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Prepared for Ministry for Primary Industries

November 2014

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Executive summary

The calendars produced in this report cover 41 key freshwater fish species in New Zealand with the majority of these being native (34) and the remaining (7) sports fish. The two New Zealand species of koura have also been included. The calendars are divided into two categories; spawning and migration. Two smaller calendars for lacustrine spawning and migration have also been produced. The calendars are designed to inform forestry management and help minimise potential effects of forestry operations on fish. Fact sheets have also been produced listing important details about each species (e.g., conservation status, spawning habitat, preferred habitat). A summary of likely forestry effects for each species has also been produced, ranking each species' ability to adapt to changes brought about by various forestry activities. These changes include increases in turbidity and sedimentation, and reduced flows from afforestation. Information provided in this report could also be used by anyone wanting to do work near and around freshwaters in New Zealand (i.e., farmers, contractors, developers).

1 Introduction

The fish spawning and migration calendars produced for this report are designed to be used as a tool to assist foresters in minimising the impacts of forestry activities on freshwater fish species. The calendars will assist forest managers determine the appropriate timing of certain activities that may adversely affect the life cycle (spawning and/or migration) of key freshwater fish species present in the forestry catchments. The calendars are intended as a general guide and are no substitute for in-depth studies of specific sites. Though the calendars have been produced for forestry operations, the information provided could be used by anyone wanting to do work near and around freshwaters in New Zealand (i.e., farmers, contractors, developers).

The likely effects of any work that could adversely impact on fish communities in streams, rivers, lakes and wetlands needs to be considered first. The fish calendars can then provide managers with information on when is the best time to undertake work in or around waterways in order to minimise harm to fish species. For example, if work was to be carried out in May or June that involves the disturbance of riparian vegetation in a stream known to contain giant or banded kokopu, it would likely disturb their spawning habitat and therefore the activity should be planned outside of these key months.

1.1 Fish species

The 41 key fish species (34 native and 7 introduced) found in New Zealand have been split into nine functional groups (based on family/habitat/attributes) for the calendars. Seventeen of these species are 'diadromous' or 'sea run', meaning they migrate between freshwater and saltwater during some part of their life cycle (McDowall 1990). These diadromous species can be split into three categories. 'Catadromous' (e.g., eels and inanga), live in freshwater, but migrate to sea to spawn, with larvae returning on ocean currents and subsequently entering freshwater as juveniles (e.g., glass eels and whitebait; McDowall, 2000). Inanga are termed marginally catadromous as adults will spawn in estuarine waters. 'Anadromous' species (e.g., lamprey, chinook salmon and some brown trout) are those where adults live at sea and then migrate upstream from the sea to spawn in fresh water. For these species, the larvae and fry rear in fresh water before migrating out to sea as juveniles. 'Amphidromous' species (e.g., large galaxiids and bullies (i.e., bluegill, redfin, common, giant), torrentfish and common smelt) undertake a migration between fresh and salt water for a purpose other than breeding. In general, adults breed in the fresh water environment, with larvae rearing at sea, and then migrating upstream into freshwater as juveniles several months later for growth to adulthood (McDowall 1990). Although a large proportion of common smelt populations are amphidromous, they also form anadromous populations, where larvae and juveniles rear in marine or estuarine waters and adults migrate into freshwater to spawn.

A number of these diadromous species also have lacustrine populations (landlocked) where no marine phase is required (e.g., large galaxiids, common bully and common smelt). Of the 41 species, 19 are non-migratory (mudfish, Cran's bully, tarndale bully, upland bully, and non-migratory galaxiids) and have no significant spawning or larvae/juvenile migrations. The seven introduced fish are in the salmonid sportfish group (i.e., trout and salmon) and all spawn in fresh water, with only two (chinook salmon and some brown trout populations) having a marine phase to their life cycle.

The non-migratory (non-diadromous) fish species do not move far from their natal reaches. These fish will spawn in locations near their natural adult habitat. These fish are not included in the migration calendar as they do not undertake large-scale migrations, but are included in the spawning calendar. If these species are present at a site, it is likely that they will spawn in the vicinity of their home range within the dates outlined in the calendar (Hamer, 2007). For these species there is an additional category added to the calendar to outline when larvae/fry/juveniles are likely to be present in abundance. Information for the two New Zealand koura species (Northern and Southern) has also been included in this report including a separate spawning calendar.

1.2 Koura

There are two species of freshwater koura in New Zealand, Northern koura *(Paranephrops planifrons*) which are found throughout the North Island, and the north & west of the South Island and Southern koura (*Paranephrops zealandicus*) which are found in Canterbury, Otago and Southland. Koura are non-migratory and female koura carry between 20–200 eggs attached by threads to appendages (pleopods) underneath her abdomen. Once hatched juvenile koura cling to their mother's abdomen using their rear legs until they have reached a carapace length of approximately 4 millimeters. The total duration of breeding from peak egg laying to the release of juveniles is estimated to be 28 weeks for the autumn–winter period and 19 to 20 weeks in spring–summer breeding groups for Northern lake populations (Devcich, 1979) and 25 to 26 weeks for Northern stream populations (Hopkins 1967), and up to 60 weeks for Southern koura in stream populations (Whitmore 1997). Warmer water temperatures speed up the egg development process (Jones 1981a).

1.3 Fact sheets

For each fish species and koura, fact sheets have been prepared which outline the conservation status, geographic range (including the forestry region(s) it is present in), its preferred adult, larvae/fry and spawning habitats, spawning range and peak, migration ranges and peaks, as well as a forestry activities sensitivity ranking (low to high) looking at each species' reaction to turbidity, sedimentation and afforestation (Appendix 7.1 to 7.9).

1.4 Calendars

The spawning calendar (Figure 3.2) outlines the spawning range for each species, with a peak range also given were applicable/possible (i.e., enough information was available). The year has been divided into the four seasons, starting with summer. The nine forestry regions are represented on the right side of the table, with a separate column (All) for those species found throughout New Zealand. A koura spawning calendar has also been produced that is separate from the main fish spawning calendar (Figure 3-6).

The migration calendar (Figure 3.3) covers the migration of adults to spawning habitats, larvae/fry being carried downstream to the sea or lakes, and the upstream migrations of juveniles to adult habitats. Migration activity for all species will often occur throughout the whole year. However, the majority of fish migrations will have peaks that occur at certain times as outlined in the calendar (Wilding et al. 2000, Hamer, 2007).

The upstream migration periods outlined in the calendar relate to fish entering river mouths and coastal streams and rivers (except for the lacustrine section of the calendar), but it will take some time for fish to migrate upstream to sites further inland. This needs to be taken into account for a number of species; for example, the calendar specifies when whitebait (juvenile galaxiids) will enter estuaries, streams and rivers, however, the timing for these species to reach inland sites will be contingent upon the fishes' swimming/climbing ability, the distance inland for each particular site, river gradient and flow, and if in-stream obstacles (such as culverts and weirs) are present.

Spawning and migration periods are often associated with environmental conditions like temperature, rainfall, stream and river flows, as well lunar cycles and tides. As a result, peak spawning and migration periods may vary from year–to-year depending on these conditions. For example, the marine water temperature can alter the duration of the marine growing phase for many diadromous species (Rowe and Kelly 2009), and hence influence the timing of return migrations. Upstream migrations may also be delayed by flood flows. For many fish species, seasonal temperature changes play a major role in determining the timing of spawning, so climatic variation can delay or bring forward spawning activity. However, variation of these peak times will be within the range for spawning and migration. Exceptions could occur for some species where little information exists (Hamer, 2007).

