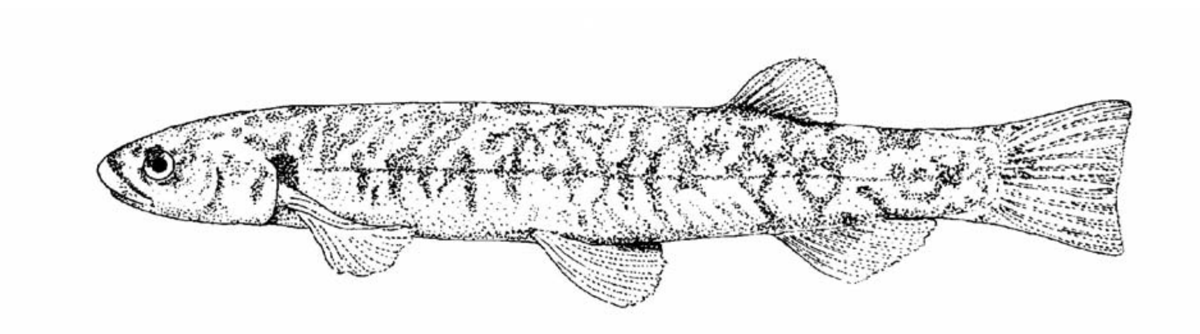


Giant kokopu

Koaro (*Galaxias brevipinnis*)

Koaro are distributed throughout the Waikato Region with populations common from coastal streams right into the headwaters of many of the Region's steeper bush catchments. Koaro generally prefer rapidly flowing, rocky streams in forested catchments and like many other galaxid species are diadromous. Adult koaro spawn in bankside debris (cobbles and woody material) along the edge of normal winter stream flows from late autumn to winter where the eggs mature for 3 to 4 weeks before hatching. The larvae are washed out to sea on the next flood event where they mature into whitebait before returning to freshwater. Koaro are excellent climbers and are often seen climbing along the wet margins of vertical structures in order to migrate upstream. While koaro are diadromous they also readily form land locked populations in lakes and upstream of large structures such as the Waikato Hydro dams and in Lake Taupo.

Because of their climbing ability, koaro are able to penetrate far inland and consequently are the most widespread of the whitebait species.



Koaro

Dwarf Galaxias (*Galaxias divergens*)

Only one population of this small, non-migratory, galaxiid is known in the Waikato Region and it occurs in the upper reaches of the Waihou River. Within the lower North Island and upper South Island it is relatively widespread occurring in small gravely streams and rivers.

Little is known about its preferred spawning locations but it is assumed that spawning occurs near the adult habitat in spring and possibly in autumn (McDowal, 2000).

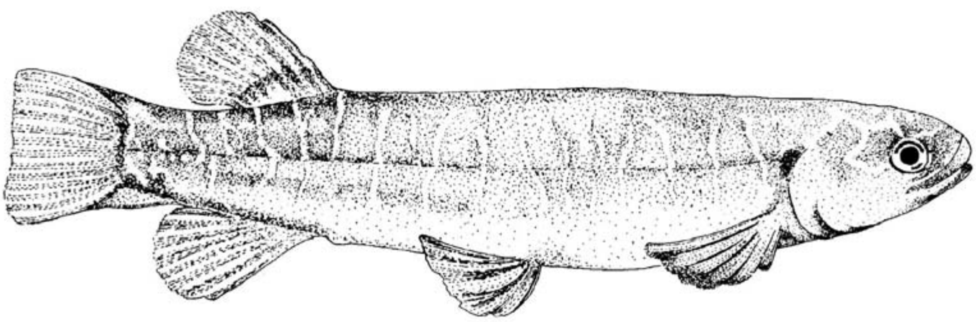
The dwarf galaxias is amber to olive green in colour with dark brown blotches on the sides and back and a silvery belly. These fish grow to 70 - 90 mm and feed on insect larvae such as mayflies and midges.

Banded kokopu (*Galaxias fasciatus*)

Located mainly in the Northern Waikato banded kokopu occupy primarily small cobbly streams with good overhead cover within native bush and exotic forestry catchments.

Banded kokopu have a similar life history to koaro, spawning in or near the adult habitat on the upper edge of high stream flows (their “nests” are normally a few centimetres higher up the bank than those of koaro (R. Allibone - pers com). Like koaro, banded kokopu are diadromous and are excellent climbers, but will readily form landlocked populations in lakes and impoundment’s, provided suitable adult and spawning habitat exists in tributary streams.

As the name suggests banded kokopu can be distinguished by vertical bands of pale colour on their sides and back. Adults feed on stream and terrestrial insects (which fall to the water surface) and grow to in excess of 200 mm. Large fish are often found in very small tributary streams.

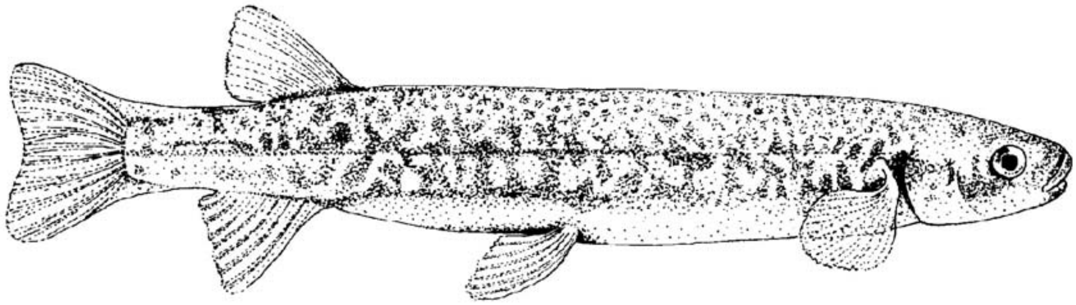


Banded kokopu

Inanga (*Galaxias maculatus*)

Inanga are abundant throughout the region and indeed throughout New Zealand. They are a shoaling fish commonly found in pools, backwaters, lagoons and swamps (McDowall, 2000). Inanga are not strong swimmers and can’t climb barriers or traverse rapids and consequently, their distribution tends to be limited to lowland streams and rivers.

Inanga are diadromous fish spawning during the autumn at the base of bankside vegetation which is inundated by high spring tides. Eggs mature in 2 to 6 weeks and hatch on the next spring tide releasing the larvae to be washed out to sea and return in late spring and summer as whitebait. In the Waikato Region, inanga are the main species of the annual whitebait harvest. Their juveniles are normally about 50mm in length and grow to a maximum adult length of about 100 – 120 mm.

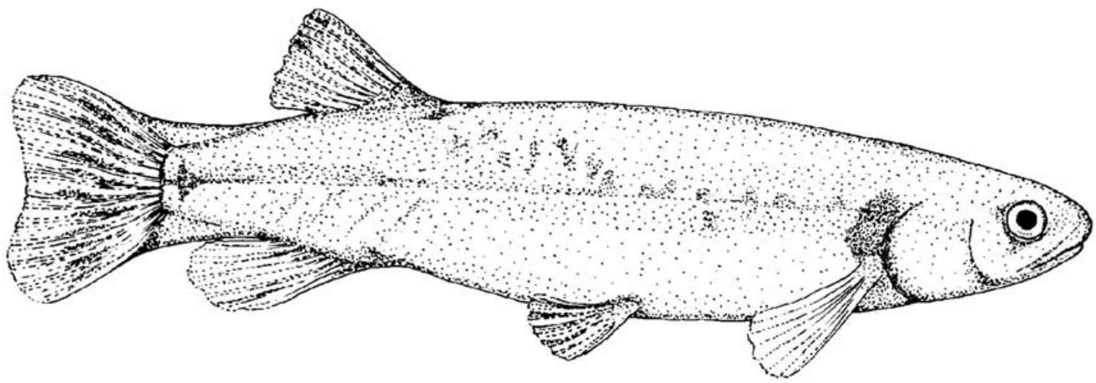


Inanga

Shortjawed kokopu (*Galaxias postvectis*)

Shortjawed kokopu are the rarest of the five galaxiid species who's juveniles make up the whitebait catch. The shortjawed kokopu is considered to be threatened, however this may be as much a result of its cryptic nature and a lack of knowledge about its habitat and distribution as its actual rarity. McDowall (1996) provides an account of the life history, distribution and habitat preferences of the shortjawed kokopu although the distribution maps do not account for recent discoveries of large, healthy, populations of this fish in the Taranaki Ring-plain and in the Waitakari Ranges.

As its name implies, the shortjawed kokopu has an undercut lower jaw, they are a light tan - olive colour with a dark spot behind the gill opening. Adult shortjawed's will reach lengths of up to 260mm with an average size of approximately 200mm.



Shortjawed kokopu

Lamprey (*Geotria australis*)

Lamprey are diadromous fish found throughout New Zealand in predominantly West coast streams of the Waikato Region. The adults spawn only once in their life, laying their eggs in streams and rivers during spring or summer. Upon hatching, the larvae (ammocoete) burrow into the stream substrate and feed by filtering the stream water. At a length of approximately 80-100mm (a process which takes several years) the larval lamprey metamorphose into a miniature version of the adult (macrophthalmia). Once fully developed the macrophthalmia undertakes a migration to sea where it develops over a period of several years before returning to freshwater to spawn. Lamprey are parasitic while at sea, attaching themselves to marine fish and mammals, rasping a hole through their skin and living off the body fluids of the host. Like eels, the lamprey are very good climbers, often leaving the water and working their way up the wet river margins to get past obstructions.

Cran's bully (*Gobiomorphus basalis*)

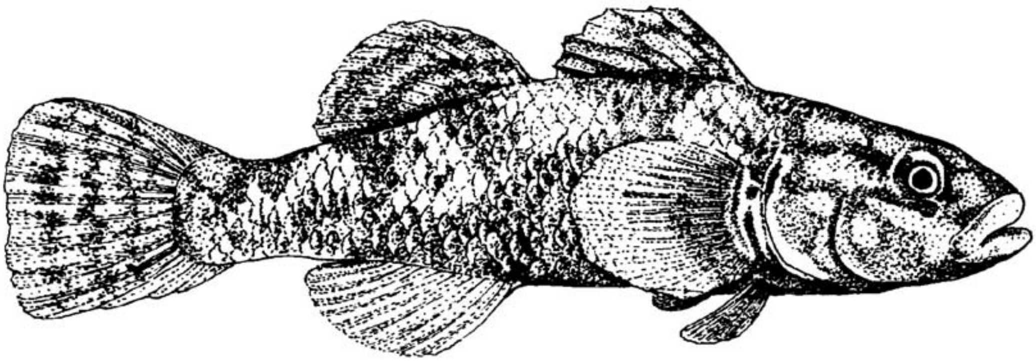
Cran's bully are widespread throughout the Waikato River catchment and the lower Coromandel Peninsula. Unlike most other bully species the cran's bully is non-migratory, living in gently flowing inland bouldery streams amongst the rocky substrate. Spawning occurs during summer and the female attaches her eggs to the base of a rock while the male takes up a guard position, defending the eggs from predation for several weeks until hatching.

Upland Bully (*Gobiomorphus breviceps*)

Upland bully are not common in the Waikato Region. Known only from the Mokau River catchment this species occurs in five isolated tributary streams which appear to be the northern most limit of this species in New Zealand. The life history of this non migratory bully is very similar to that of the Crans bully although they occupy a larger variety of habitat types, being common in lakes, slow flowing streams and rivers and wetland margins.

Common bully (*Gobiomorphus cotianus*)

Common bully are the most widely distributed freshwater fish in New Zealand (McDowall, 1990a; McDowall, 2000). Located throughout the Waikato Region it can be found in small streams, large river pools and along the shores of most lakes and wetlands. In rivers it can be located under overhanging banks and amongst debris such as logs and large rocks. The common bully is diadromous, spawning in freshwater during spring, it lays its eggs on any available hard surface, with the newly hatched larvae migrating to sea several weeks later. As with most bullies the common bully male guards the eggs for the period of development and may spawn with several other females during this period. At sea larval bullies develop to approximately 15mm before returning to the freshwater. Land locked populations of the common bully are also common. Adult common bullies can grow to over 120 mm.



Common bully

Giant bully (*Gobiomorphus gobioides*)

The giant bully is generally confined to lowland estuaries and coastal waters just above the tidal influence. Its distribution in the Waikato Region is limited to the lower Waikato River and its tributary streams, and the Coromandel peninsula with one record from Aotea Harbour. Giant Bullies are primarily nocturnal, feeding during the night and seeking the cover of overhanging banks or in-stream debris during the day. Spawning behaviour of the giant bully has not been studied however, McDowell (1990a) suggests that it is likely to be similar to that of the common bully. Adults may grow to over 250 mm in length although fish in the 120–150 mm range are more common.

Bluegilled bully (*Gobiomorphus hubbsi*)

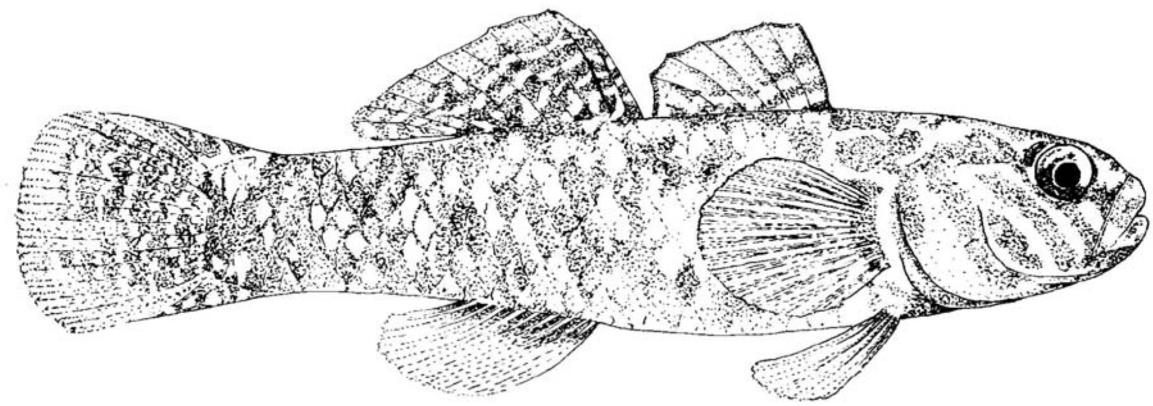
Living amongst boulders in fast moving gravely streams, the bluegilled bully can often be seen coexisting with torrentfish. Due to the nature of their habitat, bluegilled bullies, like torrentfish, are rarely seen or caught. Like the common and redfinned bully, the bluegilled bully is most diadromous, spawning in freshwater and the larvae going to sea until they reach a size of approximately 20mm.

These fish are easily identified by the bright blue gill membrane around the gill opening which occurs in both male and female fish. Bluegill bullies are generally small with most adults about 60 – 70mm in length.

Redfinned bully (*Gobiomorphus huttoni*)

The redfinned bully is widely distributed throughout the Waikato Region but is most common in the Coromandel Peninsula and in west coast streams and rivers. The redfinned bully prefers fast flowing boulder streams where it resides underneath rocks and boulders. Spawning occurs between July and November when fish lay their eggs upstream in slower moving waters. Upon hatching several weeks later larvae move to the sea where they develop for several months before moving back upstream to suitable adult habitats. The redfinned bully is a climbing species, able to climb along the wetted margins of small waterfalls and fast flowing rapids.

Male fish have bright red fins which become brighter as the fish prepares for spawning or when they become agitated.



Redfinned bully

Grey mullet (*Mugil cephalus*)

Often called sea mullet or striped mullet, the grey mullet is essentially a marine species, inhabiting harbours and bays. However, grey mullet can often be seen venturing into river mouths and lagoons and are frequently seen moving up the Waikato River as far as Cambridge.

Grey mullet feed on detritus and plant material that they suck from the substrate. They are also known to feed by grazing the surfaces of aquatic plants. Adults commonly reach 500 mm in length and are regarded as a valuable food source, particularly in the Waikato River where they are fished for year round (particularly in the vicinity of the warm water outfall from the Huntly Power station

Black mudfish (*Neochanna diversus*)

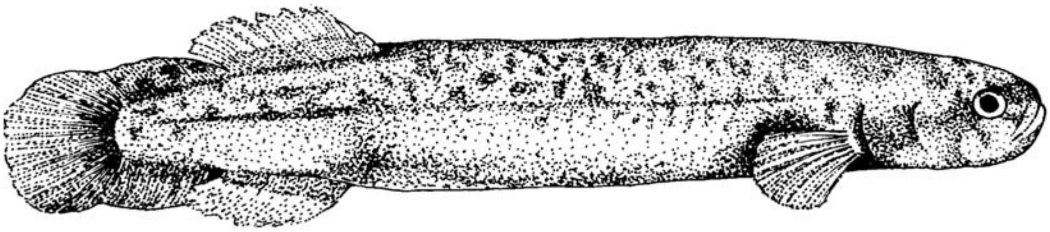
Hicks & Barrier (1996) provide a thorough account of the habitat preferences of the black mudfish.

The four species of mudfish (Black, Canterbury, Brown & Northland mudfish) found throughout New Zealand have adapted to survival in wetland and boggy habitats, often with very low pH, dissolved oxygen and almost always in areas which are seasonally dry. This adaptation is a response to the mudfish's high vulnerability to predation by other fish species. In occupying such areas the mudfish has effectively minimised competition and predation and is able to establish relatively large populations in small areas. Hicks and Barrier (1996) established the following hierarchy of factors which describe the ideal habitat of the black mudfish:

a) absence of water in summer (of sites with mudfish, 87% were dry at some point over summer);
b) low to moderate disturbance;
c) presence of emergent and overhanging vegetation;
d) semi-mineralised or peat bog substrate types;
e) absence of fish species such as common bullies and inanga; and
f) presence of tree roots.

Black mudfish are quite abundant in the Waikato region, particularly in Whangamarino Wetland, and also occur in the Hauraki Plains. Spawning occurs with the onset of the 'rainy season' in winter and may continue into spring if conditions remain suitable.

Black mudfish are under threat from habitat loss resulting from land drainage and development, and by introduced fish such as gambusia which eat mudfish fry and eggs and harass adults.

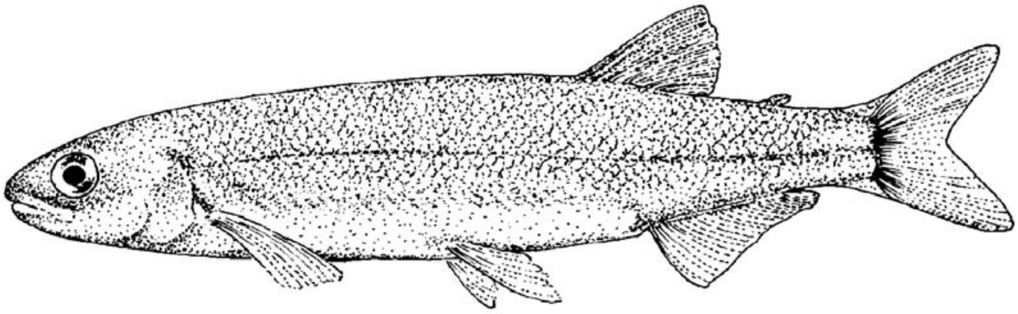


Black mudfish

Common smelt (*Retropinna retropinna*)

Common smelt are small fish inhabiting a range of habitats throughout the Waikato Region. They generally prefer water that is still or slowly moving and unlike many native species have no ability to climb or bypass barriers. They are diadromous (although lake locked populations are common) with mature individuals migrating upstream in autumn where they spawn among the sand or cobble substrate and then die. Once hatched, larvae are washed out to sea where they mature and live out most of their lives. Common smelt are often caught by whitebaiters and in some rivers such as the Waihou they are a significant recreational resource. When handled, common smelt give of a distinctive 'cucumber' odour.

Smelt are one of the most sensitive native fish to pollutants including high water temperature or ammonia. In some cases, they are as intolerant as the salmonids, which are often used as a benchmark species overseas for establishing water quality guidelines to ensure fish are protected from human activities. Smelt are therefore an appropriate native species for establishing guidelines for New Zealand waterways and usually their presence indicates that the water quality is suitable for most other fish *(New Zealand Freshwater Fish Atlas, NIWA)*.



Common smelt

Black flounder (Rhombosolea retiaria)

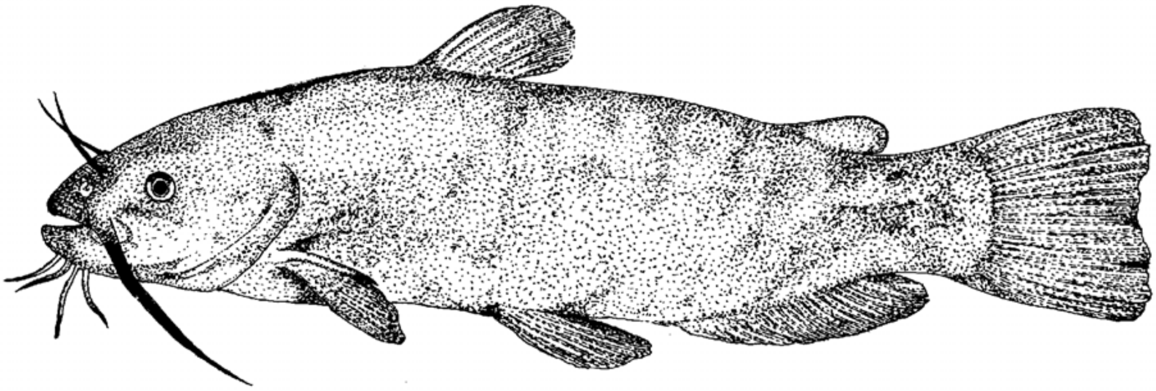
Black flounder can only be found in New Zealand waters. Inhabiting sandy or muddy estuaries and the tidal reaches of rivers, the black flounder can be found on many of the coastal rivers in the Waikato Region. Little is known about the reproductive behaviour of black flounder although McDowell (1990a) speculates that the adults migrate downstream to spawn at sea. Juvenile flounder have been found migrating upstream at a size of 10-15mm long.

1.2.2 Introduced Species

Catfish *(Ameiurus nebulosus)*

Catfish are widespread throughout the Waikato River catchment, including Lake Taupo, and in the Piako and Waitoa Rivers and most of the Waikato peat lakes. This fish was introduced to St Johns Lake, Auckland, in 1878 and subsequent liberation's to the Waikato's rivers and lakes followed soon after. Catfish thrive in a range of habitats from weedy streams to lakes and wetlands. Their impact on native flora and fauna are not well known, however, they can form large populations quickly and compete with indigenous fish and trout (Lake Taupo) for space and food.

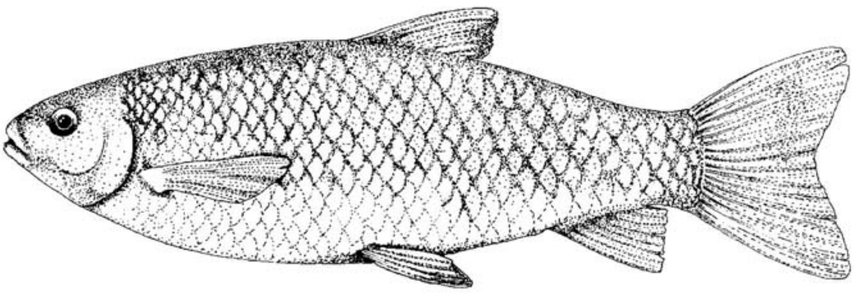
Catfish are a dark brown to olive green colour with eight distinctive barbels around their mouth and a smooth, eel like, skin. They commonly grow to 200–400 mm in length.



Catfish

Grass carp *(Ctenopharyngodon idella)*

Grass carp in New Zealand generally only exist in ponds and drains where they have been deliberately released to control nuisance aquatic weeds. Grass carp are considered to be unable to breed in New Zealand waters and as such wild populations do not appear to have formed (although small fish have been captured in the Waikato River system, it is not clear if these escaped from captive populations or not). These large fish grow very rapidly, consuming large volumes of aquatic weed, and have been recorded up to 24kg in New Zealand.



Grass Carp

Goldfish *(Carassius auratus)*

Wild (feral) populations of goldfish occur throughout the region but are most commonly found in lakes, small slow flowing rivers and streams. Wild goldfish are an olive –bronze colour, and commonly grow to about 250mm in size although McDowal (2000) notes that they may grow to 400mm. These omnivorous fish appear to have no significant adverse effects on native flora and fauna in any of the habitats within the region although this has not been well studied.

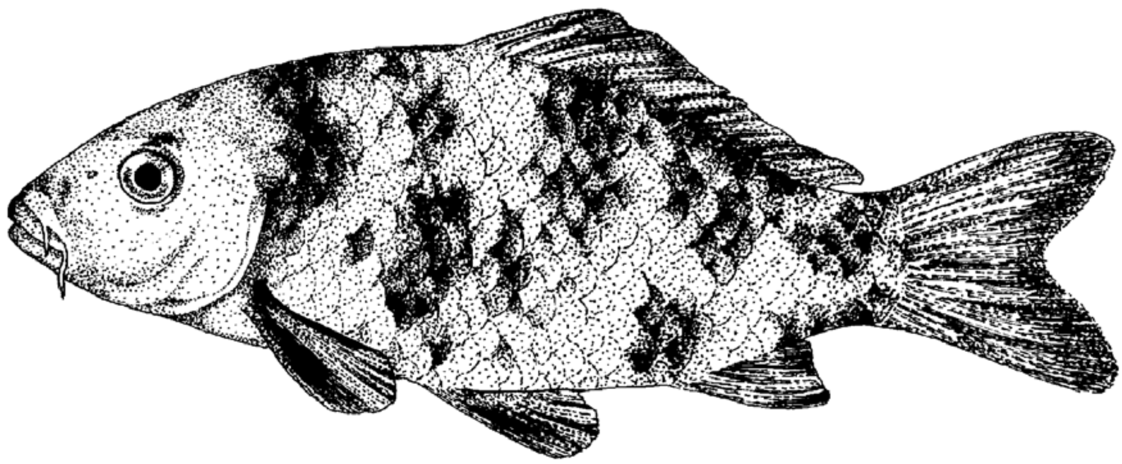
European (koi) carp *(Cyprinus carpio)*

New Zealand koi carp are an ornamental (Japanese) strain of the common or "European" carp. They were introduced to NZ in the 1960's by the release of ornamental "aquarium" fish. They are highly variable in colour - black, red, orange (most common), gold, and even white although their natural colour is olive.

Koi carp are currently restricted to the North Island and Nelson in the South Island with large populations occurring in the Lower Waikato River and around Auckland. Small, isolated populations occur in ponds and drains in other catchments (Waihou, Coromandel, Wellington) and it is likely that their full distribution is not yet known.

In New Zealand koi can grow to over 10kg and 750mm in length. They prefer still or slowly moving waters such as weedy ponds, river backwaters and lake margins and they are very tolerant of poor water quality. Spawning can occur several times a year (spring and summer) in shallow vegetated areas and egg development occurs in about 1 week.

Koi are distinguished from other "carp" species by the barbel's at the corners of their mouths although these are often absent in juveniles. They feed by sucking up bottom or bank sediments, and filtering out anything organic expelling the leftovers. Consequently, they generate highly turbid water and can undermine river banks as they feed. They also uproot vegetation and the resulting turbidity makes it difficult for plant communities to re-establish themselves.



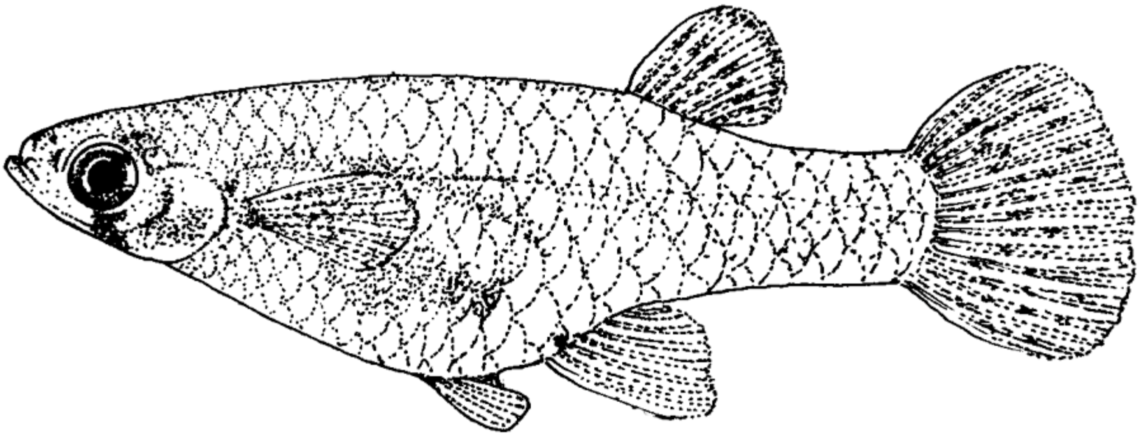
European "koi" carp

Gambusia *(Gambusia affinis)*

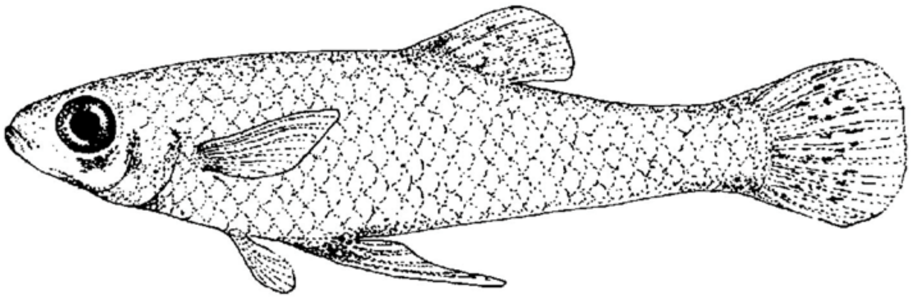
Commonly known as mosquito fish, the gambusia originates from Central America and is spread throughout the world. This small fish (40 – 60mm) is widespread throughout the Northern part of the Waikato Region and is found in most types of waterbody. It is highly tolerant of poor conditions including high and low water temperatures, pollution, low dissolved oxygen etc.

Gambusia are extremely aggressive fish and are know to congregate in packs attacking much larger fish, nibbling fins and eyes until the fish dies or is driven away.

Contrary to the popular name, gambusia are not effective at controlling mosquito populations, in fact many native species do a much better job. Gambusia are a noxious fish and an unwanted organism.



Gambusia (female)



Gambusia (male)

Rainbow trout *(Onchorhynchus mykiss)*

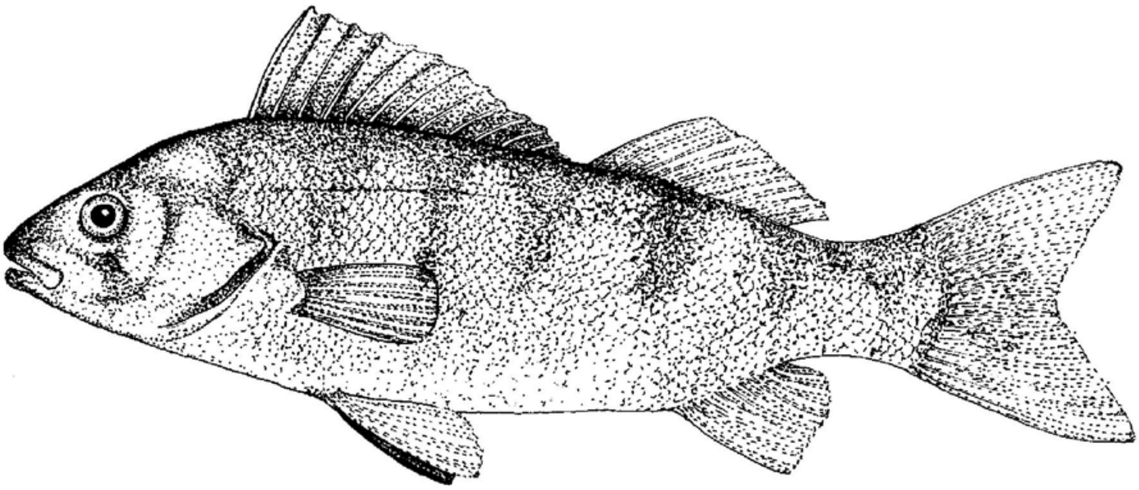
Rainbow trout were introduced to New Zealand in 1886 and are now spread throughout the country. They are widespread in the Waikato Regions rivers and streams including throughout the Taupo basin where they support an internationally renowned recreational fishery. Rainbow trout spawn in winter or early spring in gravely streams and their eggs hatch one to two months later. Juveniles may take up to 2 years to become "recreational" sized fish and to reach maturity.

Rainbow trout prefer cool, clean water and are consequently, restricted in their distribution within the Region, particularly during summer months when water temperatures in rivers like the lower Waikato can reach 25°C.

Rainbow trout are aggressive, predatory fish and are known to feed on small native fish. In Lake Taupo for instance, the introduction of Rainbow trout to the lake decimated the lake koaro population in only a few years and now only small remnant populations of koaro remain in tributary streams where trout are unable to penetrate due to waterfalls or rapids.

Perch *(Perca fluviatilis)*

Within the Waikato Region , Perch are found in the Waikato and Waihou River systems and only at low numbers. They are a moderately sized (approx. 400mm) predatory fish which feeds on invertebrates and small fish. Perch were introduced to New Zealand in the1860's as one of several species intended to establish coarse fishing opportunities. As with all aquatic life, it is illegal to transfer any fish to a new site where it does not currently exist without a licence to do so from the Department of Conservation.



Perch

Sailfin molly *(Poecilia latipinna)*

Sailfin molly are small (60 – 120mm) tropical fish which are found in only one location within New Zealand, a small geothermal spring/wetland area in Tokaanu at the southern end of Lake Taupo. This population was undoubtedly established by the release of aquarium fish and may have some small impact on the invertebrate populations of the area but its distribution is limited by the extent of warm, geothermal waters.

Guppy *(Poecilia reticulata)*

As with sailfin molly, guppies are limited in distribution to geothermaly heated areas where winter temperatures are elevated. Guppies are small fish (30 – 60mm), very similar in appearance to gambusia and are only found in the central North Island. Like sailfin molly guppies are unlikely to have any significant impact on native fisheries due to their limited distribution and reliance of geothermaly heated water.

Brown trout *(Salmo trutta)*

Like rainbow trout, brown trout were introduced to New Zealand (in 1867) in an effort to create a wild sport fishery and are now spread throughout the country. They are widespread in the Waikato Region's rivers and streams including throughout the Taupo basin. Their spawning habits and habitat requirements are similar to those of the rainbow trout although browns tend to spawn earlier, in late autumn and early winter.

Brown trout tend to grow larger than rainbow trout (commonly 800mm) and may live for more than 10 years. They are voracious predators and like rainbow trout have been associated with the demise of populations of small galaxiid fish.

Brook char *(Salvelinus fontinalis)*

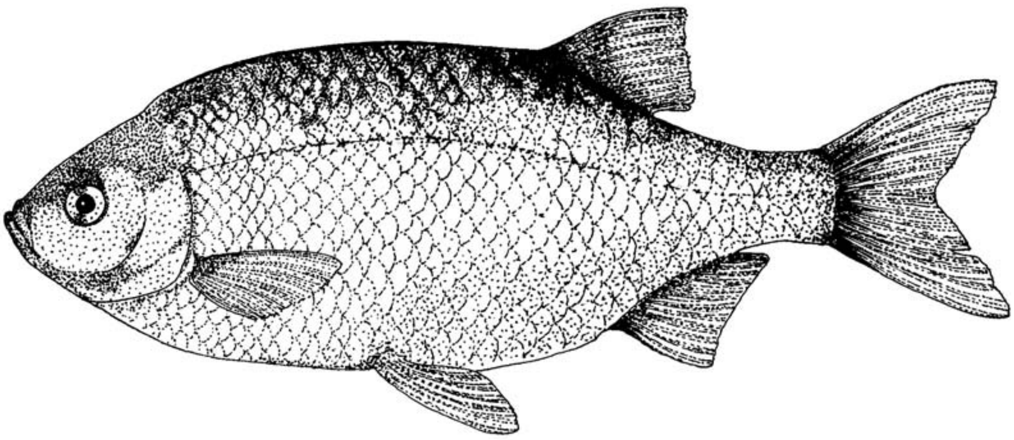
The only significant population of brook char in the Waikato Region occurs in the upper dam of the Hinemaiaia River (a tributary of Lake Taupo) although there may be small populations in some tributaries of the upper Waikato River. Brook char are a small (600mm in New Zealand) brightly marked (blue and red spots are common) salmonid species which have similar life cycles to that of brown trout.

Rudd *(Scardinius erythrophalmus)*

Rudd were introduced illegally in the 1960's and occur in large numbers throughout the Waikato River catchment and have been introduced into many of the small lakes throughout the region in an attempt to create a coarse fishery in these water bodies. Populations have also established by natural movement out of the Waikato River into tributary streams and lakes.

Rudd grow to 400mm although they are more commonly 200mm in length and the adults are voracious consumers of aquatic plant material. Unfortunately they prefer native macrophytes and their introduction into the few small lakes in the region with entirely native macrophytes (the Serpentine Lakes) is of great concern as in large numbers they may have sufficient grazing impact to contribute to a collapse of these macrophyte populations. They spawn in spring and summer and grow rapidly to their adult size. Rudd are distinguished by their silver coloration with distinct red/orange fins.

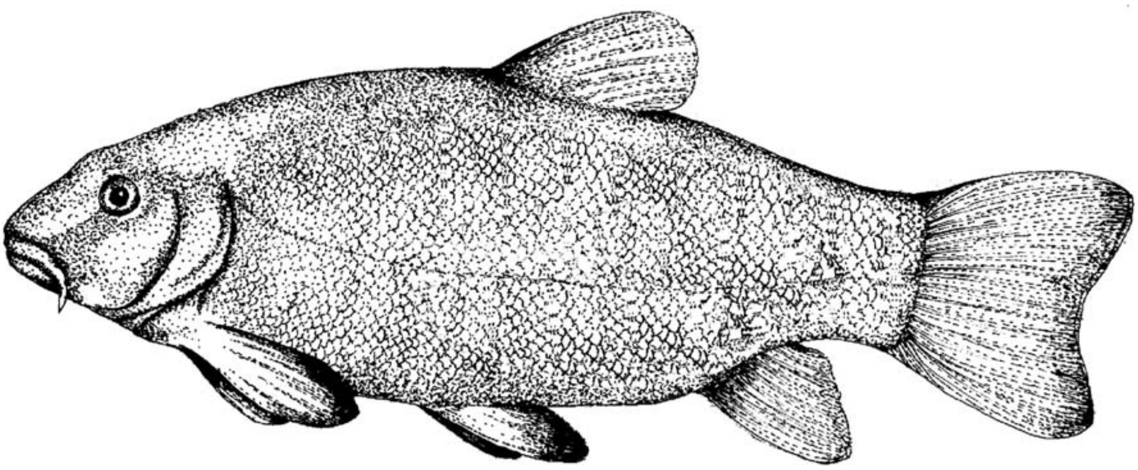
Rudd are considered to be a noxious fish in all parts of New Zealand except within the Auckland Waikato Fish and Game Council Region where they are considered to be a sport fish.



Rudd

Tench *(Tinca tinca)*

Tench are a relatively large (up to 800mm) coarse fish introduced to New Zealand in the 1860's to enhance fishing opportunities. They have not become well established and are only found in small populations in a few sites throughout the country. They are a large olive fish which inhabits sluggish, muddy bottomed waterbodies.



Tench

2 Pressures on the Region's Indigenous Fish

The distribution of most freshwater fish in the Waikato region can be explained by a small number of key factors including; the necessity for access to and from the sea for at least half of our indigenous fish, a series of introductions and transfers of indigenous and exotic fish species which have significantly reduced the distribution of many indigenous fish and the loss of substantial areas of wetland and bush covered stream habitat.

An example of the simultaneous effect of a number of pressures on a fishery is seen in the decline in the whitebait and eel fisheries in recent decades. Both of these fisheries have been exploited commercially but, along with the other indigenous fisheries of the region, have also suffered from all of the following factors:

- reduced adult and spawning habitat as a result of wetland drainage, flood protection, and hydro development. Many species depend on flooding for access to feeding and spawning habitat and these three factors have significantly reduced the frequency and extent of flooding throughout the region.
- changes in habitat and loss of marginal vegetation due to land use changes (increased pastoral farming, pine forestry and urbanisation). Most indigenous fish are cryptic and prefer streams and rivers with abundant cover and in-stream debris.
- loss of natural migration pathways due to construction of dams, floodgates and culverts. These structures also alter natural flow regimes and sediment transport thereby changing the downstream habitat.
- increased contaminant and sediment loads in previously 'clean' waterways and raised summertime temperatures due to discharges, loss of marginal vegetation and

stream bank erosion. High sediment loads or the presence of contaminants can cause avoidance behaviour in many species and limit access to some streams and rivers.

- Introduction of exotic species such as trout, koi carp, catfish and gambusia which compete for space, resources such as food, or predate directly on indigenous fish species.

These pressures on the regions fisheries are discussed in greater detail in the next sections of this report.

2.1 Habitat Destruction & Modification

One of the largest threats to the region's native freshwater fishery is the ongoing loss of suitable habitat either through significant modification (e.g. channelisation of streams), total destruction (e.g. wetland drainage and reclamation) or loss of accessibility. The major causes of habitat loss in the region fall into four groupings:

- Barriers to fish passage
- Reduction in water quality
- Flow regime modification
- Habitat loss

2.1.1 Barriers to Fish Passage

Essential to the survival of our aquatic ecosystems is their ability to provide the fish therein with easy access to spawning, feeding and healthy habitats (Odeh, 1999). The provision of this "easy access" to spawning, feeding and healthy habitats is particularly important in New Zealand where 18 of our 35 indigenous species are diadromous (McDowall, 2000). The often steep catchments and very active geological processes in our country create many natural barriers to fish passage and the addition of artificial barriers such as dams, fords and culverts further reduces the habitat available to these fish species.