1.5 Geographic variations in spawning seasons

There is limited information on geographic variations for fish spawning in New Zealand, however, latitudinal differences are to be expected. Differences in climatic conditions affecting fish maturation, and thus timing of spawning, are likely to occur from one end of the country to the other. The only real evidence we have of this occurring is that inanga will often spawn earlier in southern locations when compared with northern locations (Taylor, 2002). As a result, peak spawning may occur slightly earlier in the South Island compared with the North, however, the overall spawning range will remain the same.

There is evidence to suggest that land-locked populations spawn at different times to their diadromous counterparts. Hence a separate spawning (Figure 3.4) and migration calendar (Figure 3.5) have been produced for these populations (common bullies, common smelt, banded kokopu, giant kokopu, koaro, shortjaw kokopu and rainbow trout). A number of land-locked populations mimic diadromous behaviour, but in freshwater. For example, koaro will use lakes like the sea, spawning in tributary streams, with their larvae being washed down into the lake following hatching, where they then feed and grow before re-entering tributary streams as juveniles. Often, however, juvenile fish will stay and rear in the lake, rather than migrate back into streams like their sea run counterparts.

1.6 Geographic variations in migration seasons

Peak migration periods between the North and South Island may also be slightly different. For example, peak migration for koaro in the North Island East Coast Rivers was October compared with September in the South Island's West Coast. However, the overall migratory period for koaro was similar irrespective of geographical location (Rowe et al. 1992, McDowall and Eldon, 1980). Seasonal migrations, as highlighted by Rowe and Kelly (2009), are dependent on growth rates at sea. If marine conditions are optimal then whitebait will grow faster at sea and returning migrations will be earlier than if marine conditions are poor. As a result inter-annual variation may occur in the peak migration periods for river entry related to marine growing conditions (water temperature and food supply) for diadromous species, however the overall range for upstream migrations is unlikely to change.

2 Methods

To produce the calendars, fact sheets and forestry effects rankings, a review of the biology of each individual species was undertaken focusing on: spawning habitat requirements, the timing of spawning (including peak spawning periods), migration periods (both upstream and downstream, including peak migration) and effects of forestry activities (primarily turbidity, sedimentation and afforestation). This involved a literature review of books, scientific papers and grey literature, as well as resourcing the knowledge and experience of NIWA's freshwater fish biologists.

From the literature, spawning and migration ranges were established (indicated in light blue in Figures 3.2 to 3.5). A range was established for all species, though in some cases the available information was limited. For example, little is known about spawning timing and habitat of giant bully (*Gobiomorphus gobioides*). Where there was evidence of peak spawning and migration (indicated in dark blue in Figures 3.2 to 3.5), this was included in the calendars. However, for a number of species, peak periods of spawning and migration could not be established because of little or unreliable information. Priority was given to the latest information, for example McDowall (2000) was used ahead of McDowall (1990), which included more recent and applicable literature. For a number of species, spawning and migration ranges were stated as seasonal i.e., spring and summer. Technically the period for spring is September to November, however, August is often included as part of spring, as this is a key month in terms of spawning and migration.

A number of regions have suspended sediment load restrictions caused by in-stream works for certain times of the year to protect significant indigenous fisheries, sports fisheries and fish habitat. For example, restrictions apply August to December in the Waikato region for general waters and May to September for significant trout fisheries in the region (Waikato Regional Plan, Section 4.2.21, Appendix 1. Suspended Solids Discharge Standards for Permitted Activity Rules in Chapters 4.2 and 4.3). These restrictions were developed to enable the migration of juvenile native fish upstream and to protect trout spawning and egg development. Regional restrictions have not been applied to the calendars in this report.

2.1 Why are the calendars important?

If works are to be carried out near a waterway, or even in a catchment, the potential impacts to the waterway need to be considered. Just knowing what fish species are present in the catchment is not enough as each fish species has a spawning period with possible migrations that may be adversely affected. Once a manager knows what fish species occur in their catchment, their work timetable can be assisted by using the fish calendars to assess if their work will adversely affect the life cycles of species present. Work should be scheduled for periods that will likely have the least ecological impact, and precedence should be given to protecting species with a high conservation status (Goodman et al. 2014) and/or important sports fisheries.

Questions that managers need to consider when planning works include:

- will this work reduce fish cover
- effect spawning habitat
- alter stream flows
- reduce stream flows or dry up wetlands

- block fish passage (in-stream structures like culverts need to be fish friendly)
- cause changes to the stream bed
- increase water velocities
- cause erosion - leading to turbidity and increases in sedimentation which could lead to fish deaths
- alter migrations
- destroy spawning habitat.

The long term effects of works also need to be taken into account. For example, earth works may be undertaken in a stream at a time that will minimise harm to the species present, but the sediment load introduced into a stream can remain within the system for significant periods after the work is completed. This can potentially cause problems downstream, such as reducing fish cover, altering stream morphology and reducing spawning habitats.

3 How to use the calendars

1. Establish what fish species are present in the catchment.
2. Is it spawning season?
3. Do these species spawn in the reach affected and are larvae/fry present?
4. Are migrations taking place in the reach affected?
5. What is the conservation status of these species/are they an important sports fish?
6. Will the activity affect the fish?
7. Time the activity to minimise adverse effects.

Managers need to be aware that some fish species may not be present at certain times of the year in a particular section of a stream, but are often found further upstream in more suitable habitats. Consequently, they will have to migrate through that reach at certain times of year to reach the upstream habitats, and possibly pass back down again to spawn. Managers also need to remember that migration times are set for entry into rivers and streams at the coast. For diadromous species, additional time needs to be added for inland locations where these species are present. Use the spawning and migration calendars to determine the most suitable time to do the work (i.e., a period when no aspect of the species life cycle could be adversely affected). This will minimise the impact the work has on the fish community.

The calendars list the species by functional groups (similar family/habitat/attributes). In the migration calendar this is followed by two extra columns (Direction – upstream and down (and to estuaries for eels) and life stage (at time of migration) – adult, larvae and juvenile). The months of the year are divided into the four seasons starting with summer and the nine forestry regions (Table 3.1 & Figure 3.1) are represented at the end, including an 'All' column to indicate that the particular species is found throughout New Zealand and hence forestry regions. More detailed information for each species can be found on the fact sheets (spawning habitat, conservation status, forestry effects ranking).

Table 3-1: The nine forestry regions and abbreviations.

Forestry Region	Abbreviation
Northland	NL
Central North Island	CNI
East Coast	EC
Hawkes Bay	HB
Southern North Island	SNI
Nelson Marlborough	NM
West Coast	WC

Forestry Region	Abbreviation
Canterbury	CAN
Otago Southland	OS

Figure 3-1: Map of the nine New Zealand forestry regions (source: Ministry for Primary Industries (Forest Mapping - Wood Supply Regions) www.mpi.govt.nz).

Figure 3-2: Freshwater fish spawning calendar for key New Zealand fish species Showing spawning range, peak and occurrence of larvae/fry/juveniles within the nine forestry regions.