In a study of culverts in the Coromandel Peninsula and the Whaingaroa catchment Speirs & Kelly, (2001) found that fish passage was restricted at 75% and 55% of stream culverts respectively, and that the predominant reason for this was poor construction and maintenance of these structures.

Loss of fish passage and its associated effects are not unique to New Zealand. Odeh, (1999) reported that effective fish passage is provided at only 9.5% of the 1,825 hydro power plants regulated by the Federal Energy Regulatory Commission in the USA. Lintermans, (2000) and Mallen-Cooper, (1999) consider the loss of fish passage as one of the key factors in species decline in the Murray River (Australia) and the Australian Capital Territory.

While only a small number of native fish species are non-migratory, all of the introduced fish species in New Zealand apart from trout are capable of completing their life cycles in the sheltered waters of lakes and streams with no substantial migration. Consequently, the presence of artificial barriers such as dams and culverts in our rivers and streams not only reduces the distribution of native fish but provides "better" habitat, in some instances, for exotic species.

2.1.2 Reduction in Water Quality

The effects of poor water quality on the fisheries of the Region are possibly the most difficult to measure as they are often chronic and frequently arise from the cumulative actions of a number of contaminants over a wide area or time scale. At high concentrations most contaminants have obvious adverse effects such as death or avoidance of an area by fish.

However at low concentrations, many contaminants may have significant but less obvious effects such as a loss of fecundity (zinc, cadmium) or general health and growth, or physical effects such as a reduction in feeding ability or spawning success (fine sediment).

As noted by Alabaster & Lloyd (1980) “The proper management of a river system demands that water of suitable quality be provided for each use that is made or intended to be made of it. However, all too often water has been considered quite adequate for fish as long as there has been no obvious mortality which can be ascribed to known pollutants. Degradation of the aquatic habitat through pollution and decrease in the annual production and subsequent harvest of fish have often passed unnoted.”

Within the Waikato region there are a number of rivers and streams where the principal reason for low diversity and abundance of fish is poor water quality. Several streams on Te Aroha mountain (e.g. Tunakohoia & Tui streams) remain so contaminated by heavy metals as a result of gold mining activities that they have no fish population and almost no invertebrates despite having native bush catchments, good physical habitat and good access for diadromous fish. The Waitoa river has a very low diversity and abundance of fish and this is largely the result of high levels of industrial contamination, while the Waipa river has a good diversity of fish species but as a result of high suspended sediment levels these are at very low densities and fish tend to be poorly distributed in the middle and upper reaches of the river.

2.1.3 Physical Habitat Loss

Many authors have published on the habitat preferences of various fish species and in most cases they report that there have been significant losses of such habitat due to a variety of human activities. The most common causes of physical habitat loss include; wetland drainage (over 75% of the Waikato Region’s wetlands have been lost), stream channelisation (straightening and cleaning of streams throughout the Region continues), vegetation clearance, river dredging (sand/gravel extraction lowers river bed levels causing channelisation and a localised reduction in shallow marginal areas), and physical degradation resulting from poor water quality.

Despite these concerns, and the obvious adverse effects on the Region’s native fishery, the actual loss of native fish habitat in the Waikato Region (indeed in New Zealand), has never been quantified. It is agreed that losses have been significant and that they continue to occur, however despite new environmental legislation such as the Resource Management Act, 1991, no attempt has been made to measure changes in habitat loss. In many catchments throughout New Zealand there is no baseline data and in most areas there is no regular monitoring of physical habitat conditions.

Despite the lack of any measurement, it is clear that the loss of physical habitat for indigenous fish has stabilised since the early part of the 20th century when huge tracts of wetland and native forest were cleared to make way for farming and urban development. Unfortunately this stabilisation is more likely the result of the rarity of unimpacted habitat than a recognition of its importance.

2.1.4 Flow Regime Modification

The effects of flow regime modification on the fisheries of the Region are wide and varied. In many cases, the extent of fish distributions are determined by the presence of a particular flow regime feature such as a rapid or waterfall which limits the upstream extent of a species or a floodplain which is inundated frequently enough to support an opportunistic population of eels.

The flow regime of a river, includes such geological features as waterfalls and rapids as-well as the frequency with which flow changes occur. Floods and low flow events may be just as important to the life cycle of many species as features such as adult habitat and water quality. Changes in flow regimes act to provide spawning cues (e.g. Galaxiids respond to high tides or high stream flows to spawn), migration cues for adult fish and for the recruitment of juveniles (whitebait recruitment depends to some extent on the size of flows out of a river system to the sea).

Unfortunately modification of flow regimes throughout the region has been substantial with the construction of hydro electric dams (Waikato River, Tongariro River, Mokau River) on some of our largest rivers and smaller water supply dams and reservoirs. Large scale abstraction of water also impacts on the flow regime characteristics of many rivers and streams reducing peak flows (and lessening sediment transport and scouring of algae from rocks etc.) and further reducing low flow events.

Increased demand for water throughout the region threatens to further affect the natural flow regimes of our rivers and streams.

2.2 Harvest

Eels are an important traditional and commercial resource and the Waikato Region supports New Zealand's most productive eel fishery. However, the abundance of commercial sized eels has declined in the past two decades along with the proportion of longfinned eels. Loss of habitat and the intensive exploitation of these long–lived, slow growing fish are probable reasons for this decline.

Jellyman et al, (2000), report since 1980 recruitment of longfinned eels to New Zealand catchments has declined by an average of 7% per annum with glass eel runs estimated to be less than 25% of those recorded in the 1970's. The authors attribute much of this decline to over exploitation of eels, particularly the slower growing longfinned eel, by commercial harvesters.

Whitebait[5], are also harvested throughout the region. The estimated total catch from the Waikato River was 10.7 tonnes in 1998 and 3 tonnes in 2000. These catches are low compared to the average estimated catch between 1968 and 1985 of 14 tonnes, and significantly less than the 46 tonne average caught between 1931 and 1950.

Amongst the many factors responsible for the decline in whitebait numbers (habitat loss, loss of migratory pathways, and water quality degradation) pressure from harvest plays a significant part with increased numbers of fishers and more efficient nets adding to their success. Alibone et al. (1999) reported that recapture rates of stained whitebait by recreational fishers in the Mokau and Awakino rivers varied between 1.3% and 44.6% with a mean of approximately 19%. The authors also reported that the recapture rates of the stained fish were likely to be an underestimate of the actual rates of whitebait capture in the river. At present there is no indication of what level of long term exploitation this fishery can sustain.

2.3 Exotic Species

Intensive introduction of freshwater fish species into New Zealand began in the 1860s and has continued to the present day. Unfortunately, introductions began at a time when little was known about the abundance and diversity of our native species. Consequently, detailed information on the effects of introduced species on the natural distribution of our native fish fauna is not available and many of the "effects" reported to result from introductions are based on anecdotal information.

Although there is little explicit information available on the impact of introduced species on indigenous fauna, likely impacts include: habitat disruption, competition for space or food, predation and disease transfer. The decline of koaro in Lake Taupo as a result of the introduction of rainbow trout, and subsequently smelt, is one of the clearest examples in the

[5] Whitebait are the juvenile form of inanga, banded kokopu, shortjawed kokopu, giant kokopu, and koaro.

Waikato Region of competitive exclusion of a native species by competition and predation by an introduced species.

Table 1. lists the 14 exotic species which have been introduced to the Rivers and streams of the Waikato Region. Some, such as the guppy (*Poecilia reticulata)* and sailfin molly (*P. latipinna)* are tropical fish and consequently, are limited to geothermal waters in the region from which no native species are known. Consequently, the effects of these introductions on indigenous fish is minimal. Other introductions such as rudd (*Scardinius erythropthalmus),* Gambusia (*Gambusia affinis)* and koi carp (*Cyprinus carpio*) have very wide tolerance ranges, can be found throughout the Waikato River system and are increasingly being found in new river catchments throughout the region. All of these fish are noxious species (however, rudd are not noxious in the Auckland Waikato Fish and Game area), they are prolific breeders and are considered to have a significant detrimental impact on aquatic macrophytes and water quality (koi and rudd) and in the case of gambusia, are known to attack and damage (kill ?) native fish.

3 Major Rivers and Catchments

With a total length of approximately 43,000 kilometres of rivers and streams the Waikato Region has a wide variety of streams and rivers with very different and often rare morphologies and in-stream habitat.

The Waikato River is undoubtedly the most notable river in the Region and starts from Lake Taupo and flows for 425 km to the sea at Port Waikato. There are also other major rivers with significant sized catchments e.g., Waipa, Piako, Waihou and Awakino Rivers.

The geology of the Waikato Region varies widely creating different substrate types and levels of sedimentation. The karst landscape of the Waitomo catchment causes large portions of streams to have underground components. Streams and rivers on the volcanic plateau have often highly mobile pumice substrates that are easily disturbed. Coromandel catchments tend to be dominated by hard volcanic rock and so streams have cobbly and bouldery substrates – excellent habitats for stream biota (Taylor, 2001).

Similarly, land-use varies widely throughout the Region with rivers such as the Tongariro, and the Waipa having large portions of indigenous forest in their upper reaches, while others like the Piako and Waihou only have small portions of the catchment that remain undeveloped. As a consequence the water quality of the Regions rivers also varies considerably and can often be attributed to the activities in the catchment.

All of these factors, and many others play a part in determining the state of the freshwater fishery of the Region.

3.1 Waikato River

The Waikato River and its associated wetlands, lakes and waterways support a diverse range of fish communities including 19 species of indigenous freshwater fish and 10 known exotic species. The river supports a significant recreational whitebait fishery, a large commercial eel fishery, and a reasonable winter trout fishery.

Many of the indigenous species present in the river are diadromous and the length of the river and its huge number of tributary streams provides an uninterrupted migration pathway (downstream of the Karapiro Dam) between the sea and areas of upstream habitat unrivalled by any other river in New Zealand. For most non climbing diadromous species natural upstream passage is unlikely to have occurred past the current location of the Arapuni hydro dam as this was the site of a series of very large rapids. However, the operation of the eight hydro stations, and the control they exercise over the flow regime of the lower Waikato River has significantly altered much of the habitat in this reach. Flooding is not as frequent or extensive as it was prior to the construction of the dam system and with the addition of a flood control scheme and river dredging in the lower river, most floodplain areas have now become pasture farms. Of those wetlands that remain many have become highly degraded and continue to decline.

While it is the largest system in the region, The Waikato River is also one of the most impacted in terms of fish habitat. Loss of bush catchments due to farm and forestry development, heavy industry discharges (temperature, nutrients, heavy metals), floodplain and wetland loss, heavy recreational and commercial harvest, and flood protection have all combined to significantly reduce the fishery of this river. As noted earlier the estimated average catch of whitebait from the Waikato River between 1931 and 1950 was 46 tonnes, between 1968 and 1985 it was reduced to 14 tonnes and in 1998 and 2000 this was reduced to 10.7 and 3 tonnes respectively. No single factor is responsible for the decline in this fishery but rather a combined effect from all of the pressures discussed in section 2 of this report.

3.2 Tongariro River and Lake Taupo Tributaries

Lake Taupo and its tributaries, particularly the Tongariro river are well known for their abundant trout fisheries, however as well as trout, landlocked populations of koaro persist in many smaller tributaries. A large population of smelt also exists in the lake. This species was introduced to the lake to provide a source of food for trout and is largely the reason for the success of the trout fishery in this lake. The introduction of catfish and their apparent rising abundance is causing some concern over potential impacts on the trout fishery.

The Department of Conservation manage the trout fishery of the Taupo area including the Lake and all of its tributary streams. The fishery is described as being one of the premium wild rainbow trout fisheries in the world with the attribute most valued by anglers being that the fishery is wild and self sustaining, an attribute which is almost non-existent elsewhere in the world (Department of Conservation, 1996).

The 30 + major tributaries of Lake Taupo drain a combined catchment area of approximately 2850 km^2 which, apart from koaro and common bullies, is devoid of native fish. Historically the catchment was mostly covered in tussock grassland and native forest. Since 1840 much of the tussock has been replaced with pine plantations and pasture. Sheep and beef farming currently dominate pastoral agriculture, but there is a recent shift to more intensive dairying (Waikato Regional Council SOE report, 1998). While nutrient levels in the Lake remain at very low levels, they are rising, and there is evidence that the effect of current catchment development on water quality in the lake will not be seen for in excess of 30 years.

The lack of native fish fauna in the catchment is a combination of the recent volcanic history of the area and the presence of large barriers on the only outlet from the Lake, the Waikato River.

The eruptions of Lake Taupo (most recently ≈ 2000 years ago) and of the surrounding mountain ranges (Tongariro, Ngaruhoe, Ruapehu) would have eliminated most aquatic life in the streams of the Taupo Volcanic Zone while the presence of the Huka falls on the Waikato River immediately downstream of the Lake prevents the recolonisation of the area by diadromous fish. Koaro may have entered the Lake and its Tributaries via an historical connection between lake Rotoaira and the Wanganui River after the last eruption of Lake Taupo (McDowall, 1990). It is also possible that these fish may be the result of large scale introductions by Maori, who were quite adept at moving fish into new habitats in order to make food resources more accessible.

3.3 Waipa River

At over 129 kilometres long and with a catchment area of 3,059 km^2 (21% of the Waikato River Catchment) the Waipa River is the largest tributary of the Waikato River and joins the

Waikato River at Ngaruawahia. The Waipa's source is in the forested Rangitoto Ranges to the south-east of Te Kuiti however, the majority of the catchment is pastoral.

The Waipa River is one of the few large catchments in the Waikato River system not controlled by power generation or water storage. The steeper land at the head of the Waipa is under indigenous forest or scrub.

3.4 Waihou River

The Waihou river drains the western slopes of the Coromandel and Kaimai Ranges and some of the large flat expanse of the Hauraki plains. It is 128 km long and has a mean annual flow of 43 m^3/s (Barrier, 1994). The headwaters of the river are spring fed and consequently, have a relatively stable temperature and flow regime throughout the year. As the river passes down its catchment the influence of many small tributaries increases flow variability slightly, however relative to other non regulated North Island Rivers, the flow regime of the Waihou river is very stable.

There are no significant natural barriers to fish passage on the Waihou river system and this is reflected in the high diversity of the river's fishery, even in the upper reaches of the mainstem. Despite this high diversity of species however, the Waihou river catchment has a relatively low abundance of fish. The reasons for this are not completely understood, however the lack of riparian vegetation and the very high silt load in the lower reaches of the river are likely causes. Pressure on water resources by abstraction may also place the fishery under pressure (Barrier, 1994).

Barrier (1994) carried out a detailed study of the catchment and its biological resources including fish and this remains the most recent and thorough investigation of this type on the river. He makes the following observations and recommendations with respect to restoring and enhancing the fish populations of this catchment:

- The whitebait fishery of the Waihou river is dominated by smelt with only a few galaxiid species. This is unusual for a North Island river system and underlines the importance of protecting smelt spawning areas in this river.
- Sand dredging or similar activities should not be authorised from the lower river until a better understanding of the use of these areas by smelt and coastal fish as spawning habitat is gained.
- Avoid activities in the Kirikiri, Puriri, Omahu, Maratoto, Hikutaia, and Komata streams and tributaries of the Ohinemuri river that may disturb the stream bed or banks during trout spawning season. Also avoid any physical changes to these streams and encourage the maintenance and enhancement of riparian shading on the northern banks.
- Retire riparian margins likely to contain inanga spawning areas (described in (Barrier, 1994) Figure 3, page 9) above the spring high tide level or as a minimum modify the current grazing management of these margins from March to July each year to allow marginal vegetation to establish good spawning conditions.
- Undertake works including artificial wetland establishment and riparian planting to establish habitat for the declining eel and water bird populations.
- Reduce herbicide spraying and drag-lining of drains and streams which destroy large areas of fish and water-bird habitat annually.
- Undertake an assessment of culverts and floodgates in the catchment for fish passage and address the specific fish passage barriers referred to in the report as soon as possible.
- Investigate the distribution and abundance of adult galaxiid species in tributary streams.

Since the study completed by (Barrier, 1994) the presence of koi carp in the Hikutaia cut, the Waihou River and the Ohinemuri River has been confirmed.

3.5 Piako and Waitoa Rivers

The Piako river catchment, including that of its largest tributary, the Waitoa river extends from Hinuera in the south to the Firth of Thames and covers an area of approximately 1500 km^2 The catchment drains a large proportion of the Hauraki plains and the Hapuakohe ranges. Over 84% of the catchment is in pasture with the predominant land use being intensive dairying with drystock grazing in the hill country areas. The catchment also includes the Kopuatai peat dome (one of 5 New Zealand sites recognised as being of international conservation significance by the IUCN[6], under the RAMSAR convention) which contains nine vulnerable or threatened species including various plants, birds and the black mudfish (Waikato Regional Council, 1991).

A spring survey of the catchment's fishery values was carried out in 1990 (Meredith, 1990). Fifteen species of freshwater fish were captured from 48 sites throughout the catchment (Table 2). Shortfinned eels and longfinned eels were most widely distributed, followed by smelt, crans and common bullies, inanga and banded kokopu. Smelt was the most abundant species and despite there being good numbers of juvenile kokopu there is no active whitebait fishery in the river.

Meredith (1990) notes that despite the generally poor water quality in the Piako river catchment there is a significant diversity of fish species present with good recruitment of juvenile kokopu species. Unfortunately, as a result of the land clearance and stream chanelisation that has taken place throughout the catchment, adult habitat for these species is very limited and consequently the abundance of adult kokopu is low. The distribution of fish is further limited by water falls which form natural barriers to fish passage on all three headwater tributaries of the Piako River at Morrinsville. As a consequence, only climbing species such as eels and banded kokopu are able to pass these barriers to take advantage of the small amount of good quality habitat in these headwater streams.

The abundance of fish found in the Waitoa in the 1990 survey was significantly lower than that of the Piako. This is probably due to an avoidance response from upstream migrating fish who choose to bypass the Waitoa in favour of the less contaminated Piako river.

Eel populations throughout the catchment are exploited by commercial harvesters and consequently the eel population is strongly skewed to small eels with only a few large specimens remaining in less accessible streams.

In April 1991 a draft management plan for the catchment was presented to the Waikato Regional Council. The management plan identifies the following key management issues for the future sustainable management of the catchment and in particular its natural resources:

- The surface waters of the catchment are considerably degraded and in some reaches nutrient and contaminant concentrations are such that they are toxic to aquatic biota and constitute a health risk to stock and humans.
- Abstraction of surface water during summer low flow conditions compromises water quality, temperature and aquatic habitat.
- Disturbance of stream banks by stock and vegetation clearance on the hill country causes significant sedimentation and contributes to degraded water quality in streams and the main stem of the river.
- Indigenous habitat has been severely depleted as a result of intensive agricultural development, associated drainage, flood control works and poor water quality.
- Riparian development of the banks of tributary streams and stock exclusion from these banks is required to enhance adult fish habitat and mitigate high summer water temperatures and sediment loads in the river system.
- Development of artificial riffle structures in sluggish reaches such as the Waitoa river could enhance fish habitat and increase re-aeration of the river water.

[6] The International Union for Conservation of Nature

3.6 Mokau River

The Mokau is one of the largest rivers in the North Island. It is 158 km long, with a catchment of 1430 km^2 and a mean annual flow of 71 m^3/s. High rainfall in the area and a steep, erosion prone, silt/sandstone catchment means that the river carries a high sediment load (Hanchet, 1987; Hanchet, 1989). The tributaries of the river drain large heavily forested areas dominated by beech, tawa and mixed podocarp assemblages. The upper catchment is very steep while the middle and lower reaches tend to be more rolling country with significant pastoral areas. The banks of the river are generally well vegetated. There are two hydro electric dams on the Mokau river, the Wairere and Mokauiti dams, both of which are potentially significant impediments to fish passage although the Wairere dam is built on the foundations of a natural waterfall.

Until 1986 when Hanchet (1987, 1989) carried out a fishery survey of more than 40 sites in the Mokau River as part of an assessment of effects for a proposed coal mine, very little was known of the river's fishery values. Furthermore, subsequent work on the fishery has concentrated on whitebait in the lower reaches of the river and none has been carried out in any of the tributary rivers or streams or in the upper reaches of the river. Hanchet's work therefore remains as the only thorough record of the fishery of the Mokau River.
Hanchet (1989) recorded 14 species of freshwater fish in their 1986 survey and note that another two species have been recorded by other surveys. These fish are listed in Table 2. They noted that while the overall diversity of fish in the Mokau was on a par with that of other North Island rivers, at a smaller scale (reach or tributary) diversity and abundance was relatively low.

Predictably, diversity is highest in the lower forested reaches of the river with species such as smelt and inanga dropping away with increasing steepness and distance from the sea. An interesting finding of the report is that despite a very large and productive whitebait fishery and excellent upstream habitat there are few adult galaxiids in the river other than inanga. This is also reflected in the make up of the whitebait catch which is dominated by inanga (98+ %) with only very small numbers of banded kokopu and koaro.

The reasons for the low local diversity and low numbers of adult galaxiid species are not clear and Hanchet (1989) does not speculate on these. It is possible that the steep, erosive nature of the upper catchment and tributaries does not provide sufficiently stable stream substrate and water level for kokopu species to spawn successfully each year. However, the lower, tidally influenced, reaches of the river favoured by inanga for spawning are very much more stable and hence it is possible that the success of annual spawning for this species is more assured and they dominate the galaxiid population as a result. This however is only speculation and there are likely to be a number of other factors influencing the diversity of this fishery.

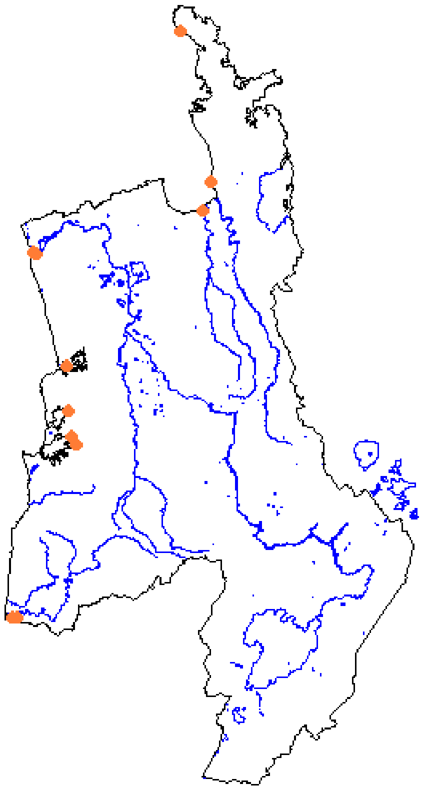
3.7 Coromandel Rivers

The Coromandel Peninsula is one of the larger areas of the region where streams can be found with a continuity of native riparian vegetation from their headwaters to the sea. The majority of streams and rivers have relatively unmodified flow regimes, satisfactory to high water quality and the absence of introduced pest fish (although many have populations of trout and in some cases mosquitofish. These steep catchments host a good diversity of fish species and in particular high numbers of banded kokopu, short and longfin eels, torrentfish, and giant, blue-gill and redfin bullies. However, reduced fish passage due to small dams, poorly constructed culverts and low stream flows in summer restricts all fish populations.

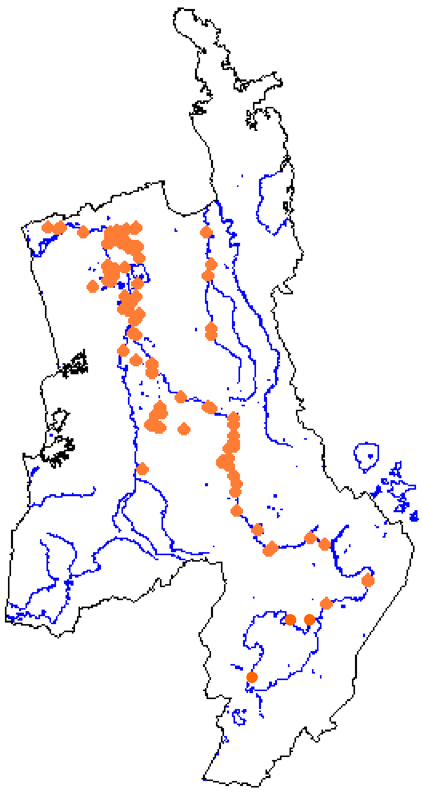
Many of these stream have not been surveyed at all or have not had any new records of the fishery for several decades. Consequently, providing any certainty with respect to their fishery value is difficult at this stage. However, based on their physical characteristics and records from other streams it is likely that most unmodified water courses in the Coromandel will have significant fish populations.

Streams and catchments in the Coromandel Ranges with particularly high fishery values include: Waiharekeke, Te puru, Huakitoetoe, Whareroa, Mataiterangi, streams above Potiki Bay, Whenuakite, Horseshoe and Sandy bay, Fantail bay, and the Awaroa and Whauwhau streams (Humphreys, 1990).

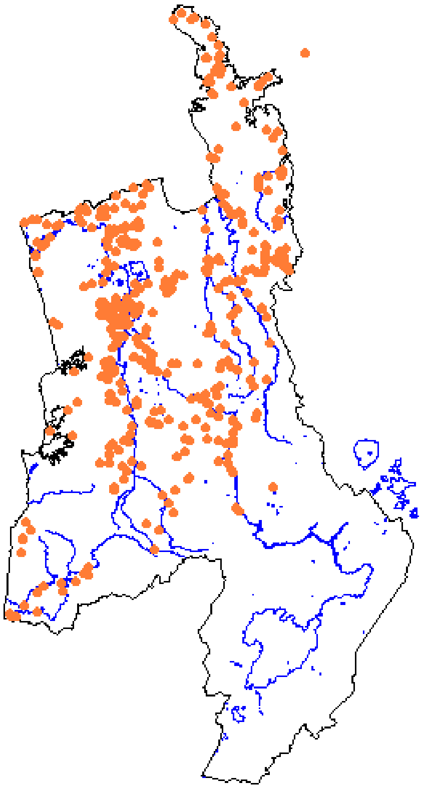
Appendix 1 – Distribution Maps for Freshwater Fish in the Waikato Region (updated in April 2001)



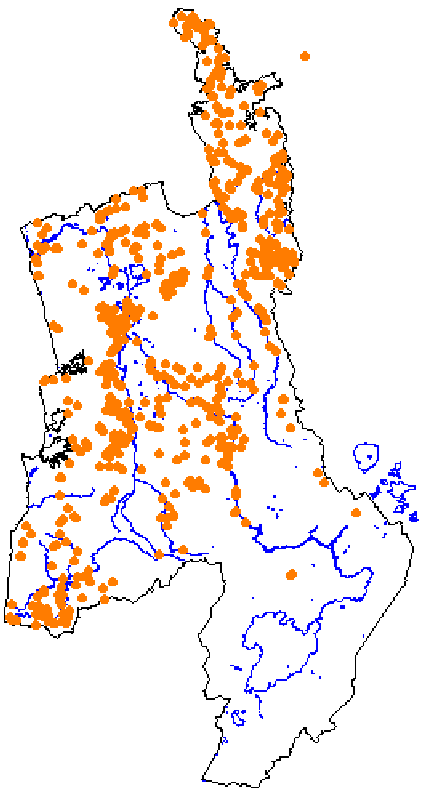
Yelloweye mullet (Aldrichetta forsteri)



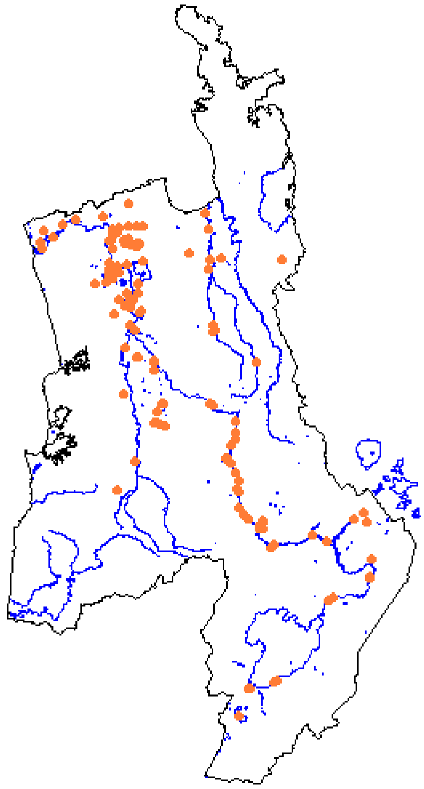
Brown bullhead catfish (*Ameiurus nebulosus*)



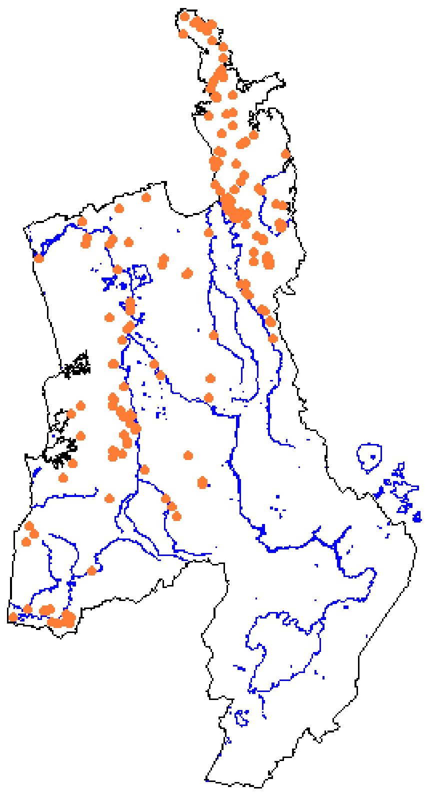
Shortfin eel (Anguilla australis)



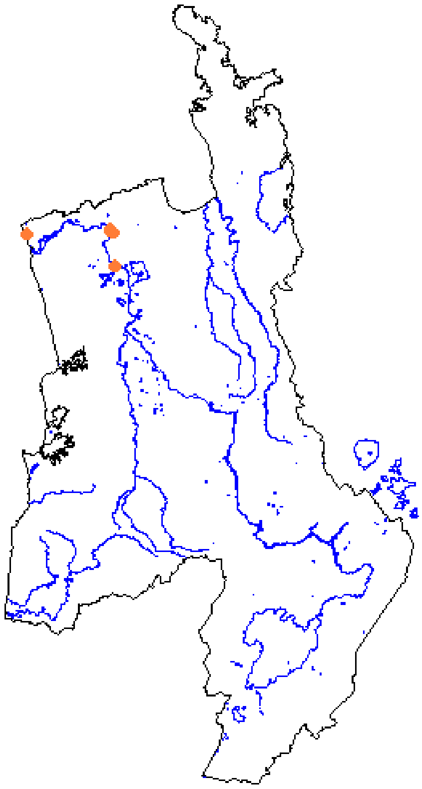
Longfin eel (*Anguilla dieffenbachii*)



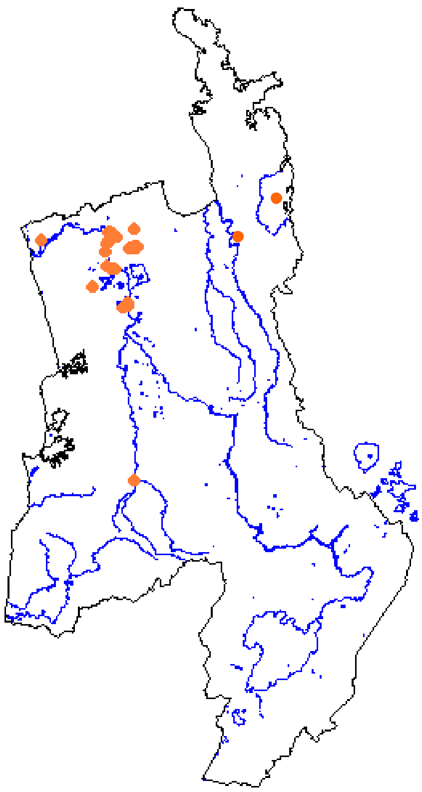
Goldfish (*Carassius auratus*)



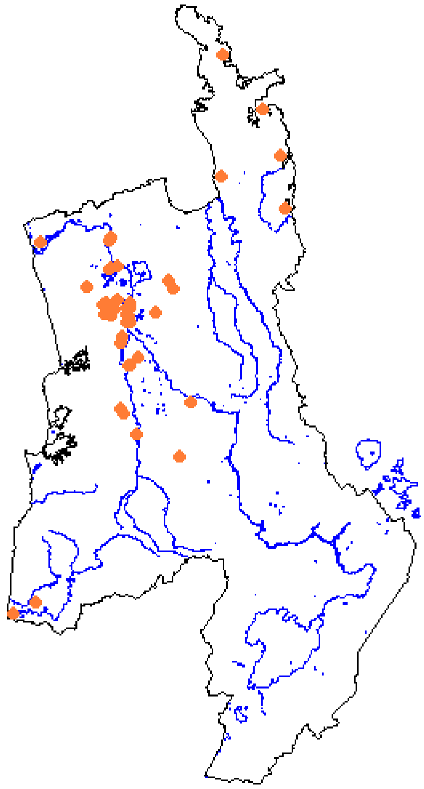
Torrentfish (*Cheimarrichthys fosteri*)



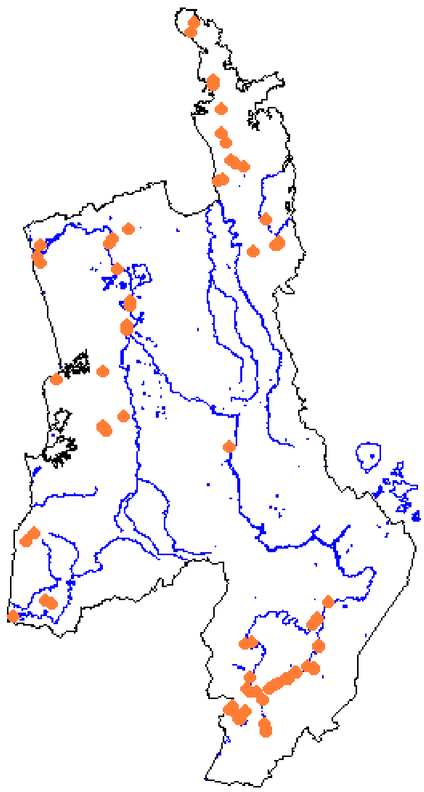
Grass carp (*Ctenopharyngodon idella*)



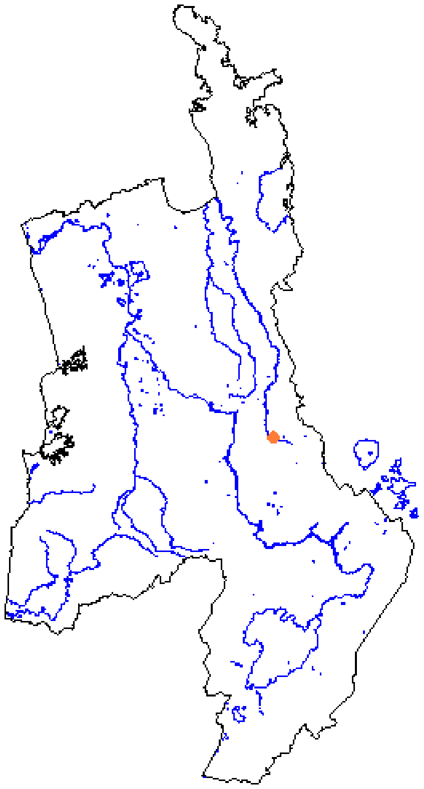
European carp (*Cyprinus carpio*)



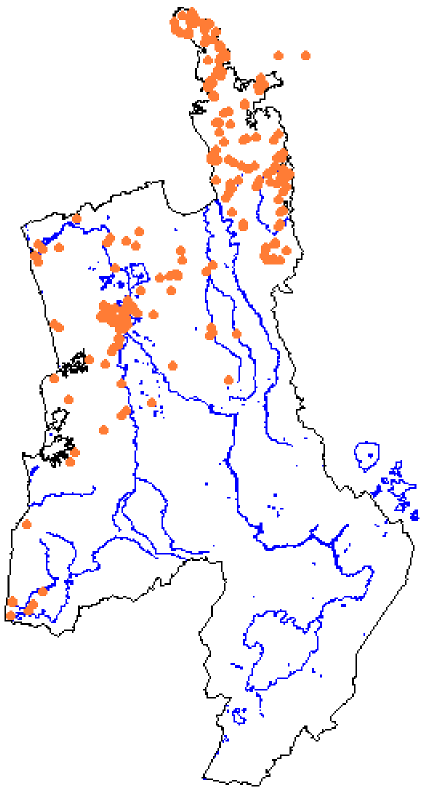
Giant kokopu (*Galaxias argenteus*)



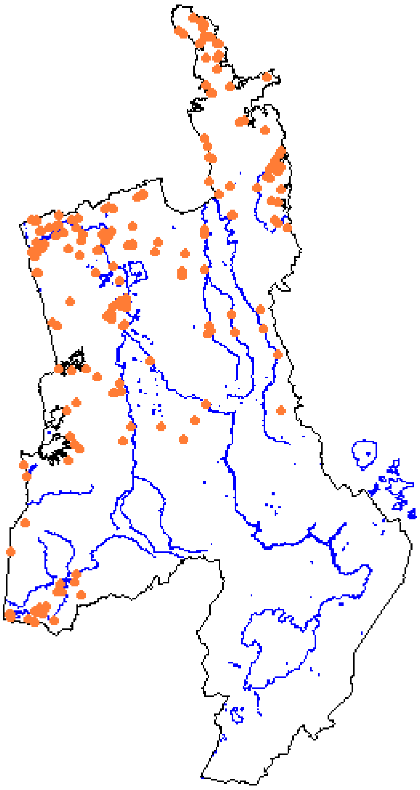
Koaro (*Galaxias brevipinnis*)



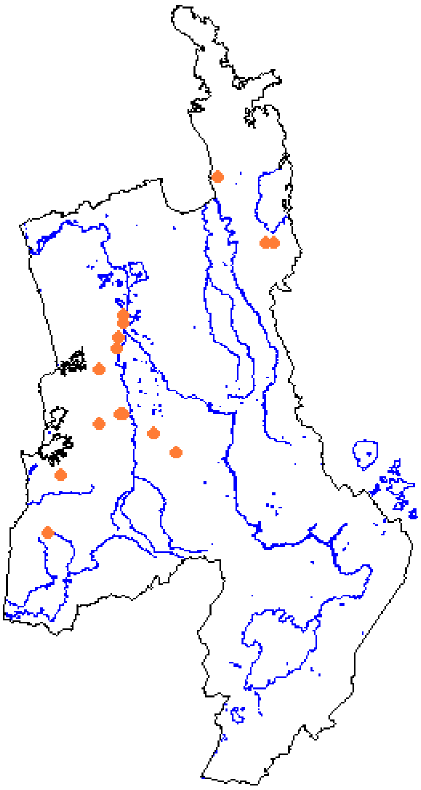
Dwarf galaxias (*Galaxias divergens*)



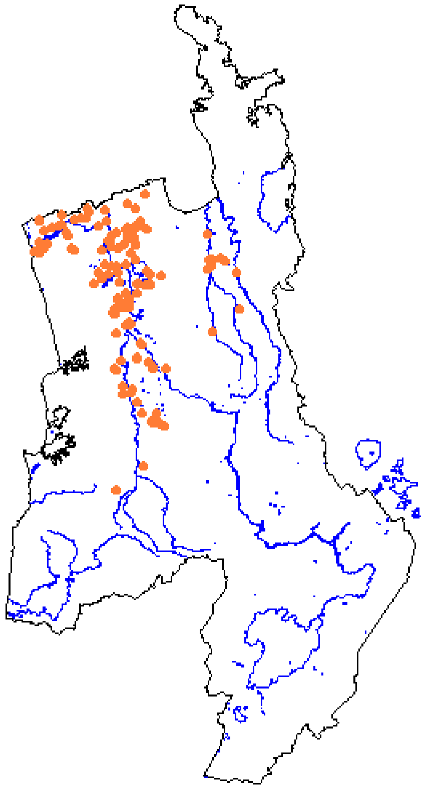
Banded kokopu (*Galaxias fasciatus*)



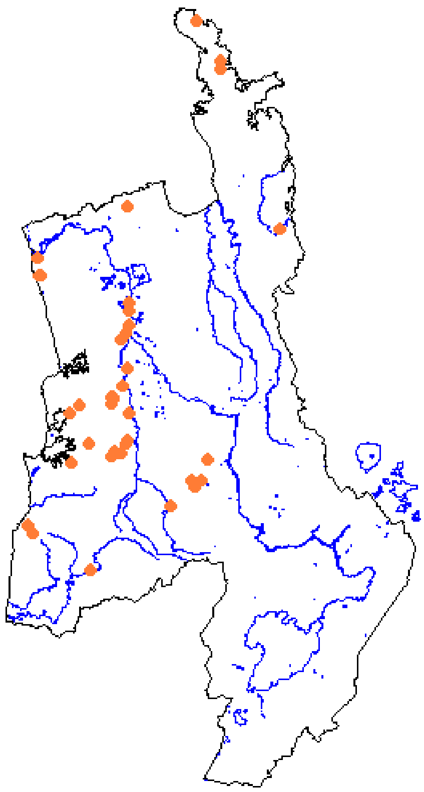
Inanga (*Galaxias maculatus*)



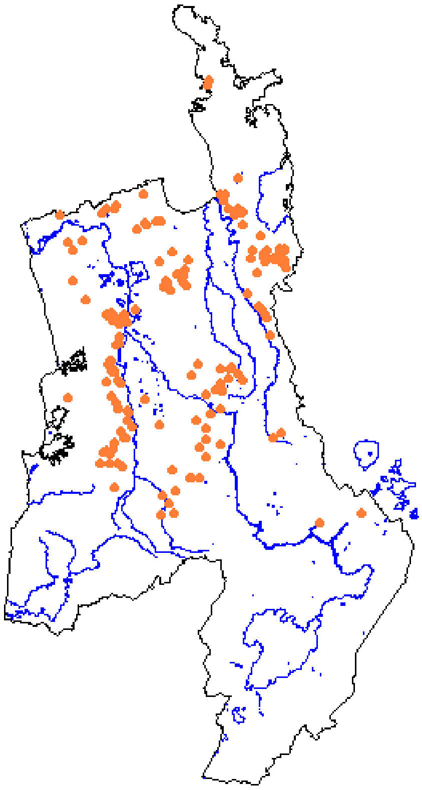
Shortjawed kokopu (*Galaxias postvectus*)