Key: Peak | Range | Larvae/Fry/Juveniles present | non migrant * | present ●

Functional Group	Species	Conservation Status	Summer D	Summer J	Summer F	Autumn M	Autumn A	Autumn M	Winter J	Winter J	Winter A	Spring S	Spring O	Spring N	All	North Island NL	CNI	EC	HB	SNI	South Island NM	WC	CAN	OS
Bullies (fast flow) and Torrentfish	Bluegill bully	●													●									
	Redfin bully	●													●									
	Torrentfish	●													●									
Bullies (slow flow)	Common bully	○													●									
	Crans bully	○														●	●	●	●	●				
	Giant bully	○													●									
	Tarndale bully*	□																			●			
	Upland bully*	○													●									
Eels	Longfin eel	●													●									
	Shortfin eel	○													●									
Inanga and smelt	Common smelt	○													●									
	Inanga	●													●									
	Stokells smelt	□																					●	
Lamprey	Lamprey	+													●									
Large Galaxiids	Banded kokopu	○													●									
	Giant kokopu	●														●	●	●		●	●	●	●	●
	Koaro	●													●									
	Shortjaw kokopu	+														●	●	●		●	●	●		●
Mudfish*	Black mudfish	●														●	●							
	Brown mudfish	●															●					●		
	Canterbury mudfish	●																					●	
	Northland mudfish	+														●								
Non-Migratory Galaxiids*	Alpine galaxias	□																					●	●
	Bignose galaxias	+																					●	
	Canterbury galaxias	●																			●		●	●
	Dusky galaxias	++																						●
	Dwarf galaxias	●															●		●	●	●	●	●	
	Eldons galaxias	++																						●
	Taieri flathead galaxias	+																						●
	Gollum galaxias	+																						●
	Upland longjaw galaxias	+																					●	
	Lowland longjaw galaxias	+++																					●	●
	Roundhead galaxias	++																						●
	Dwarf inanga	●														●								
Salmonid Sportfish	Atlantic salmon	Δ																						●
	Brook Char	Δ															●						●	●
	Brown trout	Δ															●	●	●	●	●	●	●	●
	Chinook salmon	Δ																				●	●	●
	Mackinaw*	Δ																					●	
	Rainbow trout	Δ													●									
	Sockeye salmon	Δ																					●	●

○ Not Threatened ● At Risk Declining □ At Risk Naturally Uncommon + Threatened Nationally vulnerable ++ Threatened Nationally Endangered

+++ Threatened Nationally Critical Δ Sportsfish

Figure 3-3: Freshwater fish migration calendar for key New Zealand fish species. Showing migration range and peak periods, migration direction and life stage at the time of migration, and occurrence within the nine forestry regions. * indicates the life stages that are present only within the lower reaches of rivers and streams.

Key: Peak (P) Range (R) Lower river * Present ●

Functional Group	Species	Conservation Status	Direction	Life stage	Summer D	Summer J	Summer F	Autumn M	Autumn A	Autumn M	Winter J	Winter J	Winter A	Spring S	Spring O	Spring N	All	North Island NL	North Island CNI	North Island EC	North Island HB	North Island SNI	South Island NM	South Island WC	South Island CAN	South Island OS
Bullies (fast flow) & Torrentfish	Bluegill bully	●	upstream	juvenile	R	R	R	R								R	●									
			down	larvae	R	R	R	R						R	R	R										
	Redfin bully	●	upstream	juvenile	R	R	R	R								R	●									
			down	larvae	R	R	R							R	R	R										
	Torrentfish	●	upstream	juvenile					R	P	P	P	P	R	R	R	●									
			down	larvae*	R	R	P	P	P	P	R															
Bullies (slow flow)	Common bully	○	upstream	juvenile	R	R	R	R									●									
			down	larvae*	R	R	R	R						R	P	P										
	Giant bully	○	upstream	juvenile	R	R	R	R									●									
			down	larvae*	R	R	R	R						R	R	R										
Eels	Longfin eel	●	to estuary	glass eel								R	P	P	P	R	●									
			upstream	juvenile	P	P	P	P	R							R										
			down	adult				R	R	R																
	Shortfin eel	○	to estuary	glass eel	R								R	P	P	P	●									
			upstream	juvenile	P	P	P	P	R							R										
			down	adult			R	R	R	R																
Inanga and smelt	Common smelt	○	upstream	juvenile									R	P	P	R	●									
			down	larvae*		R	R	R	P	P	P	R	R													
	Inanga	●	upstream	juvenile						R	R	R	P	P	P	P	●									
			down	larvae*	R	R	R	P	P	P	P	P	R		R	R										
	Stokells smelt	□	upstream	adult*	P	R	R	R							R	P									●	
			down	larvae*	R	P	P	R						R	R	R										
Lamprey	Lamprey	+	upstream	adult					R	R	R	R	P	R	R	R	●									
			down	juvenile	R	R	R	R	R	R	R	R	R	R	R	R										
Large Galaxiids	Banded kokopu	○	upstream	juvenile	R								R	P	P	R	●									
			down	larvae				R	R	R	P	P	R	R												
	Giant kokopu	●	upstream	juvenile	R										R	P		●	●	●		●	●	●	●	●
			down	larvae						R	P	P	R	R												
	Koaro	●	upstream	juvenile										P	P	R	●									
			down	larvae						P	P	R	R	R												
	Shortjaw kokopu	+	upstream	juvenile										R	R	R		●	●	●		●	●	●		●
			down	larvae						R	P	P	R													
Salmonid Sportfish	Atlantic salmon	Δ	upstream	adult	R	R	R	R	R	R																●
			down	juvenile						R	R	R	R													
	Brook Char	Δ	upstream	adult	R	R	R	R	R	R									●						●	●
			down	juvenile						R	R	R	R													
	Brown trout	Δ	upstream	adult	R	R	R	P	P	P									●	●	●	●	●	●	●	●
			down	juvenile	R	R	R	R	R	R	R	R	R	R	R	R										
	Chinook salmon	Δ	upstream	adult	R	R	R	R	P	P	R													●	●	●
			down	juvenile						R	R	R	P	P	R											
	Rainbow trout	Δ	upstream	adult						R	P	P	R	R			●									
			down	juvenile	R	R	R	R	R	R	R	R	R	R	R	R										
	Sockeye salmon	Δ	upstream	adult				P																	●	●
			down	juvenile					R	P	R															

○ Not Threatened ● At Risk Declining □ At Risk Naturally Uncommon + Threatened Nationally vulnerable ++ Threatened Nationally Endangered

+++ Threatened Nationally Critical Δ Sportsfish

Figure 3-4: Lacustrine spawning calendar.

Key: Peak | Range | present •

Functional Group	Species	Conservation Status	Direction	Life stage	Summer D	Summer J	Summer F	Autumn M	Autumn A	Autumn M	Winter J	Winter J	Winter A	Spring S	Spring O	Spring N	All	North Island NL	CNI	EC	HB	SNI	South Island NM	WC	CAN	OS
Large Galaxiids	Banded kokopu	o	upstream	juvenile	?	?	?	?	?	?	?	?	?	?	?	?		•	•			•	•			
			down	larvae	?	?	?	?	?	?	?	?	?	?	?	?										
	Giant kokopu	•	upstream	juvenile	?	?	?	?	?	?	?	?	?	?	?	?			•			•		•		
			down	larvae	?	?	?	?	?	?	?	?	?	?	?	?										
	Koaro	•	up & down	adult													•									
			upstream	juvenile																						
			down	larvae																						
	Shortjaw kokopu	+	upstream	juvenile	?	?	?	?	?	?	?	?	?	?	?	?		•	•	•		•	•	•		•
			down	larvae	?	?	?	?	?	?	?	?	?	?	?	?										
Salmonid Sportsfish	Rainbow trout	Δ	upstream	adult															•							
			down	juvenile																						

o Not Threatened • At Risk Declining + Threatened Nationally vulnerable Δ Sportsfish

Figure 3-5: Lacustrine migration calendar.

Key: Peak | Range | Larvae/Fry/Juveniles present | present •

Functional Group	Species	Conservation Status	Summer D	Summer J	Summer F	Autumn M	Autumn A	Autumn M	Winter J	Winter J	Winter A	Spring S	Spring O	Spring N	All	North Island NL	CNI	EC	HB	SNI	South Island NM	WC	CAN	OS
Bullies (slow flow)	Common bully	o													•									
Smelt	Common smelt	o													•									
Large Galaxiids	Banded kokopu	o	?	?	?	?	?	?	?	?	?	?	?	?		•	•			•	•			
	Giant kokopu	•	?	?	?	?	?	?	?	?	?	?	?	?			•			•		•		
	Koaro	•													•									
	Shortjaw kokopu	+														•								
Salmonid Sportsfish	Rainbow trout	Δ															•							

o Not Threatened • At Risk Declining + Threatened Nationally vulnerable Δ Sportsfish

Figure 3-6: Koura spawning calendar.

Females with young (most vulnerable) | Range | Young of the year present | present ● | Not Threatened ○

Functional Group	Species	Conservation status	Summer			Autumn			Winter			Spring			All	North Island					South Island			
			D	J	F	M	A	M	J	J	A	S	O	N	All	NL	CNI	EC	HB	SNI	NM	WC	CAN	OS
Koura	Northern Koura	○														●	●	●	●	●	●	●		
	Southern koura	○																					●	●

4 Discussion

The calendars in this report have been created for use by forest managers in New Zealand, but can be applied in other industries such as farming or construction where a freshwater waterway could be adversely impacted. It is hoped that works that may affect wetlands, streams, rivers and lakes can be scheduled at the best time of year to minimise adverse effects to freshwater fish.

The information provided in the calendars are based on both literature and professional biologist's observations. However, the timing of peak spawning and migrations can vary from year-to-year and between regions depending on a number of factors. Also for some species there is little known information to produce accurate predictions so caution is needed for these less well studied species.

As a result of land use changes and continued urban and industrial development, native freshwater fish species have been declining both in numbers and distribution (McDowall 1996, Goodman 2014). To maintain fish populations in New Zealand care is needed to protect spawning habitat and maintain migratory pathways (Wilding 2000). For example, inanga spawn on spring high tides in estuaries and lower stream/river sections (March to June peak) in suitable intertidal vegetation which will keep the eggs moist and humid as the tide ebbs. Any work at this time of year that may affect this vegetation (i.e., heavy machinery, trampling, grazing) will destroy inanga eggs and result in a reduction in whitebait recruitment. In fact, it has been shown that egg densities and survival are significantly reduced by 75% and 25%, respectively, if these grasses are disturbed (e.g., cut) several months prior to the spawning season (Hickford & Schiel 2014). The migration of fish species also needs to be taken into account when works are undertaken. For example, sediment runoff into a stream can reduce water clarity, and adversely affect migration pathways, feeding, stream morphology, fish cover and spawning habitat.

The 41 key fish species included in this calendar are primarily native with only seven introduced species (sports fish). There are a number of other freshwater fish in New Zealand that are not included in this report, but most of these are introduced 'undesirables' or 'marine wanderers'.

Most of New Zealand's native fish species are small (less than 150 mm), cryptic and benthic (McDowall 1990). Many of these native fish require movement between fresh water and the sea as part of their life cycle (i.e., diadromy). Connectivity between freshwater and marine environments is the most important factor influencing the distribution of native fish in New Zealand (Hayes et al. 1989; McDowall 1993; Jowett and Richardson 1996). As a result, fish diversity and abundance is highest at low elevations close to the sea and lowest at high elevations further inland. At higher elevations, non-diadromous (non-migratory) fish are dominant. There are, however, some diadromous species that are excellent climbers, such as koaro and longfin eels, and these species are often found at high elevations and some distance inland (McDowall 1990). A number of hydroelectric dams throughout the country block the migrations of some diadromous species. At a number of these dams juvenile eels (elvers - upstream migrants) are collected at the base of dams (in traps), transferred above the dam(s) and released into lake and/or riverine habitat to continue their migrations. Other species blocked by dams are not included in the transfer process, though occasionally they are transferred as a by-catch.

The timings of upstream migrations in the migration calendar are based on fish entering coastal streams and rivers. As the fish move up the waterways, penetrating further inland, the appearance of migratory life stages may be lagged relative to the time periods shown in the calendars. The upstream migration rates of a number of species have been studied. Juvenile inanga or 'whitebait', which is the predominant whitebait species, have been observed migrating upstream at a rate of 0.31 km/day (approximate rate) during spring and 1.36 km/day during summer (Stancliff et al. 1988). In the same study Stancliff et al. (1988) also found that juvenile smelt are capable of migrating upstream at 4.2 km/day, although the majority of smelt moved at a slower rate, and banded kokopu migrated upstream at a constant rate of 1.96 km/day. These rates were calculated in the Lower Waikato River above the influence of tides. Upstream movement may be faster or slower in the lower river contingent upon whether migrants utilise selective tidal transport. The migration rates reported by Stancliff et al. (1988) are also relative to the water velocities and flow of the Waikato River over the migratory period. In other rivers and streams, a different rate would be expected depending on water velocities, flow, gradient, fish habitat and cover as well as presence of in-stream barriers. Climatic conditions also need to be taken into account. For example if there is a flood during migration, fish will often wait until the flows have receded before moving upstream. Upstream migration speeds for juvenile eels or elvers will vary between systems for example McDowall (1990) found that elvers move upstream at a rate of 1.5-2 km/day whereas Jellyman and Ryan (1983) reported them moving at 0.8 km/day in a different system.

To use the calendars managers will need to know what fish species occur in their catchments. This can be done by viewing the New Zealand freshwater fish prediction model (Leathwick et al. 2008) or the New Zealand Freshwater Fish Database (NIWA) www.niwascience.co.nz/services/nzffd/ . For a more accurate assessment of fish communities, fish surveys could be undertaken involving various techniques (electric fishing, netting, spotlighting) to determine what fish are present. Ideally the survey should be carried out by professionals who are able to apply the most appropriate techniques to the habitat to be surveyed, identify fish species correctly and operate safely and without causing harm to the environment (i.e., transfer of invasive organisms e.g., pest fish and eggs, aquatic weeds, didymo).

When planning work consideration should also be given to the conservation status (species importance and vulnerability as detailed in the fact sheets) of fish that maybe affected. This also applies to sports fish which are afforded protection under the Freshwater Fisheries Regulations 1983.

5 Summary of the impacts of forestry activities on key freshwater fish in New Zealand

Plantation forestry is a large industry in New Zealand that has resulted in significant land-use change in both the North and South Islands. Forestry has a number of economic (i.e., major contributor to gross domestic product) and environmental benefits these include carbon sequestration and when forests are mature, erosion control. Established plantation forests also have a similar hydrological effect to native forests in reducing flood peaks (Davie and Fahey 2005). Pine afforestation of pastoral land in New Zealand has been shown to have marked beneficial effects on stream water quality, morphology and ecology (invertebrates), restoring stream habitat to conditions more closely resembling those found in native forest streams, with the most important factor being the benefits of increased shade (Quinn et al. 1997). Rowe et al. (1999) found no differences in native fish populations between mature exotic pine forest sites and native forest sites in east coast streams of the North Island. In comparison to conventional agricultural crops, established plantation forestry provides greater environmental benefits by protecting soil and water values, providing a greater level of biodiversity and also providing social benefits such as hunting and recreation opportunities (Dyck 1997).