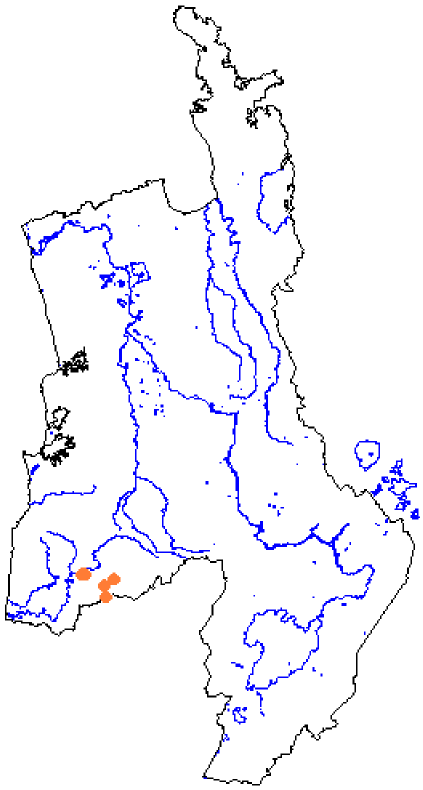
Gambusia (*Gambusia affinis*)



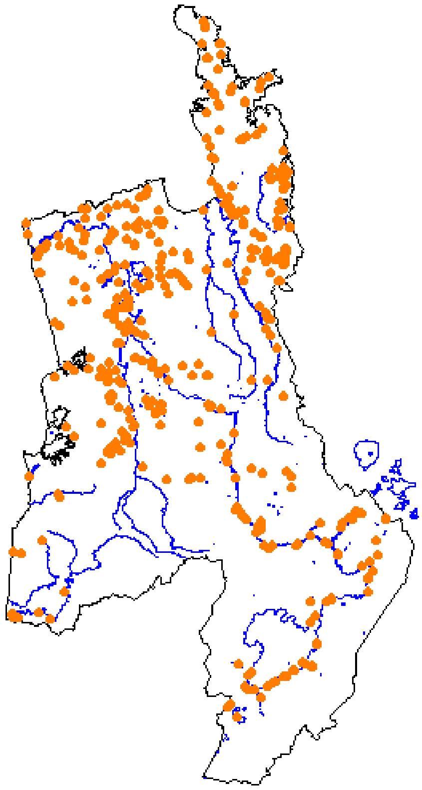
Lamprey (*Geotria australis*)



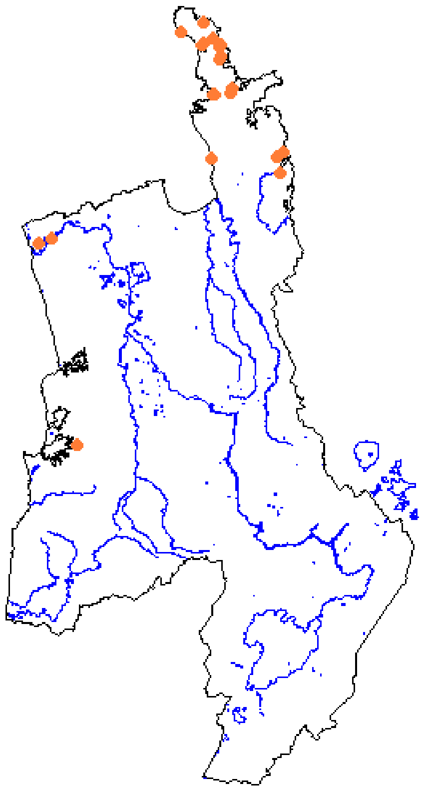
Crans bully (*Gobiomorphus basalis)*



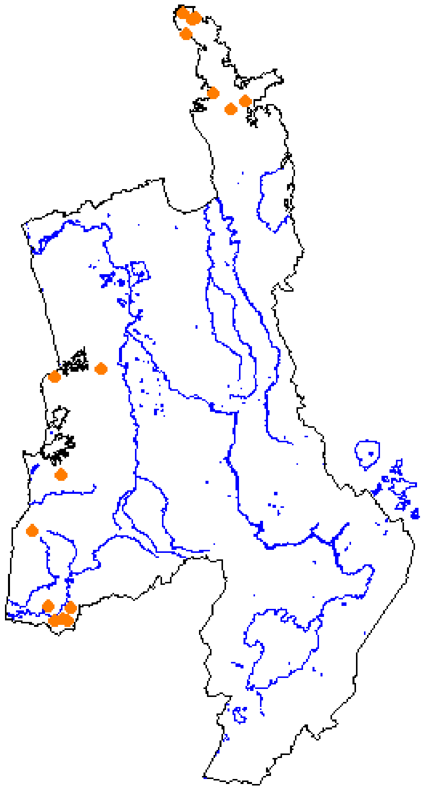
Upland bully (*Gobiomorphus breviceps*)



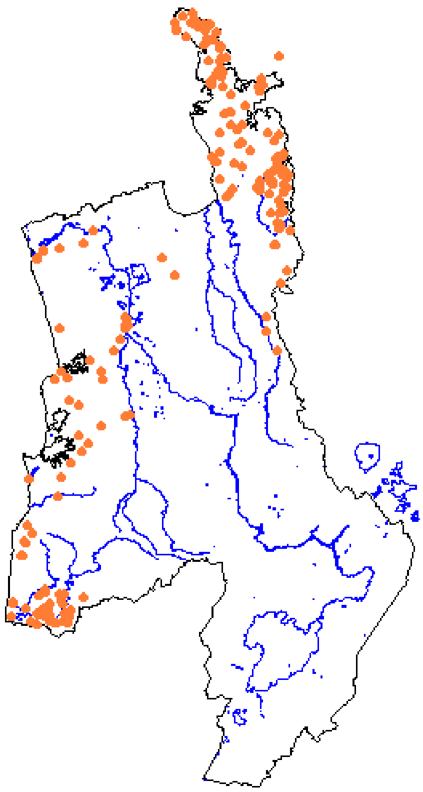
Common bully (*Gobiomorphus cotidianus*)



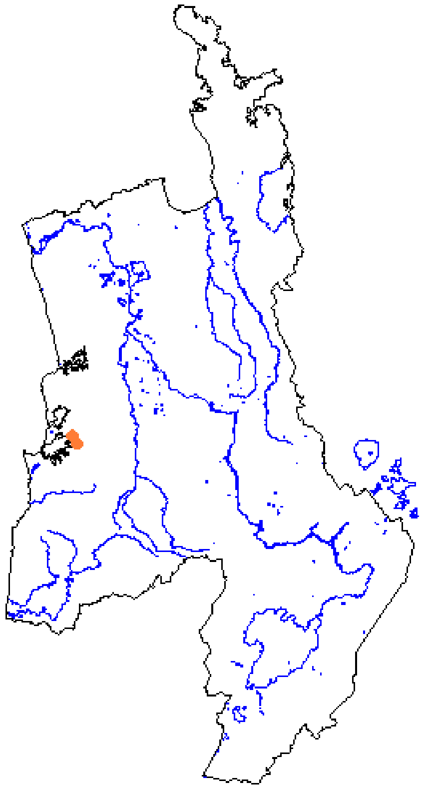
Giant bully (*Gobiomorphus gobioides*)



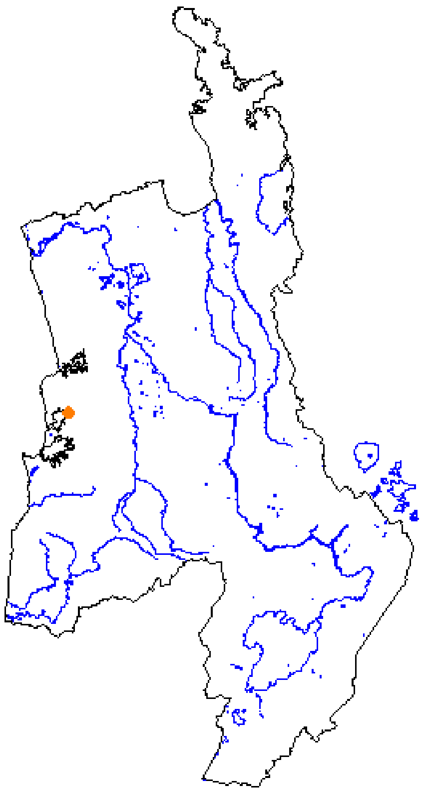
Bluegill bully (*Gobiomorphus hubbsi)*



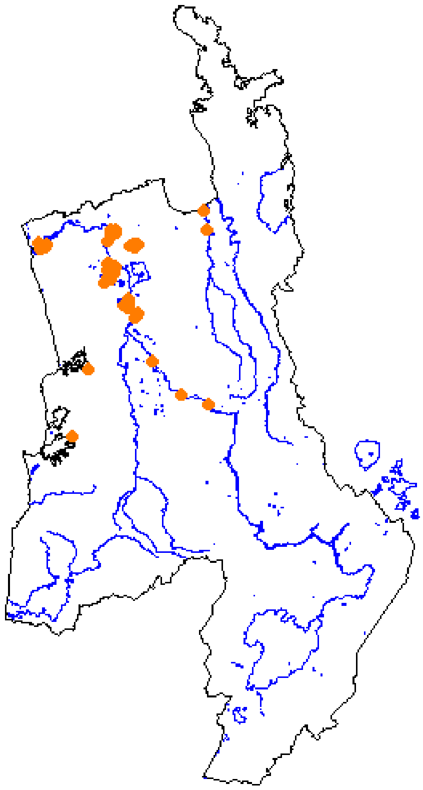
Redfin bully (*Gobiomorphus huttoni*)



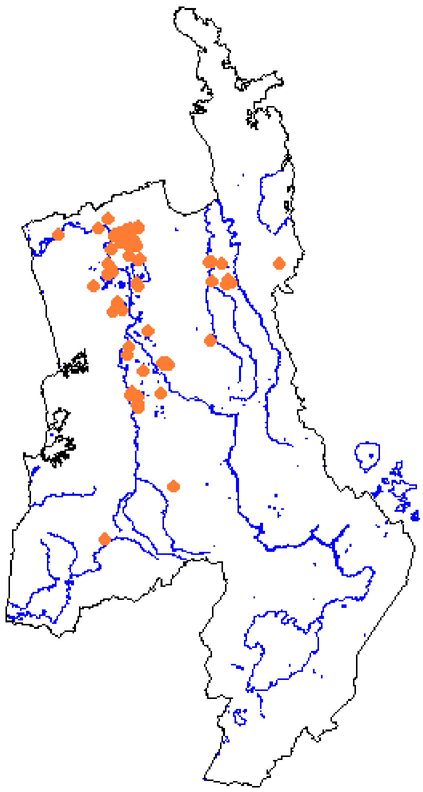
Estuarine triplefin (*Grahamina sp.)*



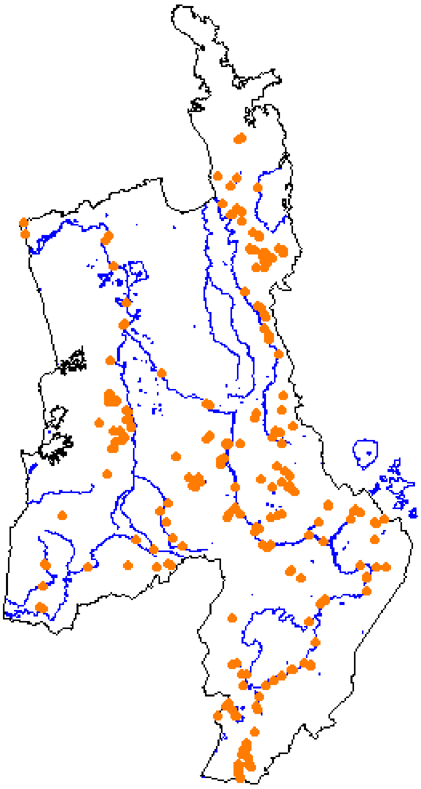
Stargazer (*Leptoscopus macropygus*)



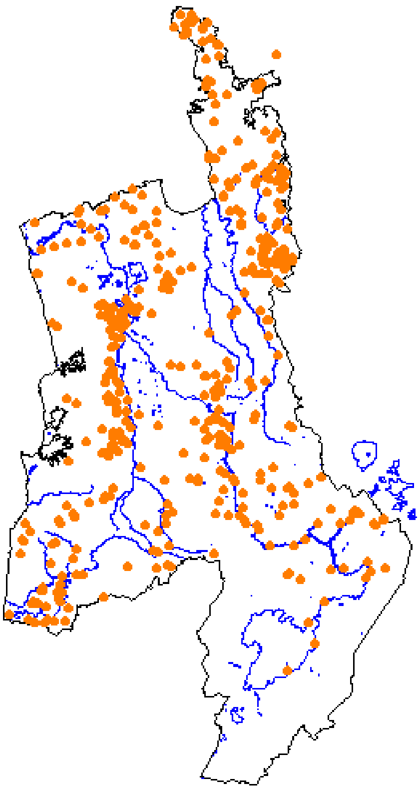
Grey mullet (*Mugil cephalus*)



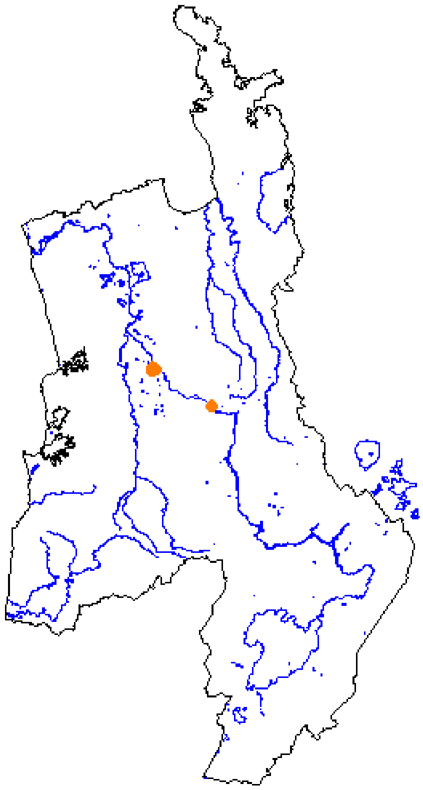
Black mudfish (*Neochanna diversus*)



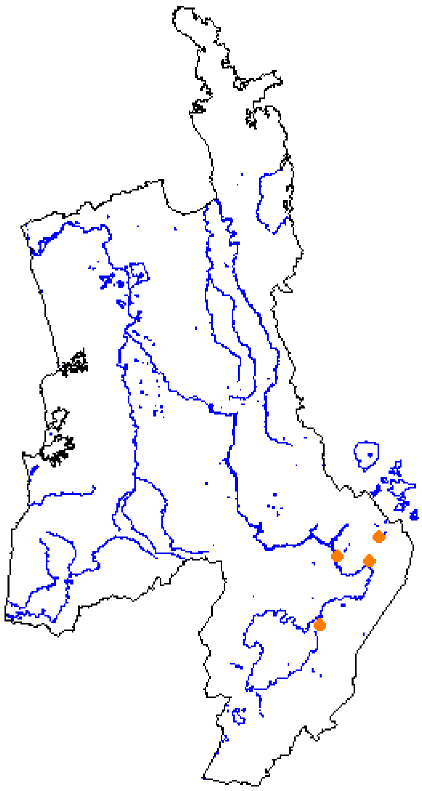
Rainbow trout (*Oncorhynchus mykiss*)



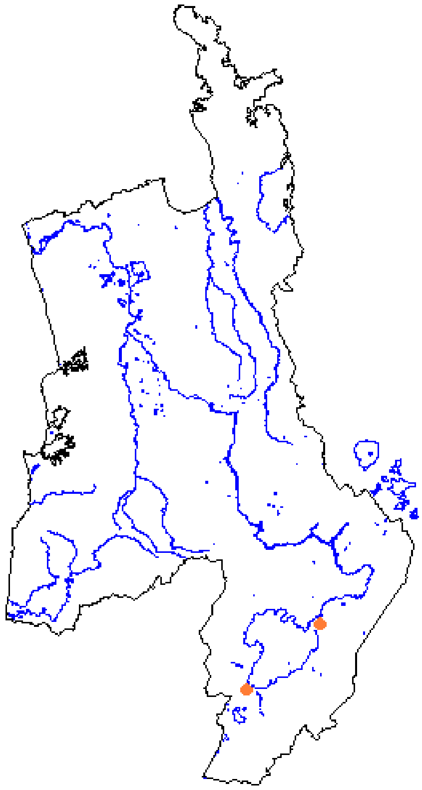
Koura (*Paranephrops sp.)*



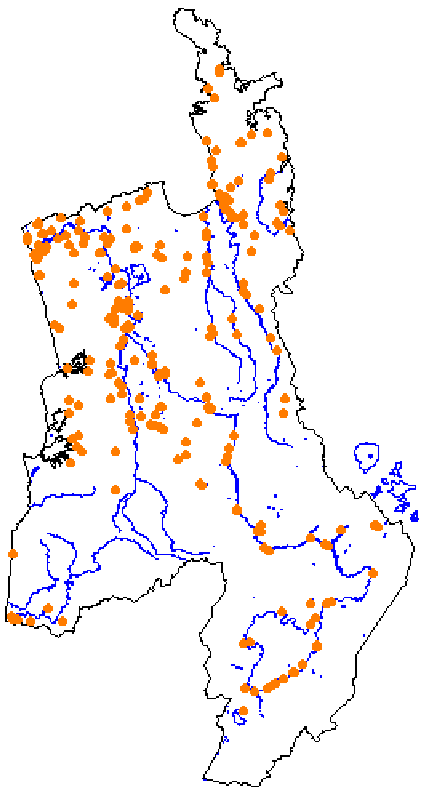
Perch (*Perca fluviatilis*)



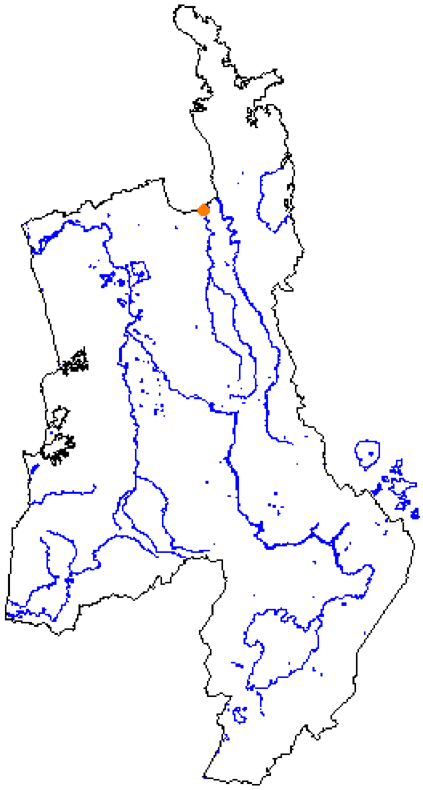
Sailfin molly (*Poecilia latipinna*)



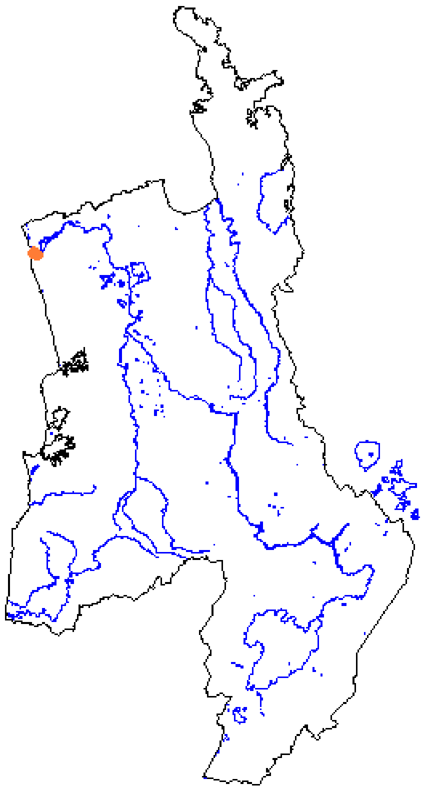
Guppy (*Poecilia reticulata*)