Plantation forestry and associate operational activities also have a number of negative environmental impacts which need to be properly managed to minimise effects, particularly to stream habitats. The forestry cycle in New Zealand involves a number of activities such as mechanical land preparation, afforestation, pruning/thinning, harvesting and replanting, all of which have recognised impacts on stream ecosystems. The most commonly documented impacts to streams are associated with land clearing and harvesting activities for forest plantations as these are known to alter: light and temperature regime, impact allochthonous energy inputs to streams (e.g., leaves and wood), change flow regimes and increase sedimentation (Boothroyd et al. 2004; Quinn et al. 2004). If sound land management practices are not adhered to then forestry activities can alter stream ecosystem function and negatively impact the invertebrate and fish values of waterways within plantation forests.

Likely effects on key freshwater fish species from forestry activities in New Zealand are:

1) An increase in suspended sediment which can alter the water chemistry, cause water temperature decreases, reduce the water clarity and increase turbidity, thus reducing primary production (Ryan 1991; Van Nieuwenhuyse & LaPerriere 1986). Increases in turbidity can affect feeding rates of fish (Rowe & Dean 1998), and a number of fish species have shown avoidance of turbid waters, limiting migration and recruitment (Rowe et al. 2000; Boubee et al. 1997). High sediment concentrations can also harm fish directly by causing death, reducing growth or resistance to disease (Richardson and Jowett, 2002).

2) Disposition of sediment which can block interstitial spaces (gaps between particles in the stream substrate) resulting in reduced fish cover, shelter, foraging areas, food supply, reduced spawning sites and less successful egg and larval development for many species (McDowall 1990; Jowett & Richardson 2002; Jowett & Boustead 2001). An increase in sedimentation can also affect stream morphology, reducing pool-run-riffle sequences by decreasing pool volume and subsequently resulting in reduced fish cover and fish density (Ryan 1991; Bjornn et al. 1977). Deposition of sediment on the riverbed can change and

reduce physical habitat for bottom-dwelling invertebrate and fish species by filling in the spaces between larger substrate particles and creating a smoother bed (Diplas & Parker 1992). This decreases hydraulic roughness and increases water velocity. Thus, not only is there less shelter for fish, but at the same time the increase in water velocity makes shelter from the current even more critical (Richardson and Jowett, 2002). This is important in New Zealand as many of our key fish species are benthic and their larvae/fry require calm water in streams and rivers to rear. This applies to riffle-dwelling species as well as species that prefer gentler flows (Jellyman and McIntosh 2008; Berkman & Rabeni, 1987).

3) Afforestation has been shown to reduce water yield and associated stream flow responses. Afforestation of pasture may reduce water yield by 30-50% five to ten years after planting and between 25-30% for tussock grasslands (Otago and Canterbury), with a similar percentage reduction in low flows. Reduced water yields from afforestation is likely to be greatest in areas of high rainfall (Fahey 1994). However, in some cases low flows are affected to a lesser extent than annual yield (Davie and Fahey 2005). However, Davie and Fahey (2005) also acknowledge that more research is needed on the effects of afforestation in New Zealand.

   Reduced river flows (by up to 50%, Fahey 1994) due to afforestation may result in habitat loss, displacement and possible biota mortalities in small ephemeral streams. The effects of reduced water yield from afforestation may however be mitigated by lower evaporation rates from soils in pine forests because of lower wind velocities and heavy litter accumulation (Hewlett 1958), as well as providing benefits like increased shading, cooler water temperatures and low nutrient input. It should also be noted that there is no significant difference in water yield between native forests and mature pine forests (Fahey 1994). Fahey (1994) also highlighted an increase in water yield by 60-80% after forestry harvesting in moderate-to-high rainfall areas, which can result in mean flood peaks rising by up to 50% compared with a forested site. However, this hydrological impact must be viewed in the context of the area harvested compared with the total forest area.

It is well documented that increased turbidity and sediment loads have negative impacts on fish communities in New Zealand (Rowe et al. 2000; Richardson and Jowett, 2002). It is likely that all fish species are negatively affected by forestry activities, but some species are able to cope better than others with these effects. The forestry effects ranking system (below) for key fish species in New Zealand attempts to rank each species' sensitivity to turbidity, sedimentation and flow reductions caused by afforestation. For some species extensive research has been undertaken on responses to turbidity and sedimentation, but for other species little information is available. For species with little or no information, expert opinion has been used to estimate likely sensitivity. For afforestation effects, the majority of species are assessed based on expert opinion due to a lack of studies on the sensitivity of native species to reduced flows.

Each fish in the calendar was reviewed in terms of its likely impact from forestry activities. These impacts have been split into three categories; turbidity, sedimentation and afforestation. Effects from turbidity are upon migration/recruitment and feeding, sedimentation incorporates reduced cover, foraging and food, spawning and stream morphology, and afforestation covers reduced flows.

A ranking was given to each species (Table 5.1) for these forestry effects, and the sum of individual rankings was used to summarise the overall sensitivity of individual species (Figure 5.1). Ranking categories are low (1-3), medium (4-6) and high (7-9) with zero not applicable. All species with a total score of 40 and above can be considered highly sensitive, species with a score of 30 to 39 will have a medium impact and species with a score below 30 are considered the least likely to be impacted by forestry effects. Sedimentation is considered the most important of the forestry effects to impact upon freshwater fish in New Zealand and was thus given four ranking categories that were added to the totals. This was followed by turbidity with two categories, and afforestation with one. It is intended that the overall totals will provide users with an understanding of which species will be most impacted.

A separate graph has also been created (Figure 5.2) excluding the afforestation ranking. For this figure all species with a total score of 30 and above can be considered highly sensitive, species with a score of 20 to 29 will have a medium impact and species with a score below 20 are considered the least likely to be impacted by forestry effects.

Table 5-1: Turbidity, sedimentation and afforestation effects ranking for key freshwater fish species. Ranking categories are low (1-3), medium (4-6) and high (7-9) with zero not applicable

Functional Group	Spawning Calendar	Turbidity		Sedimentation				Afforestation	Totals
	Species	Migration/Recruitment	Feeding	Reduced cover	Foraging and food	Spawning	Morphology	Reduced flows	
Bullies (fast flow) and Torrentfish	Bluegill bully	3	3	3	8	4	4	6	31
	Redfin bully	3	3	7	7	7	7	6	40
	Torrentfish	3	3	3	8	4	4	6	31
Bullies (slow flow)	Common bully	3	3	3	5	5	9	5	33
	Crans bully	3	3	5	5	5	9	5	35
	Giant bully	3	3	3	5	4	4	4	26
	Tarndale bully	2	4	2	2	4	0	2	16
	Upland bully	3	5	7	7	7	7	6	42
Eels	Longfin eel	2	2	5	3	2	3	5	22
	Shortfin eel	4	3	3	2	2	3	5	22
Inanga and smelt	Common smelt	3	3	2	4	4	6	5	27
	Inanga	2	3	2	4	3	6	5	25
	Stokells smelt	2	3	2	2	7	3	3	22
Lamprey	Lamprey	1	1	2	2	3	5	3	17
Large Galaxiids	Banded kokopu	8	7	8	5	4	7	5	44
	Giant kokopu	8	7	5	5	3	5	4	37
	Koaro	2	3	7	6	5	6	7	36
	Shortjaw kokopu	8	7	8	5	4	7	5	44
Mudfish*	Black mudfish	3	4	3	3	3	2	7	25
	Brown mudfish	3	4	3	3	3	2	7	25
	Canterbury mudfish	3	4	3	3	3	2	7	25
	Northland mudfish	3	4	3	3	3	2	7	25

Functional Group	Spawning Calendar	Turbidity		Sedimentation				Afforestation	Totals
	Species	Migration/Recruitment	Feeding	Reduced cover	Foraging and food	Spawning	Morphology	Reduced flows	
Non-migratory Galaxiids*	Alpine galaxias	3	5	9	9	9	9	8	52
	Bignose galaxias	3	5	9	9	9	9	8	52
	Canterbury galaxias	3	5	7	7	7	7	7	43
	Dusky galaxias	3	5	9	9	9	9	8	52
	Dwarf galaxias	3	5	9	9	9	9	8	52
	Eldons galaxias	3	5	7	7	7	7	7	43
	Taieri flathead galaxias	3	5	7	7	7	7	7	43
	Gollum galaxias	3	5	6	6	6	6	7	39
	Upland longjaw galaxias	3	5	9	9	9	9	8	52
	Lowland longjaw galaxias	3	5	9	9	9	9	8	52
	Roundhead galaxias	3	5	9	9	9	9	8	52
	Dwarf inanga	2	4	2	2	4	0	2	16
Salmonid Sportfish	Atlantic salmon	3	6	7	7	8	7	5	43
	Brook Char	3	6	7	7	8	7	5	43
	Brown trout	3	5	7	6	8	6	5	40
	Chinook salmon	3	6	7	7	8	7	5	43
	Mackinaw	2	4	2	2	4	0	2	16
	Rainbow trout	3	6	7	7	8	7	5	43
	Sockeye salmon	3	6	7	7	8	7	5	43
Koura	Northern	3	3	7	6	3	8	5	35
	Southern	3	3	7	6	3	8	5	35

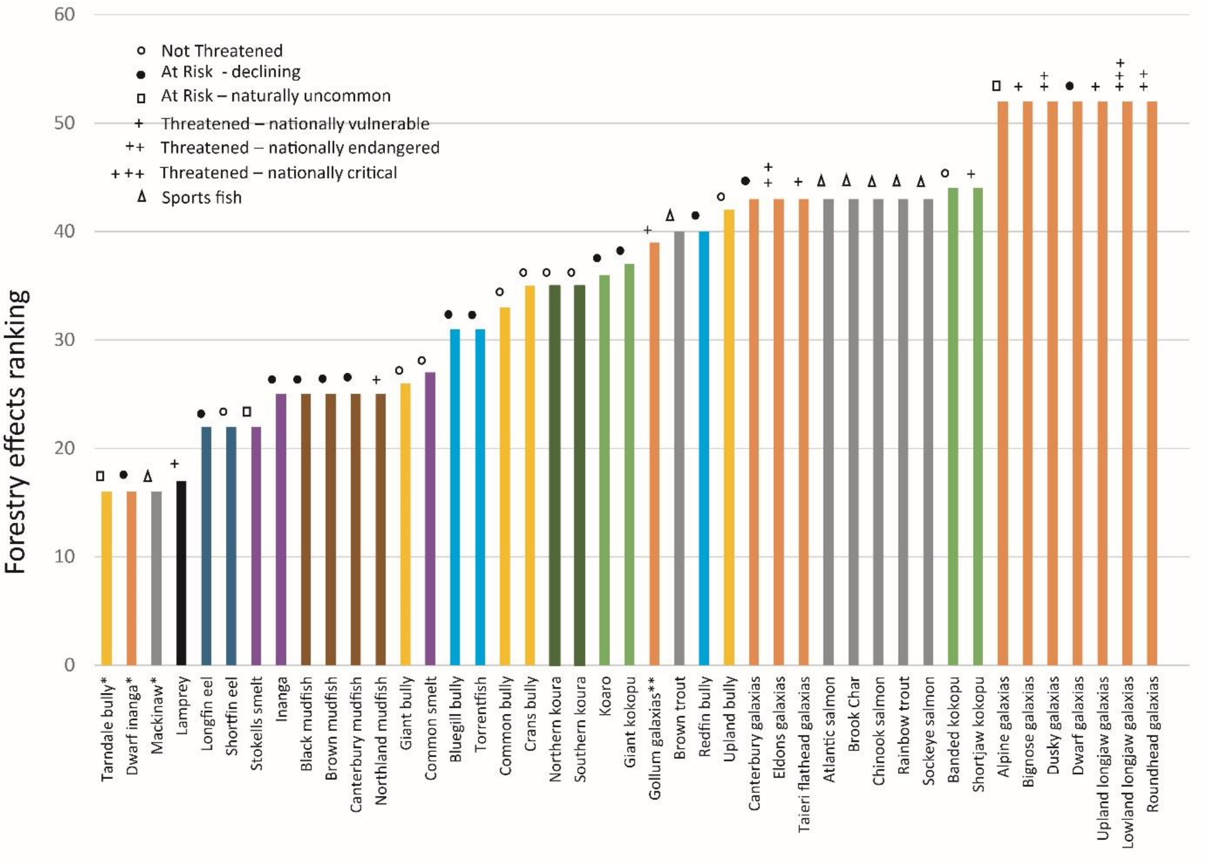

Figure 5-1: Combined forestry effects rankings from Table 5.1 (totals). Functional groups are match by colour (black for lamprey, yellow for bullies slow flow, orange for non-migratory galaxiids, grey for salmonid sportsfish, dark blue for eels, purple for inanga and smelt, brown for mudfish, light blue for torrentfish and bullies fast flow, light green for large galaxiids and dark green for koura). * denotes life cycle within lakes; **Gollum galaxias wetland and stream fish combined.