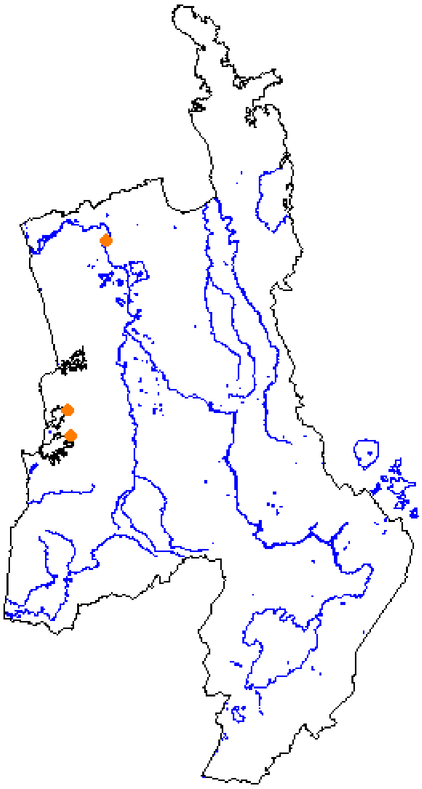
Common smelt (*Retropinna retropinna*)



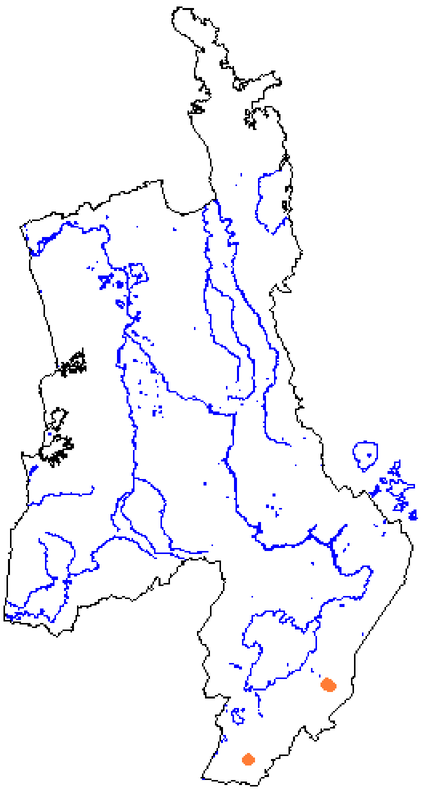
Yellowbelly flounder (*Rhombosolea leporina)*)



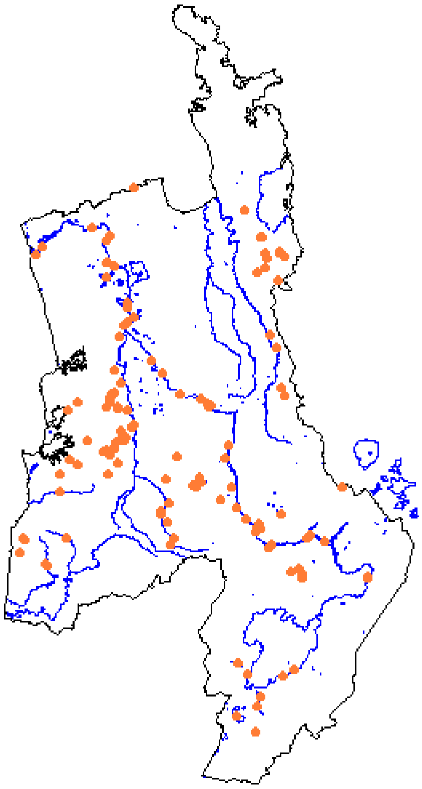
Sand Flounder (*Rhombosolea plebia*)



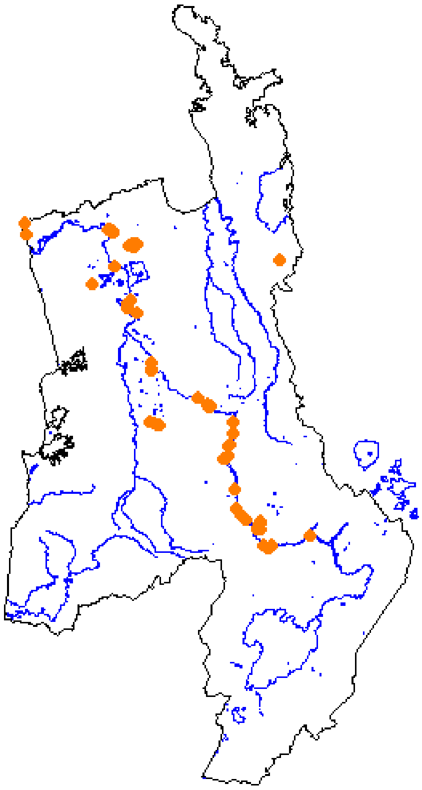
Black flounder (*Rhombosolea retiaria*)



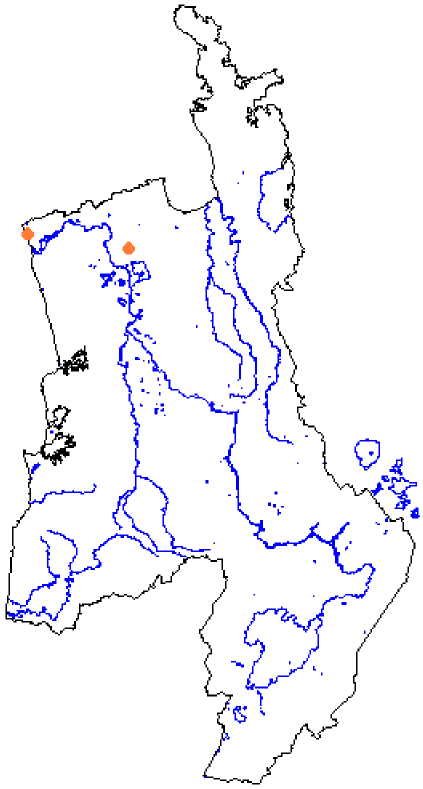
Brook char (*Salvelinus fontinalis*)



Brown trout (*Salmo trutta*)



Rudd (*Scardinius erythrophthalamus*)



Tench (*Tinca tinca*)

Appendix 2 – Annotated Bibliography of publications and reports related to the freshwater fish and fish habitat of the Waikato Region

Alabaster, J. S., Lloyd, R. (1980). Water Quality Criteria for Freshwater Fish. London - Boston, Butterworths.
Contains water quality requirements and limits for European freshwater fish species. Includes chapters on suspended solids, pH, temperature, ammonia, monohydric phenols, dissolved oxygen, chlorine, zinc, copper, cadmium, and toxicity testing procedures.

Allen, D. G. E., P.W. (1989). Lake Aratiatia fish survey. Hamilton, Ministry of Agriculture and Fisheries**:** 24.
A large fish kill occurred while lake levels were lowered in an attempt to control weed growth. This initiated an alternative method for weed control where the lake level is lowered during winter nights instead of over summer days. This is an attempt to kill off weed beds through exposure to winter frosts rather than by dehydration. This report details fish survey results before and after lake lowering.

Allibone, R. (2000). Fish population and fish passage monitoring for Orokonui Creek, Otago. Wellington, Department of Conservation**:** 8.
Deals with the monitoring of fish passage over a weir on the coastal Orokonui Stream in Otago. Includes methodology for dyeing whitebait and glass eels and for upstream/downstream monitoring of native fish populations and brown trout using a variety of methods.

Allibone, R. B., Jacques.; West, David. (1999). The ones that got away: determining whitebait movements and rates of escape. Water & Atmosphere. **7:** 11-13.
A report on mark recapture trials on inanga whitebait in the Mokau and Awakino Rivers. Discusses various staining techniques and the effect of tides and river levels on recapture rates of inanga by recreational whitebait fishers.

Anon (1988). Huntly Thermal Power Station thermal discharge water right variation - Summary report of fisheries issues. Hamilton, Anon.
A report summarising the modifications made to the power station in order to improve the fishery. This includes modifications to the intake screens and outfall. It also investigates the impacts that thermal discharge will have on fish migrations and distribution.

Auckland Acclimatisation Society. (1986). Fisheries information and wildlife values of tributaries of the Waihou River and selected streams of the Western Coromandel. Hamilton, Wildlife Service.
A selection of information about fish and other wildlife in the Waihou River and many streams of western Coromandel.

Barrier, R. F. G. (1994). Biological Resources of the Waihou River. Private Consultant report to Environment Waikato**:** 74.
This report identifies the biological resources of the Waihou River. Habitat condition is characterised, priorities for habitat rehabilitation and enhancement are set, and further resource investigations are also prioritised.

Bioresearches (1986). Fisheries impacts of the NZ Steel Elbow intake, Waikato River. Bioresearches Ltd: 26.
This study looks at the species of fish at risk of entrainment in the steel works water intake. It summarises the migration behaviour of whitebait species, glass eels, and smelt, and determines the abundance of fish species around the intake area and actually being entrained.

Bioresearches (1987). Fisheries impacts of the NZ Steel Maioro intake, Waikato River. Auckland, Bioresearches Ltd: 22.
This study looks at the species of fish at risk of entrainment in the steel works water intake. It summaries the migration behaviour of whitebait species, glass eels, and smelt, and determines the abundance of fish species around the intake area and actually being entrained. Discusses the impact of the intake and possible remedies.

Boubee, J., Nichols, S., & Jowett, I. (1998). A Review of Fish Passage at Culverts - With Potential Solutions for New Zealand Native Species. Hamilton, National Institute of Water and Atmospheric Research: 79.

Boubee, J. A., Schicker, Kathryn, P., Stancliff, Allen, G. (1991). "Thermal avoidance in inanga, *Galaxias maculatus* (Jenyns), from the Waikato River, New Zealand." New Zealand Journal of Marine and Freshwater Research **25**: 177-180.

Boubee, J., West, D., Chisnell, B. (1992). Fish survey of the Rotowaro catchment., NIWA.

Boubee, J. A. T., West, D.W. (1994). Fisheries survey of a renown mine area. Hamilton, NIWA.
A fisheries survey of the Rotowaro catchment found two diverse catchments. Tapp Stream is almost entirely pastoral while the Renown Stream flows through regenerating scrub and rehabilitated mine workings.
The pastoral nature of the Tapp Stream is reflected in its fish populations with only shortfinned and longfinned eels, and koura being recorded. Freshwater mussels and possibly common bullies are also likely to be present. Smelt and inanga migrate into lower reaches in the summer. Kokopu are unlikely to be present in significant numbers in the catchment.
In comparison the Renown Stream was found to contain banded kokopu and the less common giant kokopu as well as both species of eels and koura. No fish were caught in the settling pond of the streams above. This is most likely due to the overhanging culvert.

Burns, C. W. (1977). Biological aspects of water pollution. Wellington, Nature Conservation Council: 16.
This report gives British and American examples of water pollution and how these countries are overcoming such problems. The physical effects of pollution on the aquatic environment is discussed, as well as the effects on invertebrates and fish life. Different classes of water pollutants are discussed.

Burstall, P. J. (1955). Report on the Whanganui, Waihaha and Waihora Streams. Rotorua, Ministry of Fisheries: 9.
Descriptions of each streams catchment with associated tributaries is included. Biological descriptions include fish, spawning areas, flora, birds, deer and possum (still in low numbers and spreading).

Cada, G. F. (1990). "A review of Studies Relating to the Effects of Propeller-type Turbine Passage on Fish Early Life Stages." North American Journal of Fisheries Management **10**: 418-426.

Cada, G.F. (1997). Shaken, Not Stirred: The recipe for a Fish Friendly Turbine. Proceedings of Waterpower '97: Proceedings of the International Conference on Hydropower., New York, American Society of Civil Engineers, New York.

Cadwell, N. (1990). Low flow impacts on the Mangatangi stream. Hamilton, Waikato Regional Council.
The Mangatawhiri stream used to be an important trout fishery, however, after the construction of the Mangatawhiri dam in 1977 the trout fishery declined to the point where trout were not found at all. The main findings were:
1. DO levels were generally high
2. Temperatures increased downstream, but were lower in the tributaries
3. Periphyton community structure changed from a dominance of diatoms to a dominance of filamentous green algae over the summer.
4. Macroinvertebrates were dominated by pollution tolerant genera.
5. Macroinvertebrate and periphyton mass increased downstream.
6. Macroinvertebrates and periphyton diversity decreased downstream.
7. Fish community was depauperate.
8. Smelt and inanga were caught in reasonable numbers at only two sites.

Causes of ecological impacts identified were:
1. Sustained low flows.
2. Lack of flood events.
3. Lack of riparian cover.
4. Stock trampling.
5. Agricultural run-off.

Chisnall, B. L. (1987). Juvenile eel biology in the backwaters of the Waikato River. Biology. Hamilton, Waikato**:** 152.
The general ecology of eels in shallow backwater habitats is studied. Age/growth relationships, food availability, feeding, species distribution and associated seasonal patterns.

Chisnall, B. L. (1998). Juvenile grass carp in the Waikato River, May 1997. Wellington, Department of Conservation**:** 10.
This report by NIWA was commissioned by the Department of Conservation after the recovery of a juvenile grass carp from Lake Whangape (lower Waikato River basin) in May 1997. The report compares the growth patterns on scales and otoliths of the wild-caught juvenile grass carp with those from fish both kept in ponds and stocked in the catchment, to determine whether this fish could be an escapee or the progeny of natural reproduction in the Waikato. Conclusions suggest fish is an escapee. Recommends a database is set up of data/scales etc provided by fishers.

Church, D. F., Davis, S.F., & Taylor, M.E.U. (1979). A review of the habitat requirements of fish in New Zealand rivers. Wellington, National Water and Soil Conservation Organisation**:** 48.
New Zealand and relevant overseas information is reviewed in relation to the habitat requirements of freshwater fish. Topics dealt with include depth requirements, temperature, sediment, shelter, stream morphology, dissolved oxygen, other gases, pH, and effects of boats.

Coffey, B. T. (1974). Report on fish kills: Aratiatia lake. Hamilton, New Zealand Electricity department.
This report concerns itself with the procedure used and the results obtained when attempting to define the cause of considerable fish kill in Aratiatia Lake.

Coffey, B. T., Coates, G.D., Coleman, P, L. (1975). Huntly Power Station, Biological study: Waikato River. Hamilton, New Zealand Electricity.
A report submitted in order to investigate the flora and fauna around the proposed Huntly power station. Resident and animal communities were restricted to low flow environments (0-0.25m.sec^{-1}) during summer. Open water temperatures varied between 9.0c and 24.0c. Resident plant and animal communities are restricted to low flow environments adjacent to the river banks. It was in these areas that finely divided sediments and organic debris accumulated, and benthic communities were encountered.
Phytoplankton communities were similar in density to those present in other eutrophic environments in the central north Island of New Zealand, and were dominated by the diatom *melosira granulata var. angustissima*. No true zooplankton communities were recognised. Periphyton were common as epipelic and epiphytic communities. Egeria densa, Potomogeton crispus and Ceratophyllum demersum were the dominant submerged macrophytes. Their lower depth limits was associated with the mobility of sediments in the channel (current velocity); their upper depth limit with water level fluctuations and competition with vigorous emergents such as *Ludwigia peploides, Myriophyllum aquaticum* and *Glyceria maxima.* The extent of seasonal, emergent, macrophyte populations was limited by the extensive closed canopy of willow trees along the banks of the experimental study area.
the most abundant resident fish were the short finned eels, longfinned eel, catfish, and goldfish. Migratory species which moved through the experimental study area included eel elvers, mullet and adult eels. the migration of glass elvers and whitebait occurred downstream of Huntly

Collier, K. (1990). Fisheries and Forestry. Wellington, Department of Conservation**:** 6.
A conference on fisheries and forestry was held by MAF Fish in February 1990 to discuss the impacts of exotic pine plantation harvesting on fisheries. This brief report provides a summary of presentations and issues raised. Includes results from studies undertaken in Canada.

Coutant, C. C. (1974). Temperature Selection by Fish - a Factor in Power-Plant Impact Assessments. Environmental Effects of Cooling Systems at Nuclear Power Plants, Oslo.

Cox, T., Rutherford, K. (1998). How do fluctuating temperatures in streams affect invertebrates? Water and Atmosphere. **6:** 27-28.

Cryer, M. (1991). Lake Taupo trout production: a four year study of the rainbow trout fishery of Lake Taupo, New Zealand. Turangi, Department of Conservation.
the rainbow trout population of Lake Taupo was surveyed over a two year period using and echo sounder, multi-panel gillnets, and scuba diver counts. The number of trout in the lake was found to vary from a high of over 2 million individuals in February/March 1988, to a low of under 200,000 in November 1989. this variation was caused mostly by changes in the number of small individuals, and the number of legal sized varied only between about 60,000

and 170,000.the diet for rainbow trout was almost entirely smelt, however larger fish also took benthic fish, insects and freshwater crayfish. Over the two years the trout dynamics showed similar trends, but numbers were considerably lower in the second year.

Cudby, J. (1984). Fishery aspects of the Wairehu Canal hydro-electric scheme. Turangi, MAF.
Details the impacts that that a hydro electric proposal will have on the Wairehu Canal fishery, with recommendations for their solution.

Davenport, M. W. (1984). Investigation of the Aquatic Biological Resources of the Mangatawhiri Catchment. Hamilton, Waikato Valley Authority.
Initiated in response to proposals to build a dam in the Mangatawhiri catchment. Findings presented of a survey if the Mangatawhiri river catchment below the existing supply dam.

Davenport, M. W. S., M.J. (1985). Waikato coal fired power station investigations: review of aquatic invertebrate monitoring at Huntly and thermal tolerance studies. Hamilton, Waikato Valley Authority**:** 31.
Sampling of the aquatic macroinvertebrate fauna of macrophyte beds and the benthic fauna of fine sediments adjacent to the Huntly power station has continued to yield similarly diverse communities at sites upstream and downstream of the thermal discharge. No major changes have yet been detected. A preliminary analysis and summary is made of the acute effects of elevated temperatures on various fish and invertebrates from the Waikato River. Species which may be sensitive to thermal stress are identified.

Davidson, C. M. (1999). Morphological specialisation's for air breathing and aestivation physiology in the Black Mudfish (*Neochanna diversus* Stokell, 1949). Biological. Hamilton, University of Waikato**:** 102.
This thesis documents the physiology of aestivating black mudfish and investigated the mudfish's ability to breath air.

Davis, S. F. (1987). Wetlands of National Importance to Fisheries, Ministry of Fisheries**:** 48.
Wetlands which are known to have significant fisheries values are proposed for inclusion in a Schedule of the revised Water and Soil Conservation Act. Wetlands selected in the Waikato Region are Whangamarino Swamp; Firth of Thames; Hauraki-Piako-Kopuatai Peat Domes; Kawhia, Aotea and Raglan harbours; Lakes Taharoa, Numiti, Rotoroa and associated wetlands; and Mangaparo (Clarkes) swamp.

Dean, T. I., Richardson, Jody. (1999). "Responses of seven species of native freshwater fish and a shrimp to low levels of dissolved oxygen." New Zealand Journal of Marine and Freshwater Research **33**: 99-106.

Department of Conservation. (1992). Issues and priorities in the Taupo trout fishery: a public discussion paper, Department of Conservation.
This report discusses the issues and priorities regarding the Taupo trout fishery. Issues include water quality, hydro power development, natural impacts, fishery use and fishery status.

Department of Conservation. (1995). The Taupo Fishery - wild trout. Rotorua, Department of Conservation.

A small booklet about the trout fishery at Taupo. Colour photos, general information, etiquette etc.

Department of Conservation. (1996). Taupo sport fishery management plan. Taupo, Tongariro-Taupo Conservancy, Department of Conservation**:** 49.

Donovan, W. F. (2000). The Hinemaiaia Fishery. Auckland, Bioresearches**:** 43.
An assessment of the Hinemaiaia Fishery with respect to the effects of the Hinemaiaia Dams. Key issues relate to the effects of the dams on rainbow trout spawning habitat in the lower river which flows into Lake Taupo and on fish passage and access to the upper reaches of the river which are presently dominated by Brook Char.
This management plan sets out the goals and objectives for managing the fishery over the next 10 years. It describes the resource, the users, and native fish species issues.

Eaton, A. D., Clesceri, L.S. & Greenberg, A.E., Ed. (1995). Standard methods for the examination of water and wastewater. Washington, American Public Health Association.
Part 8 discusses toxicity monitoring methods using annelids, molluscs, crustaceans, aquatic insects and fish. Part 10 discusses biological examination of species including macroinvertebrates and fish.

Empson, P. W., Meredith, A.S., Boubee, J.A.T. & Whittman, K.H. (1992). Ichthyoplankton studies on the lower Waikato River IV. Annual variations in distribution. Hamilton, MAF Fisheries**:** 35.

Ferris, G. (1975). Rivers and lakes of the North Island. Auckland, William Heinemann Ltd.
Historical trout fishing guide covering the North Island rivers and lakes.

Fish and Game New Zealand. (1996). Fish and Game New Zealand - special edition 3 1996, NZ Fishing news.
A series of articles about tracking Waikato brown trout and general trout fishing.

Garrick, A. S. S., A.J. (1986). A preliminary assessment of the flora and fauna in the vicinity of the Huntly West No. 1 coal mine - Draft. Wildlife Service, Wellington**:** 133.
A list of fish species caught in Lakes Rotongaro and Waahi is presented as well as species biomass. There is discussion of potential impacts of coal mine expansion on fisheries and prospects for enhancement.