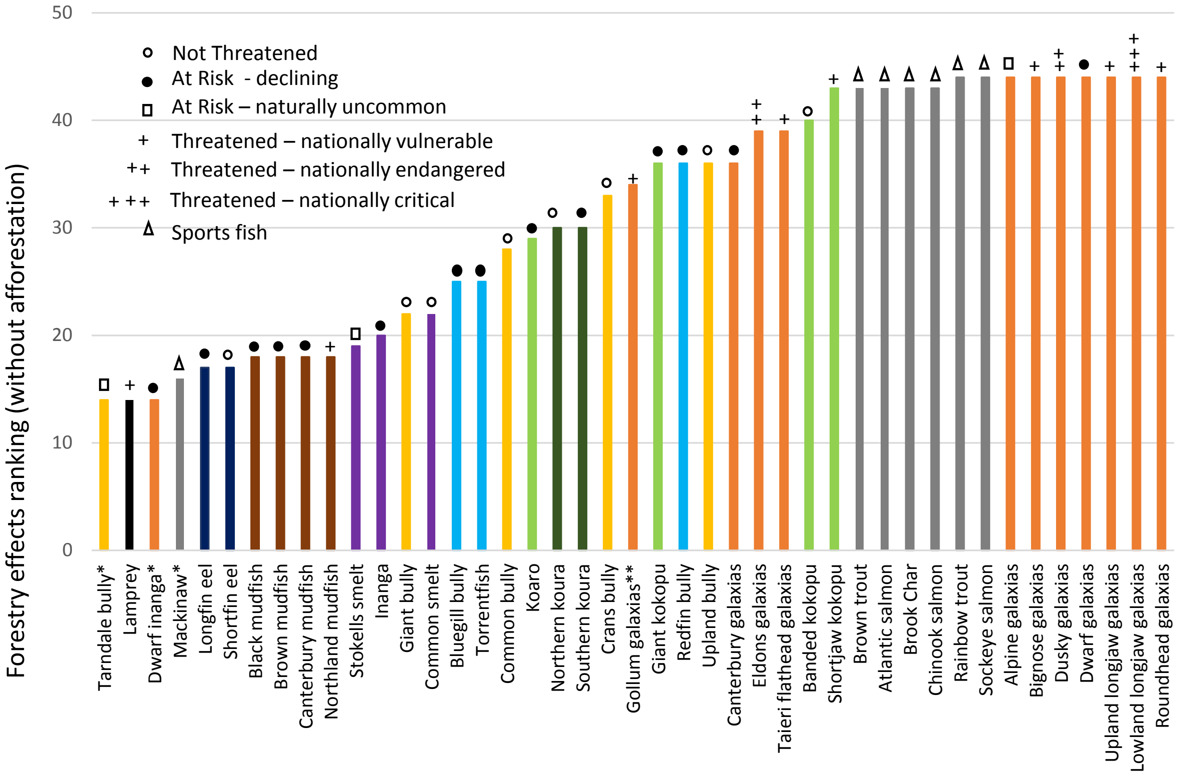

Figure 5-2: Combined forestry effects rankings from Table 5.1 (totals excluding afforestation). Functional groups are match by colour (black for lamprey, yellow for bullies slow flow, orange for non-migratory galaxiids, grey for salmonid sportsfish, dark blue for eels, purple for inanga and smelt, brown for mudfish, light blue for torrentfish and bullies fast flow, light green for large galaxiids and dark green for koura). * denotes life cycle within lakes; **Gollum galaxias wetland and stream fish combined.

5.1 Non-migratory galaxiids

Non-migratory galaxiids is the name given to a group of small (i.e., <150 mm) native fish that live their entire life cycle in freshwater habitats. Whilst technically non-migratory galaxiids includes two Genus', *Galaxias* and *Neochanna* (mudfish), in this document this term is used with reference to *Galaxias* species only. There are currently 12 described non-migratory galaxiids and they are generally found in the South Island - 11 of the 12 described species in this report; only 2 species are found in the North Island (but it is likely that more species will be described in the next decade). Compared to other fish families found in New Zealand (and globally), the family Galaxiidae is characterised by a very high percentage of threatened species (McDowall 2006), and the non-migratory galaxiids in particular are a highly threatened group of species. Of the 12 described non-migratory species, eight species are considered 'threatened' and the four other described species are classified as 'at risk'; there are no non-migratory galaxiid species described as 'not threatened' (Goodman et al. 2014). Thus, their ongoing management is a high priority for the Department of Conservation and should be an important consideration in plantations where forestry activities occur alongside these species.

For forestry managers it is important to recognise that non-migratory galaxiids can be found throughout a catchment, but they are generally absent in the lower reaches of rivers. The likelihood of encountering these fish increases with distance inland once the abundance of diadromous species (i.e., species that move between fresh water and marine environments) has decreased. The habitat conditions preferred by these species can vary, particularly at different life stages. For example, as larvae non-migratory galaxiids prefer slow-flowing backwater habitats, but as juvenile and adult fish they generally live in faster-flowing habitat such as riffles and runs (Jellyman and McIntosh 2008). Stream morphology changes brought about from sedimentation would reduce these slower flowing areas impacting on non-migratory galaxiids.

Substrate is particularly important to many New Zealand indigenous freshwater fish including non-migratory galaxiids because they are small and benthic, spending most of their lives in riffles and runs, where gravel and cobble substrates provide shelter from the current and predators, and provide an area for foraging and nesting. Though there are few studies looking at the effects of sedimentation on non-migratory galaxiids, Jowett and Boustead (2001) found that the abundance of upland bullies (*Gobiomorphus breviceps*) (a non-migratory bully that has similar benthic habits to many of the non-migratory galaxiids) reduced by more than 60% when sediment was added to cobble habitat, hence reducing cover. This detrimental effect of sedimentation would likely be similar for species with similar benthic habits, like non-migratory galaxiids. It is also likely that sedimentation would detrimentally affect spawning and the production of prey species of non-migratory galaxiids (though this has not been studied for non-migratory galaxiids). The increased suspended solids would likely result in displacement/avoidance as well as potentially reduce feeding ability (again this has not been studied for non-migratory galaxiids). As many of the non-migratory galaxiids inhabit small shallow streams, reduced flows resulting from afforestation would result in habitat loss and displacement and even mortalities in some small ephemeral streams. For the reasons outlined above most non-migratory galaxiids have been given a high forestry effects ranking apart from the Canterbury, Eldon's and Taieri flathead galaxias, which have been given medium to high ranking as they do inhabit some lowland sites reasonably well (though often full of parasites). Gollum galaxias also has been given medium to high ranking as some of these fish are found in wetland areas rather than streams making them less susceptible to turbidity and sedimentation. Dwarf inanga are a lake fish and for this reason have been ranked low to medium.

5.2 Mudfish

Despite their name mudfish prefer clean rather than turbid water and are not generally found in eutrophic wetlands. Many sites that contain mudfish are now small remnants of once larger habitats and their future at these sites is uncertain, since water levels in small wetlands can be very unstable (Ling, 2001). Afforestation close to these wetlands could dry them up for longer periods than normal. Though mudfish have the ability to aestivate for several months (live within the mud when water dries up) the availability of water to these species is important. Sediment run-off causing increases in turbidity and a state of gradual eutrophication needs to be managed carefully close to mudfish populations (Ling, 2001). Effects from forestry on mudfish are reduced because of the habitat they occupy. Though mudfish can still be affected by turbidity and sedimentation, the main adverse factor would likely be afforestation and the associated impacts on hydrology. Consequently, mudfish are ranked low to medium for turbidity and sedimentation, and high for afforestation.

5.3 Salmonid sportsfish

Trout and salmon will avoid highly turbid water with some mortalities occurring. They also generally grow more slowly in turbid water (Sigler et al. 1984). Visual feeding can also be affected by higher turbidity (O'Scannell 1988), though Rowe (et al. 2002) found that turbidity did not affect the feeding ability of rainbow trout. Benthic food organisms may also be smothered by silt, making the impact twofold – not only are the food items reduced in number, but they are also harder to visually locate

(Ryan, 1991). Sedimentation can cause egg mortality and many salmonids will not spawn on gravels that have become silted (Alabaster and Lloyd, 1982). The deposition of sediment also reduces the amount of interstitial space between rocks and stones which is used by juvenile salmonids as shelter (Bjornn, 1971). Changes to stream morphology by increases in sediment loads can reduce the hydraulic roughness of a stream bed increasing water velocities, particularly near-bed velocities (Jowett and Boustead, 2001), resulting in less habitat being available for both adult fish and fry. Reduced flows from afforestation could reduce the available area for spawning in small tributaries and adult habitat in the main-stems of larger rivers and streams. Effects from forestry on salmon and trout would be medium for turbidity, high for sedimentation (especially for spawning) and medium for afforestation. The Mackinaw would be less effected than the other fish in this group as its life cycle is entirely lake based.