Hanchet, S. (1987). "Fish Survey of the Mokau River." Freshwater Catch **31**(Autumn): 13-14.
A brief report in this popular journal on the results of a fishery survey carried out in 1986 on the Mokau River for State Coal as part of an assessment of effects for a proposed coal mine in the Mokau Coal field.

Hanchet, S. (1988). The effects of Koi on the New Zealand aquatic ecosystems. Hamilton, MAFFish.
This report attempts to assess the potential impacts if koi carp on New Zealand's aquatic environment (includes aquatic vegetation, water quality,

invertebrates, waterbirds, fish). It concludes that koi carp have a detrimental impact on aquatic vegetation, fish and waterfowl.

Hanchet, S.H., Hayes, J.W., (1989) Fish and fisheries values of the Mokau River and tributaries draining the Mokau coalfield. MAF Fisheries. p. 79.
This is a fish resource inventory of the Mokau River undertaken for State Coal as part of an environmental impact assessment for a proposed development of the Mokau coalfield. Species recorded in samples and fisheries values are reported. Fish distribution is related to geomorphologic, vegetation, hydrological, and geographical characteristics of the catchment.

Hayes, J. (1998). Trout as indicators of stream health. Biological monitoring of freshwaters - seminar, Wellington, NZ Water and Wastes Association Inc. & Cawthron Institute.
Discusses Instream Flow Incremental Methodology (IFIM), and trout foraging and energetics modelling.

Hayes, J. W., Hanchet S.M. (1987). Fish Survey of the Rotowaro Catchment and Fisheries Issues Relevant to Coal Mining, MAF: 20.
Fish were surveyed from the Te Wha, Managakotukutuku, Awaroa, Waitawhara and Waikokowai streams which drain into Lake Waahi. Eels, banded kokopu, Cran's bully, common bully, mosquito fish and koura were found. The effects of past, present and future mining activities are discussed.

Hayes, J., W., Rutledge, M.J., (1987). The effect of turbidity on the diets of fish in Lakes Waahi and Whangape. Rotorua, MAF.
Stomach contents of 3 species of small carnivorous fish and of shortfinned eels were compared between two shallow lakes in the Waikato River basin to determine the effect of turbidity on diet. Lake Waahi and the south arm of Lake Whangape was, until recently, clearer an dominated by submerged macrophytes. Stomach contents of 50 common bullies, common smelt, and mosquito fish, taken during two days in spring by beach seining, were compared between each of the above 3 water bodies. Stomach contents of 149 and 159 shortfinned eels from six weekly fyke and trap net samples were compared between Lake Waahi and the main body of Lake Whangape.

Mysid shrimp dominated the diets of all species of the small fish from turbid water bodies, except for mosquitofish in the south arm of Lake Whangape. Mysids were not as important in the diets of these fish in the main body of Lake Whangape, and were not important in Lake Waahi before it became turbid. Chironomid larvae and pupae dominated the diets of small fish in the main body of Lake Whangape although mysids were important prey of shortfinned eels in both lakes, particularly in Lake Waahi. The importance of mysids in the diets of fish from Lake Waahi and the south arm is consistent with the high biomass of mysids in turbid waters in the lower Waikato River basin. Their importance, although less so, to fish in the main basin of Lake Whangape may be related to a recent increase in turbidity and biomass of mysids in that water body.

Henriques, P. R. (1979). Fish kills - Kopokorahi Arm of Lake Maraetai. Hamilton, Waikato Valley Authority: 7.
Eight goldfish kills from 1973-79 are detailed. Limited assessment of the fish kills determines the cause as de-oxygenation in all cases except for the incidents in June 1977 and April 1979. The April 1979 fish kill was due to

toxic effects from the spillage of sodium pentachlorophenate. Details of Kinleith Mill's operations are examined.

Hickey, C. W., Roper, D.S., van der Krogt, A. (1992). Upper Waikato River Freshwater Mussel Study. Hamilton, Water Quality Centre, DSIR.
Studies proposed and carried out to date in 1991/92 are reviewed. Mussels incubated (caged) for 3 months in the Kinleith effluent system have shown:
- that freshwater mussels can respond to high levels of stress within a relatively short time period
- that stress responses can be detected using physiological measurements
- physiological measurements indicated that the J pond and Kopakorahi Stream sites induced stress in mussels
- no significant physiological differences were detected between Lake Maraetai and Kinleith outfall sites
- organic analyses would form a useful addition to this study, by indicating contaminant concentrations present in stressed mussels.
This would identify the likely causal components.

Hicks, B. (1984). Methods for estimating freshwater fisheries resources. Biological Monitoring in Freshwaters: Proceedings of a Seminar, Hamilton, 21-23 November 1984 Part 2, Hamilton, National Water and Soil Conservation Authority, Ministry of Works and Development.
Describes various techniques for gathering fish abundance, identity, population dynamics, habitat, diet and exploitation rate data.

Hicks, B. J., Barrier, R. F. G. (1996). "Habitat requirements of black mudfish (Neochanna diversus) in the Waikato region, North Island, New Zealand." New Zealand Journal of Marine and Freshwater Research **30**: 135-151.
Black mudfish (Neochanna diversus) were found at 39 of 80 sites in the Waikato region, New Zealand, ranging from large wetlands to small swampy streams. Of the sites with mudfish, 87% were dry at some time during summer. Sites with mudfish also generally had emergent and overhanging vegetation and tree roots, and showed low to moderate human impact. Black mudfish coexisted at some sites with juvenile eels or mosquitofish, but were absent from all sites with common bullies (Gobiomorphus cotidianus) or inanga (Galaxias maculatus).

Sites with mudfish had almost exclusively semi-mineralised substrates or peat; only one site had mineralised substrate. Geometric mean catch rate for the 39 sites with mudfish was 0.70 fish per trap per night. Mean summer water depth was only 2.1 cm at sites with mudfish, compared to 22.6 cm at 41 sites without. Winter and maximum water depths were also less at sites with mudfish than at sites without mudfish. Mean turbidity was 11.5 nephelometric turbidity units (NTU) at sites with mudfish, but 21.3 NTU at sites without mudfish. Mudfish catch rates were negatively correlated with summer water depth, winter water depth, disturbance scale rating, and turbidity. A discriminant function model based on these variables successfully predicted 95% of the sites with mudfish. Habitat preference curves are also presented.

Humphreys, E. A., & Tyler, A.M. (1990). Coromandel Ecological region - Survey report for the Protected Natural Areas Programme. Hamilton, Department of Conservation, Waikato Conservancy**:** 283.

Jellyman, D. J. (1985). Freshwater fisheries values and impact assessment. Biological Monitoring in Freshwaters: Proceedings of a Seminar, Hamilton, 21-23 November 1984 Part 2, Hamilton, National Water and Soil Conservation Authority, Ministry of Works and Development.
The use of fish in biological monitoring is reviewed, and two NZ impact assessments are outlined.

Jellyman, D. J., Graynoth, E., Francis, R.I.C.C., Chisnall, B.L., Beentjes, M.P. (2000). A review of evidence for a decline in the abundance of longfinned eels (*Anguilla dieffenbachii*) in New Zealand. Hamilton, NIWA.
This report reviews available data to see whether there is evidence of a decline in the recruitment of longfinned eels (*Anguilla dieffenbachii*) in New Zealand waters. Data reviewed were glass elver and elver catches and species proportions , age composition of both juvenile and adult eels, changes in abundance and size distributions of longfins; computer models were then developed to simulate the influence of changes on recruitment on age and side composition of populations.

Jones, P. (1996). Biomarker and contaminant accumulation studies of caged and feral fish in the Waikato River. Lower Hutt, ESR Environmental**:** 75.
This study was designed to provide data on the presence of environmental contaminants in the Waikato River and their possible effects on fish. It investigates the accumulation and effects of contaminants in eels using a biomarker approach. The use of bullies was investigated but discarded.

Jones, P. (1999). "Monitoring Aquatic Ecosystems with Caged Eels." Water and Wastes In New Zealand(January): 39-41.
Brief paper describing methods for caging eels for in situ biomarker testing. Describes some physiological responses to various stressors and contaminants.

Jowett, I. G. R., Jody. (1995). "Habitat preference of common, riverine New Zealand native fishes and implications for flow management." New Zealand Journal of Marine and Freshwater Research **29**: 13-23.

Joy, M. K., Death, R.G. (2000). "Development and application of a predictive model of riverine fish community assemblages in the Taranaki region of the North Island, New Zealand." Journal of Marine and Freshwater Research **34**: 241-252.
Uses a reference site approach to make predictions on the effect of structures on fish migration in the Taranaki ring plain.

Kessels, G., Askey, P. (1993). Biota Survey of the Pukewhau Stream. Hamilton, Works Consultancy Services Ltd.
Works Consultancy Services Limited undertook aquatic macroinvertabrate, fish and terrestrial flora and fauna surveys of the Pukewhau Stream, Coromandel on the 8 and 9 December 1994. The purpose of this study was to identify any significant fauna or flora species or communities within the Pukewhau Stream catchment that may be affected by the water abstraction proposal for the Coromandel water supply.
The biota is of a relatively stable, healthy and unmodified catchment typical of many such streams on the Coromandel peninsula. Macroinvertabrate diversity and density was high, and indicate cool water temperatures and stable flows. Fish fauna is typical of well vegetated streams with physical

characteristics providing a diversity of habitats. No rare or endangered species were found. A reduction in water flows would result in adverse effects downstream of intake site. the most principle results will be a reduction in the habitat availability. It may also impede the movement of galaxiid fish species.

Kingett Mitchell & Associates. (1994). ECNZ Riparian Protection Project - Native Fisheries Enhancement, Kingett Mitchell & Associates Ltd: 22.
ECNZ commissioned this report to look at a number of streams that could have their habitat enhanced to encourage native fish populations. This mitigation effort is to help minimise any effects of the Huntly power station on native fisheries of the Waikato River. The status of stream habitats and fish populations in the lower reaches of the Waikato River are summarised. The Waioteatua Stream tributary, "Firing Range", "Forested" and "Never Never" streams were selected for fencing and riparian planting.

Kingett Mitchell &Associates., Ministry of Energy - State Coal Mines. (1988). Aquatic resources in the Rotowaro area and Lake Waahi existing and predicting conditions. Auckland, Kingett Mitchell & Associates.

An improved water clarity of Lake Waahi will facilitate re-colonisation by aquatic plants. This, in turn, may encourage more diverse invertebrate, fish and water fowl communities.

Mining operations in the catchment could influence aquatic biological resources via the disposal of waste water or the diversion and relocation of streams. The potential effects this may have on aquatic resources in the catchment can be assessed by examining existing and proposed operations.

Waste water disposal practices in the Rotowaro district are currently being revised. Proposed changes will reduce the output of suspended solids into the receiving stream waters. Neutralisation of waste water will eliminate the problem of pH fluctuations, and also reduce concentrations of zinc and nickel to levels that are not toxic to aquatic life. Previously affected biological communities immediately downstream of waste water discharges will respond to these changes. An increase in the diversity of invertebrates is expected to as animals arrive through drift from upstream areas, or migrate into and re-colonise these areas. However, North Island agricultural catchments are not expected to change following the reduction of suspended solids in the mine effluents, due to the natural background levels in agricultural catchments.

Any reduction in suspended solid output from the Rotowaro coalfields will improve the clarity of Lake Waahi. Once water clarity conditions are suitable for plant growth, aquatic plants previously inhabiting the lake may re-colonise. This will depend on many factors, including suitability of sediments root growth, wave action, wind exposure and nutrient regime of the lake.

Lintermans, M. (2000). The Status of Fish in the Australian Capital Territory: A Review of Current Knowledge and Management Requirements. Environment ACT: Canberra. p. 108.

Livingston, M. E. (1987). Fish and wildlife habitat assessment in rivers: An annotated bibliography. Wellington, National Water and Soil Conservation Authority: 186.

This document gives an annotated bibliography of work in the field of fish and wildlife habitat assessment in rivers. It is presented alphabetically and in subject groupings.

Lokman, P. M., Young, Graham. (2000). "Induced Spawning and early ontogeny of New Zealand freshwater eels (Anguilla dieffenbachii and A. australis)." New Zealand Journal of Marine and Freshwater Research **34**: 135-145.
Artificially induced spawning and egg development and hatching in short and lonfinned eels was carried out. Electron micrographs of egg development and leptocepahli are included.

Mallen-Cooper, M. (1999). Developing Fishways for Non-salmonid Fishes: A Case Study from the Murray River in Australia. Innovations in Fish Passage Technology. M. Odeh. Bethesda, Maryland, American Fisheries Society**:** 173-196.

McCarter, N. H. (1990). Environmental tolerances of native fish species: A literature review. Rotorua, MAF Fisheries**:** 24.
Literature is reviewed under the following topics: 1. summary of species; 2. environmental tolerances (water quality and measuring methods); and 3. principle environmental factors.

McCullogh, C. D. (1998). Habitat Requirements of Key Palustrine Wetland Species in the Waikato Region. Hamilton, McCulloch Freshwater Consultancy.

McDowall, R. M. (1982). A listing of Ministry publications on freshwater fish and fisheries. Christchurch, Ministry for Agriculture and Fisheries**:** 92.
This document lists all publications produced by MAF including research bulletins, occasional publications, technical reports etc.

McDowall, R. M. (1984). The status and exploitation of non-salmonid exotic fish in New Zealand. Christchurch, Ministry of Agriculture and Fisheries**:** 61.
Covers the history and status of introduced fish in New Zealand. Potential use and management is discussed.

McDowall, R. M. (1984). Escape of grass carp from the Aka Aka-Otaua drainage system. Christchurch, Ministry of Agriculture and Fisheries**:** 67.
Describes the events leading up to and following the escape of grass carp from the Aka Aka and Otaua drainage system.

McDowall, R. M. (1990). Conservation of New Zealand's Freshwater Fishes. Christchurch, MAF Fisheries**:** 62.
Includes status reports on native and introduced freshwater fish in New Zealand.

McDowall, R. M. (1990a). New Zealand Freshwater Fishes - A Natural History and Guide. Auckland, Heinemann Reed & MAF Publishing Group.

McDowell, R. M. (1991). Fish populations and fisheries of the Lower Waikato River and The Impacts of Huntly Thermal Power Station. Christchurch, MAF.
This report aimed to collect information on a) migratory fish pathways in the lower Waikato River, and b) resident fish populations in the Waikato River at Huntly. It also briefly describes the Waikato river, the impacts that human activities have had on the river, the knowledge of

the fish fauna of the river, reviews the fisheries amenities and evaluates the likely impacts on the fish fauna.

McDowall, R. M. (1993). Potential impacts of the discharge of cooling waters from the Huntly power station on larvae of common smelt *(Retropinna retropinna)*. Christchurch, NIWA**:** 11.
Spawning and hatching of common smelt takes place in the Waikato River from about Ngaruawahia downstream, with much of it below the thermal discharge from the Huntly thermal power station. The thermal discharge has an elevated temperature average of 8.6 oC. As smelt larvae hatch and migrate during autumn-winter and there is rapid mixing of the thermal discharge it is considered that the discharge will not be of concern to larval smelt populations.

McDowall, R. M. (1995). "Seasonal pulses in migrations of New Zealand diadromous fish and the potential impacts of river mouth closure." New Zealand Journal of Marine and Freshwater Research **29**: 517-526.
Provides information on the seasonal migrations (timing) of 16 New Zealand freshwater fish and the potential for these seasonal migrations to be impacted by river mouth closure.

McDowall, R. M. (2000). The Reed Field Guide To New Zealand Freshwater Fishes. Auckland, Reed Books.

McDowall, R.M., Eldon, G.A., The ecology of whitebait migrations (Galaxiidae: Galaxias spp.). 1980, Ministry of Agriculture and Fisheries: Christchurch. p. 172.
This study sampled rivers along the West Coast of the South Island, in particular the Waiatoto River system. Whitebait samples collected are analysed to determine age, migratory patterns, stocks, management etc.

McDowall, R.M., Eldon, G.A., Bonnett, M.L.; Sykes, J.R.E., Critical habitats for the conservation of shortjawed kokopu, Galaxias postvectis (Clarke). 1996, Department of Conservation. p. 80.

Meredith, A. S. (1989). The contributory catchments of the Whangamarino wetland: Biology and water quality considerations. Hamilton, Waikato Catchment Board**:** 44.
Whangamarino contributory catchments are described and information shortfalls identified. Further investigations are suggested to enable catchment management to be addressed.

Meredith, A. (1990). Piako/Waitoa Fisheries Studies. Hamilton, Waikato Regional Council.
Piako/Waitoa management plan investigations identified there was no information on the composition or state of the fisheries resources of the catchment. This report details the results of a spring survey of the catchment. Over 40 sites were surveyed to give an estimation of species diversity and distribution.

Meredith, A. (1996a). The Role of Fisheries Data in Regional Monitoring of the Waikato Region: 1. A Bibliography of Publications and Sources of Information. Hamilton, Waikato Regional Council.
an annotated bibliography of all relevant fisheries publications. see also part 2

Meredith, A. (1996). The Role of Fisheries Data in Regional Monitoring of the Waikato Region: 2. The Significance of Barrier Structures to Fish Distributions. Hamilton, Waikato Regional Council.
This report assesses the extent of physical barriers to fish movement in the Waikato Region. The range of natural and artificial physical barriers is listed and then a list of such known barriers in the Region is listed. A series of species specific distributions are presented for the lower Waikato/Waipa catchment. This allows consideration of fish distribution patterns in relation to barriers.

Meredith, A. S. (1998). Huntly Power Station macroinvertabrate sampling: fish egg by-catch significance. Hamilton, Waikato Catchment Board.
When collecting macroinvertabrates their is often a by-catch of fish eggs. These eggs are almost exclusively of the feral goldfish which is a seasonal and temperature dependant spawner in marginal weedbeds. this starts in October when the water temperature rises above 16.0c, and finishes around March. Most spawning activity is in spring and early summer.

Meredith, A. S., Davenport, M.W. & Scrimgeour, G.J. (1988). NZ Forest Products, Kinleith mill investigations - Effects of pulp and paper mill effluent on macroinvertebrate and fish communities in Lake Maraetai. Hamilton, Waikato Catchment Board: 37.
Fish communities in Lake Maraetai are surveyed for the effects of the Kinleith mill effluent discharge. Rudd and goldfish were most abundant at effluent effected sites. Brown trout and rainbow trout were found only at 'clean' sites. Common bully were caught at both sites, and smelt were caught mainly at clean water sites but also at dilute effluent affected sites. These small native fish numerically dominated the catch in summer but in winter they were less abundant. Total biomass did not generally differ between clean and affected sites.

Meredith, A., Empson, P., Fish communities of Coromandel streams: and an assessment of the effect of water supply intakes and other structures on fish communities. 1995, Environment Waikato: Hamilton. p. 20.
Fish sampling was undertaken at sites also sampled for macroinvertebrates and habitat characterisations. No exotic fish species were found highlighting the high value of these waterways. Further fish sampling was conducted to characterise the impacts of community water supply intakes on fish communities throughout the Peninsula. Various effects were recorded depending on intake structure type.

Meredith, A. S., Empson, P.W., Boubee, J.A.T. & Mitchell, C.P. (1987). Ichthyoplankton studies on the lower Waikato River. I. Entrainment at Huntly power station. Rotorua, MAFFish: 22.
The survival of Ichthyoplankton and other zooplankton entrained in the condenser cooling water of Huntly power station was studied. Smelt larvae suffered 100% mortality at 32 oC. There appeared to be no mortality of zooplankton but post-larval fish suffered 100% mortality. A large number of planktonic invertebrates, predominantly copepods and cladocerans, were present in both river and outfall samples throughout the year. Zoaea of freshwater shrimp *(Paratya)* are over 1000 times more numerous than any larval fish species migrating past Huntly, but they appear to be unaffected by

entrainment at winter and spring temperatures. Other authors had found that *Paratya* were thermally sensitive.

Meredith, A. S., Empson, P.W., Boubee, J.A.T. & Mitchell, C.P. (1989). Ichthyoplankton studies on the lower Waikato River. II. Larval distributions at Huntly. Rotorua, MAFFish**:** 58.
Plankton nets were set across the Waikato River near the Huntly power station. Four types of larvae were caught - smelt, bullies, goldfish, and kokopu. Densities were highest during darkness. Distinct distribution patterns were evident.

Mills, G. N. (1995). Mercury and arsenic in Waikato River fish. Hamilton, NIWA.
This report used Hg and As in fish flesh in order to determine their levels in Waikato River fish. Their levels were generally above background levels and generally increased up stream. Hg and As levels were below health regulations for human consumption however the consumption of trout and eels at some sites could potentially pose a threat to human health due to bio-accumulation of Hg. Hg levels were similar to those obtained in earlier studies, however As levels were higher than those reported earlier. This data shows that fish act as a useful biomonitor of Hg.

Mitchell, C. P. (1983). The value and function of the elver pass at the Huntly thermal power station. Rotorua, Ministry of Agriculture and Fisheries**:** 18.
An elver pass was constructed to allow elvers to migrate upstream past the Huntly thermal power station. Elver use of the pass was monitored between December 1981 and January 1982. Elver migration does not appear to be affected by power generation and the associated water discharge. Other fish species could not use or were not attracted to the pass.

Mitchell, C. P. (1990). Fish Passes for native Fish: A Guide for Managers. Hamilton, MAF Fisheries**:** 20.
Provides information on the distribution and life cycles of native fish, their migratory behaviour and fish pass designs for the various swimming types and capabilities of native fish. Also provides a good assessment of the various problems associated with fish passes and their design and problems caused by water takes.

Mitchell, C. P., Smith, P.J., & Northcote, T.G. (1993). "Genetic differentiation among populations of new Zealand common smelt, *Retropinna retropinna* (Richardson), from the Waikato basin." <u>New Zealand Journal of Marine and Freshwater Research</u> **27**(2): 249-255.
Discusses in some detail the genetic and morphological variation within populations of smelt within the lower Waikato in particular with reference to the Waikato River, Lakes Whangape, Waahi, Rotomanuka, Rotongaro, Rotokauri, Rotorua and Rotoiti.

Morgan, D. R., & Graynoth, E. (1978). The influence of forestry practices on the ecology of freshwater fish in New Zealand - An introduction to the literature. Christchurch, Forest Research Institute**:** 36.
This report gives an overview of the literature available at the time dealing with the effects of forestry practises. Topics covered include stream flows, sediment, debris, steam morphology, dissolved oxygen, light, temperature, nutrients, dissolved inorganic and organic materials, chemicals, and mill pollution.

Nichols, S. N. (1996). Studies on Freshwater Shrimp *Paratya curvirostris* (Heller, 1862) in the Waikato River. Department of Biological Sciences. Hamilton, University of Waikato.

Nickel, M. (1982). Grass carp for aquatic weed control: preliminary cost comparisons, Economics Division, Ministry of Agriculture & Fisheries: 15.
Speculative results on the various costs of mechanical vs. chemical vs. biological weed control. Weed control by grass carp appears to be slightly cheaper than chemical control and far cheaper than mechanical control.

NIWA Ecosystems. (1993). The environmental impacts of operating the Mangatawhiri Dam on downstream ecosystems, NIWA: 84.
This report is part of a resource consent application providing an assessment of any actual or potential effects that the dam and reservoir may have on the environment, and the ways in which any adverse effects may be mitigated. The study focuses on periphyton, water quality, and fisheries. It was concluded that a fish passage was unnecessary as all fish species occurring above the gorge were found above the weir. Discussion about the re-establishment of a trout fishery is included.

Odeh, M., Ed. (1999). Innovations in Fish Passage Technology. Bethesda, Maryland, American Fisheries Society.
A series of papers dealing with recent advances in fish passage at structures and techniques. Includes examples from simple passes on weirs to passes designed for downstream passage at large Hydro Dams and the use of acoustic and light screens.

Palmer, D., Boubee, J.A.T., & Mitchell, C.P. (1987). Impingement of fish and crustacea at Huntly thermal power station, MAF Fisheries: 40.
This report investigates the impingement of fish on the intake screens at Huntly thermal power station and recommends improvements to the intake structure.

Plafkin, J. L., Barbour, M.T., Porter, K.D., Gross, S.K. & Hughes, R.M. (1989). Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. Washington, US Environmental Protection Agency.
Details the rapid bioassessment protocols designed to provide basic aquatic life data for planning and management purposes.

Poynter, M. (1985). Bream Bay catchment freshwater fisheries report. Dargaville, Northland Federation of Acclimatisation Societies (Inc.): 9.
This report identifies the freshwater fishery values of the rivers, streams and estuaries of the Bream Bay catchment. Water management options are discussed to help protect and sustain the ecological values of the freshwater and estuarine environments that are interconnected.

Pridmore, R. D., Cooper, A.B. (1985a). Biological Monitoring in Freshwaters - Part 1. Biological Monitoring in Freshwaters, Hamilton, National Water and Soil Conservation Authority.
A series of papers presented at a conference covering
- Philosophy on monitoring
- Biostatsitics

- Monitoring of aquatic plants
- Monitoring of aufwachs communities
- Monitoring of macroinvertabrates
- Monitoring of fish

Pridmore, R. D., Cooper, A.B. (1985). Biological Monitoring in Freshwaters - Part 2. Biological Monitoring in Freshwater, Hamilton, National Water and Soil Conservation Authority.

Richardson, J. (1998). Fish Health Profile Manual, NIWA**:** 89.
Manual provides instructions for conducting fish health profiles using the U.S. methodology, with a few NZ adaptations. Colour photographs are included showing various organs.

Richardson, J., Boubee, J.A.T., West, D.W. & Mora, A.L. (1993). Thermal tolerance of adult freshwater fish: implications for Huntly thermal power station. Hamilton, NIWA**:** 20.
The thermal rank and short term (10 min) tolerance of six species of native freshwater fish were determined by laboratory tests. Smelt were the most sensitive species, and had a short term LT50 of 31.9^{o}C when acclimatised at 20 ^{o}C. Long term tests showed the LT50 for smelt acclimatised at 20^{o}C decreased to about 27 ^{o}C after five days. Recommends 1) rapid mixing of the thermal discharge should continue; 2) instantaneous temperature in the mixing zone should not exceed 30 ^{o}C; and 3) daily mean temperature in the fully mixed discharge should not exceed 25 ^{o}C.

Richardson, J., Boubee, J.A.T., West, D.W., Mora, A.L. (1993). Temperature Preferences and Avoidance Temperatures of Selected Freshwater Species: Implications for Huntly Thermal Power Station. Hamilton, NIWA Ecosystems.

Richardson, J., Jowett, I., Smith, J., Christiansen, R., Christiansen, B. (2000). Inanga comings and goings - what happens to the whitebait that do get away? Water & Atmosphere. **8:** 6-7.
Brief article on fish movement in and out of a Mokau stream. Size and age at migration and seasonality of migrations.

Richardson, J., McDowall, R.M., An annotated bibliography of the indigenous New Zealand freshwater fish. 1987, MAFFish: Wellington. p. 138.
Updated bibliography with over 2000 titles. Restricted to indigenous freshwater fish.

Richmond, C. J. (1984). Bioassays using freshwater fish for water quality monitoring and assessment. Biological Monitoring in Freshwaters: Proceedings of a Seminar, Hamilton, 21-23 November 1984 Part 2, Hamilton, National Water and Soil Conservation Authority, Ministry of Works and Development.
Provides information on the existing and potential uses of fish bioassay techniques, and comments on their application and interpretation.

Rowe, D. K. (1984). Fishery values and water quality. Biological Monitoring in Freshwaters: Proceedings of a Seminar, Hamilton, 21-23 November 1984 Part 2, Hamilton, National Water and Soil Conservation Authority, Ministry of Works and Development.
Fish stocks are defined by species and catchment, and fishery values are classified into ecological, biological/scientific, and exploitable categories.

Once fishery values in a catchment are known, the water quality and quantity limits needed to conserve them can be determined. Recommends that managers should emphasise trial-and-error approaches to setting water right limits.

Rowe, D. K. (1984). Importance of water temperature to the trout fishery in the lower Waikato River, Fisheries Research Division, MAF, Rotorua.
Discusses the effect of temperature perturbations from geothermal inputs on the distribution of trout. Trout in the Waikato River are near the NZ geographical limit to their naturally self-reproducing population range, which is probably determined mainly by temperature.

Rowe, D. K. (1996). Interim report on studies related to the effects of land-use changes on native fish. Hamilton, NIWA.
Financial support from Carter Holt Harvey Forests Ltd. has resulted in a successful bid to FRST on the effects of suspended solids on fish migrations in coastal streams and rivers. This will enable suspended solids guidelines for coastal streams and rivers to be developed for industries such as forestry. Studies supported by Carter Holt Harvey Forests Ltd. established (1) that native fish species were relatively scarce in rivers with high levels of SS during the fish migration season, and (2) that streams in native forest. however, fish communities in pasture streams differed significantly from those in forested streams. Some implications of these findings are discussed.

Rowe, D. K. & Schipper, C.M. (1985). An assessment of the impact of grass carp *(Ctenopharyngodon idella)* in New Zealand waters. Rotorua, Ministry of Agriculture and Fisheries**:** 177.
This report documents the history of grass carp experiments in NZ. It also outlines the biology of grass carp and describes potential uses and impacts.

Rowe, D., Town, J., Cosh, D., & Scott, J. (1985). Report and recommendations on the future of grass carp *(Ctenopharyngodon idella)* in New Zealand, Ministry of Agriculture and Fisheries**:** 28.
This report reviews submissions made on the MAF environmental impact assessment of grass carp in NZ. It outlines the MAF Co-ordinating Committee's conclusions on the use of grass carp as a weed control agent and makes recommendations on the future of these fish in NZ. It concludes that grass carp will not reproduce in NZ waters except for the Lower Waikato River. Here, spawning may occur, but at worst a small low-density population would develop. This would not create any observable impact on the Waikato River, or its flora and fauna. The controlled use of grass carp is recommended, with the possible general availability of grass carp a future option.

Saxton, B. A. (1985). Trout in the lower Waikato River. Rotorua, Ministry of Agriculture and Fisheries**:** 22.
Brown trout were introduced into the lower Waikato River in 1873, and rainbow trout in 1883. This report reviews the existing published data on trout populations and details results from fish analysed from a fishing competition in the area. Few sea-run brown trout are found in the Waikato River. Information on size, species composition, and sex ratios is discussed.

Schicker, K. P., Boubee, J.A.T., Palmer, J.D., A G Stancliff, A.G. & Mitchell, C.P. (1989). Elver movement in the Waikato River at Huntly, MAF Fisheries**:** 28.

This report describes the distribution of elvers in the Waikato River at Huntly during their upstream migrations. It discusses the elvers ability to negotiate thermal and velocity barriers created by Huntly thermal power station.

Shaw, D. J., Fletcher, M., Gibbs, E.J., (1985). Taupo - A treasury of trout, Taupo Times Ltd.
This book looks at the Taupo fishery, investigating the fishing activity itself as well as the economic benefits to the local community.

Simon, M. (1986). Responses of common smelt larvae *(Retropinna retropinna)* to continuous and short-term elevated temperatures: assessing the effects of thermal plume entrainment. Hamilton, Waikato Valley Authority**:** 18.
This report describes studies on the temperature tolerance of smelt larvae, in an attempt to assess the potential impacts of thermal discharges on larval fish migration in the lower Waikato River. An earlier study Simons (1984) had found smelt to be the most sensitive to elevated temperatures. Results suggest that the proposed thermal discharge will not affect smelt larvae except possibly in summer. Management of the discharge could ensure that adverse effects do not occur.

Simons, F. J. (1983). Preliminary investigation of the responses of juvenile shortfinned eels *(Anguilla australis)* to elevated temperatures. Hamilton, Waikato Valley Authority**:** 20.
Eels at various acclimated temperatures were tested for their response to elevated temperatures. The significance of the results is discussed in reltion to thermal discharges into the Waikato River.

Simons, M. (1984). Species-specific responses of freshwater organisms to elevated water temperatures. Hamilton, Waikato Valley Authority**:** 17.
Critical thermal maximums are determined for 6 fish (smelt, inanga, Cran's bully, common bully, shortfinned eel elvers, and mosquitofish) and 2 crustaceans (freshwater crayfish, freshwater shrimp). Animals acclimated to 20^{o}C had higher CTM's than those acclimated to 12 ^{o}C, and the thermal tolerance ranking of species was unaffected by acclimation temperature.

Simons, M. (1986). Effects of elevated temperatures and thermal shock on larval fish: ecological implications with respect to thermal plume entrainment. Hamilton, Waikato Valley Authority**:** 28.
Larval temperature tolerance and Ichthyoplankton migrations in the Waikato River are discussed in relation to the proposed development of a thermal power station at Clune Road. Larval activity and survival following a sudden elevation in temperature and continuous exposure is dependant on species, acclimation temperature, magnitude of temperature change and duration of exposure. Smelt larvae seemed more sensitive to high temperatures than inanga larvae.

Simons, M. (1986). Responses of common smelt larvae *(Retropinna retropinna)* to continuous and short-term elevated temperatures: assessing the effects of thermal plume entrainment. Hamilton, Waikato Valley Authority**:** 18.
This report describes studies on the temperature tolerance of smelt larvae, in an attempt to assess the potential impacts of thermal discharges on larval fish migration in the lower Waikato River. An earlier study Simons (1984) had found smelt to be the most sensitive to elevated temperatures. Results suggest that the proposed thermal discharge will not affect smelt larvae

except possibly in summer. Management of the discharge could ensure that adverse effects do not occur.

Simons, S. J. (1986). Effects of elevated temperatures on two whitebait species (*Galaxias maculatus* and *G. fasciatus*) and the shortfinned eel (*Anguilla australis*): Ecological implications of thermal discharges to the Waikato River. Hamilton, Waikato Valley Authority**:** 62.
Critical thermal maximums are worked out for juvenile inanga, banded kokopu and shortfinned eels. Banded kokopu were the most sensitive species and eel elvers the most tolerant to raised temperatures. The upper temperature limits for long-term survival (>5 days) were estimated to be <26°C for banded kokopu, 26-27°C for inanga, and 30°C for shortfinned elvers. These results are discussed in relation to industrial thermal discharges.

Slaven, D. C. (1990). Hunua ecological district freshwater fisheries survey - Recreational trout fishery potential and evaluation. Auckland, Ecology Specialist Services.
This report identifies areas with the Hunua Ranges suitable for the establishment of a recreational trout fishery. It also evaluates the impact of such a fishery on the ecological integrity of the native freshwater fisheries of the Hunua Ecological District. Recommends that the native freshwater fisheries within the Ecological District are recognised as significant and protected, and the ARC restrict trout introductions to the Mangatawhiri Reservoir.

Speirs, D. A., Kelly, J. (2001). Fish Passage at Culverts - A Survey of the Coromandel Peninsula and Whaingaroa Catchment (11/00 - 04/01). Hamilton, Environment Waikato.

Speirs, D. A., Kusabs, I. (2001). Relative Effects of Stream Flow, Water Temperature and Abstraction on Trout in the Torepatutahi Stream. Hamilton, Environment Waikato.

Stancliff, A. G., Boubee, J.A.T., Palmer, D., Mitchell, C.P. (1988). Distribution of migratory fish and shrimps in the vicinity of the Waikato thermal power stations, Ministry of Fisheries.
Follows the upstream migration of galaxiids, smelt, common bullies, and freshwater shrimps and their ability to negotiate thermal and velocity barriers created by thermal power stations on the Waikato River.

Stancliff, A. G., Boubee, J.A.T., Palmer, D., & Mitchell, C.P. (1988). The upstream migration of whitebait species in the lower Waikato River. Rotorua, Ministry of Agriculture and Fisheries**:** 44.
The upstream migration of whitebait species was monitored at the existing and the proposed thermal power station sites. The timing of major migrations is determined in order to assess the impact of thermal discharges on fish populations. Spent adult inanga, kokopu species and koaro are not thought to be greatly affected by thermal discharges as they migrate during winter and spring when the river temperature is low. Juvenile inanga and smelt however reach the power station in summer and could be adversely affected by the thermal discharge plume.

Stancliff, A. G., Boubee, J.A.T., & Mitchell, C.P. (1988). *The Whitebait Fishery of the Waikato River*. Rotorua, Freshwater Fisheries Centre, MAF Fish.
details historical records of the whitebait fishery of the Waikato River, species composition, migration timing, environmental influences, value of the catch.

Stancliff, A. G., Boubee, J.A.T., & Mitchell, C.P. (1989). Cross-channel movement of small migratory fish and shrimps in the Waikato River near Huntly thermal power station., MAF Fisheries**:** 30.
The upstream migration of dye-marked inanga, banded kokopu, common bullies, and freshwater shrimps was monitored. The Huntly power station discharge to the Waikato River was found to effect the migration of these fish species on the power station side of the river. The discharge velocity effected migration of some species. High plume temperatures (especially in summer) also effected migration of some species.

Stokes, R & McMaster, B. (1990). Proposal to release grass carp (Ctenopharyngodon idella) into the lower Whangamaire Stream, Taupiri. Hamilton, Waikato Regional Council**:** 19.
The Taupiri Drainage Advisory Sub-Committee had decided to release grass carp in the lower Whangamaire Stream in an endeavour to combat the rapid weed growth in the lower reaches of the stream. This report outlines their proposal and assess possible environmental consequences.

Strickland, R. R. (1980). Fisheries aspects of the Whangamarino swamp. Turangi, Ministry of Agriculture and Fisheries**:** 37.
This report reviews literature about the Whangamarino swamp, presents results from electric fishing surveys and relates species distribution with habitat. The importance of the swamp as a resource to fishers and the public is researched and a questionnaire to commercial eelers included.

Strickland, R. R. (1985). Fisheries aspects of the Taharoa lakes and Wainui Stream. Rotorua, MAF.
A grey mullet fishery in Lake Taharoa has been lost because access for juvenile mullet from the sea to the lake has been blocked by a dam. Construction of the dam allowed New Zealand Steel Mining Limited (NZMS) to abstract water for their iron-sand mining operation. A fish pass , which was a condition of their water right was installed to allow fish access to the lake. Although it is negotiable by some species, it is impassable to mullet.
the various surveys conducted and reports produced on the fisheries problems at Taharoa are summarised and discussed in this report. A number of options which will assist in restoring previous fisheries values are presented and action required by the parties involved to resolve the problem is recommended.

Strickland, R. & Hayes, J. (1998). How useful are fish as indicators? Biological monitoring of freshwaters - seminar, Wellington, NZ Water and Wastes Association Inc. & Cawthron Institute.
Advantages and disadvantages of using fish as indicators of ecosystem health or variability. Discusses sampling methods and provides some case studies.

Taylor, A., Barnes, G., Speirs, D.A., Turner, S., Vant, W. (2001). Outstanding Waterbodies in the Waikato Region. Environment Waikato Technical report, 2001/12: Hamilton.

Taylor, M. J. (1988). Features of freshwater fish habitat in South Westland, and the effect of forestry practices. Christchurch, Ministry of Agriculture and Fisheries: 89.
The preferred habitats of 16 fish species are described. Banded kokopu, short-jawed kokopu, blue-gilled bully, brown trout, and torrent fish are considered to be the species most sensitive to the effects of forest harvesting. Selective logging has a much lower impact on fisheries than clear felling. The effects of agriculture and exotic reforestation are also discussed.

Town, J. C. (1981). Fish kill - Kopokorahi arm of Lake Maraetai NZ Forest Products discharge. Hamilton, Waikato Valley Authority: 3.
This report details the chronic poisoning of approximately 500 goldfish in Lake Maraetai on the 6th October 1981. An accidental spill of black liquor and creosote left the Kopokorahi arm grossly discoloured and foam covered substantial portions of the water surface.

Town, J. C. (1981). Lake Maraetai fish kill - March-April 1980. Hamilton, Waikato Valley Authority: 2.
This report details the chronic poisoning of goldfish, common bully, and rainbow trout in Lake Maraetai in March and April 1980. The kill coincided with the resumption of operations at the Kinleith Mill. The lake had received no effluent during the month preceding the kill. Waters in the Kopokorahi arm were grossly discoloured and a thick white scum covered some of the lake surface.

Town, J. C. (1983). Waikato Coal-fired Power Station. Evaluation of some possible biological effects of thermal pollution on Waikato River Ecology. Wellington, Electricity Division.
This report is an evaluation of the possible effects of an open cycle cooling of a 1000 MW coal-fired power station on the ecology of the lower Waikato River.

Town, J. C. (1985). Commercial freshwater eel fishery. Wellington, Ministry of Agriculture & Fisheries: 24.
This report summaries the commercial eel fishery, describes present management, issues and problems, and presents management options.

Waikato Valley Authority (1979). The Waikato River: a water resources study. Wellington, Waikato Valley Authority: 225.
This document presents a collection of articles on surveys conducted from 1972 to 1978 to describe the physical, chemical and biological conditions of the water of the Waikato River. There is a section on the biology of resident animals which includes lists of species found during surveys.

Waikato Valley Authority (1981). Whangamarino swamp resources study. Hamilton, Waikato Valley Authority: 167.
This report is prompted by the demand for more Whangamarino wetland to be drained and used for farmland. Knowledge of the soils, vegetation and fauna of the swamp is presented. An indication of agricultural potential and flood water storage is also discussed.

Waikato Valley Authority (1982). Whangamarino Swamp: A draft management guideline. Hamilton, Waikato Valley Authority: 9.

This documents details management options and recommendations for the management of Whangamarino Swamp. These guidelines are the product of a working group made up of members from local authorities, Acclimatisation Society, Department of Lands and Survey, Wildlife Service, and the W.V.A.

West, D. W., Chisnall, B.L., & Boubee, J.A.T. (1993). Fish Populations Of Lake Waahi - 1993 Survey. Hamilton, National Institute Of Water & Atmospheric Research**:** 25.

West, D. W., Roxburgh, T. (2000). Fish communities of Lake Whangape, Waikato - April 2000 survey. Hamilton, Department of Conservation, Waikato Conservancy**:** 13.
Details a fishery survey carried out on Lake Whangape by the Department of Conservation in order to establish a baseline the Lake's fish populations prior to the closure of the lake to commercial eel fishing. Discusses methods used and provides details of the fish populations captured.