5.4 Bluegill bully

Bluegill bullies are relatively insensitive to elevated suspended solids in terms of avoidance (Rowe et al. 2000). They are common in turbid rivers, and therefore better adapted to cope with increased solids loading in rivers (Rowe et al. 2000). This may, however, be related to their habitat preferences being less affected by sedimentation i.e., fast flowing runs and riffles. However, Hanchet and Hayes (1989) found a negative association with bluegill bullies and silt. Jowett et al. (1996) also found the abundance of bluegill bullies was higher at native forest sites than exotic forest sites, which was also positively correlated with a higher invertebrate density. Reduced flows from afforestation would reduce available habitat resulting in lower numbers, with riffles being particularly sensitive to reduced flows.

Turbidity	Low
Sedimentation	Medium - High
Afforestation	Medium

5.5 Redfin bully

Redfin bullies are insensitive to elevated suspended solids with respect to both avoidance and feeding (Boubee et al. 1997; Rowe et al. 1998, 2000). However, they are not common in turbid rivers, which is likely to be related to high concentrations of settled solids reducing food supply and benthic habitat (cover and spawning sites) (Rowe et al. 2000; Jowett and Boustead 2001). Reduced flows from afforestation would reduce available habitat resulting in lower abundances.

Turbidity	Low
Sedimentation	High
Afforestation	Medium

5.6 Torrentfish

Torrentfish are relatively insensitive to elevated suspended solids in terms of avoidance (Rowe et al. 2000). They are common in turbid rivers, and therefore better adapted to cope with increased solids loading in rivers (Rowe et al. 2000), although this may be related to their habitat preferences being less affected by sedimentation i.e., fast flowing runs and riffles. However, Hanchet and Hayes (1989) study found a negative association with torrentfish and silt which may be correlated with a higher invertebrate density. Reduced flows from afforestation would reduce the availability of preferred riffle habitats resulting in lower abundances.

Turbidity Low

Sedimentation Medium

Afforestation Medium

5.7 Common bully

Common bullies are relatively insensitive to elevated suspended in terms of avoidance (Rowe et al. 2000). Feeding rates decline as turbidity levels increase (Rowe and Dean, 1998). However, they are still relatively common in turbid rivers, and therefore may be adapted to cope with increased solids loading in rivers (Rowe et al. 2000). This may be a result of less cover requirements for this species. However, they would likely be negatively affected by an increase in sedimentation in terms of cover (Jowett and Boustead 2001). A change in stream morphology would reduce the amount of pool habitat that common bullies favour reducing numbers. Reduced flows from afforestation would reduce available habitat resulting in lower abundances.

Turbidity Low

Sedimentation Low - Medium

Afforestation Medium

5.8 Cran's bully

Not a lot of information is available on Cran's bully, but they inhabit similar habitats to that of common bullies and is likely to have the same responses to that of common bullies in relation to forestry impacts (see above). The main difference is that it is a non-migratory species and thus larvae would require quiet areas (stream margins and backwaters) to rear. A reduction in pool habitat would likely negatively affect this species.

Turbidity Low

Sedimentation Medium

Afforestation Medium

5.9 Giant bully

Not a lot of information is available on the effects of forestry on giant bullies, but inhabits similar habitats to that of common bullies at low elevations and is likely to have similar responses to that of common bullies in relation to forestry impacts (see above).

Turbidity Low

Sedimentation Low

Afforestation Low

5.10 Tarndale bully

Little information is available on the effects of forestry on Tarndale bullies, however its feeding ability could become affected if the turbidity in the lake increased, but as it is a lake species forestry effects would likely be minimal.

Turbidity	Low
Sedimentation	Low
Afforestation	Low

5.11 Upland bully

Jowett and Boustead (2001) found that the abundance of upland bullies (*Gobiomorphus breviceps*) reduced by more than 60% when sediment was added to cobble habitat, reducing cover. However, there is no information on the effects of turbidity for upland bullies. It is a non-migratory species that prefers quieter flows and larvae would require quiet areas (stream margins and backwaters) to rear. A reduction in pool habitat would likely negatively affect this species.

Turbidity	Low - Medium
Sedimentation	High
Afforestation	Medium

5.12 Longfin eel

Longfin eels are insensitive to elevated suspended solids in terms of avoidance (Rowe et al. 2000; Boubee et al. 1997). They are common in turbid rivers, and therefore better adapted to cope with increased solids loading in rivers (Rowe et al. 2000). However, Hanchet and Hayes (1989) study found a negative association with longfin eels and silt. Longfin eels prefer water with higher concentrations of dissolved oxygen and longfin elvers prefer substrates of coarse gravel and rock (Jellyman, 1977 and 1979). Reduced flows from afforestation would reduce available habitat resulting in lower abundances.

Turbidity	Low
Sedimentation	Low
Afforestation	Low

5.13 Shortfin eel

Shortfin eels are insensitive to elevated suspended solids in terms of avoidance (Rowe et al. 2000; Boubee et al. 1997). However, shortfin eels have been found to have a reduced abundance in turbid rivers compared with longfin eels (Rowe et al. 2000). Shortfin elvers prefer mud and silt substrates and static water (Jellyman, 1977, 1979) and do not penetrate as far inland as longfin eels. Reduced flows from afforestation would reduce available habitat resulting in lower abundance.

Turbidity	Low
Sedimentation	Low

Afforestation Low

5.14 Common smelt

Smelt avoid low levels of suspended solids (Rowe et al. 2009; Rowe and Dean 1998), however their feeding was not reduced by an increase in turbidity (Rowe et al. 2002). Smelt are likely less affected by settled solids as they are less benthic than other species and live mostly in the water column (Jowett and Boustead, 2001). However, this species is less common in turbid rivers (Rowe et al. 2000) and lacustrine stocks are known to be reduced by increased siltation in lakes (Rowe and Taumoepeau, 2004). Reduced flows from afforestation would reduce available habitat resulting in lower abundances.

Turbidity Low - Medium

Sedimentation Low - Medium

Afforestation Medium

5.15 Inanga

Inanga are unlikely to be adversely affected by increases in suspended solids (Rowe et al. 2009) However, Rowe et al. (2000) found that occurrence of inanga declined as the duration of turbid conditions increased. Juvenile inanga feeding rates were significantly reduced by increases in turbidity (Rowe and Dean, 1998), but adult inanga feeding was not reduced by an increase in turbidity (Rowe et al. 2002). Inanga are likely less affected by settled solids as they are less benthic than other species and live mostly in the water column (Jowett and Boustead, 2001). This species is also common in turbid rivers (Rowe et al. 2000). Reduced flows from afforestation would reduce available habitat resulting in lower abundances.

Turbidity Low

Sedimentation Medium

Afforestation Low

5.16 Stokell's smelt

Little is known about Stokell's smelt, but its reaction to sediment and turbid conditions would likely be similar to that of common smelt. It does, however, spawn in river and estuarine gravels that could become affected by sedimentation. Apart from spawning and egg development it lives entirely at sea so forestry effects would be limited.

Turbidity Low

Sedimentation Low

Afforestation Low

5.17 Lamprey

Lamprey are likely to be unaffected by short-term increases in turbidity and often migrate upstream during periods of high flow and turbidity. Lamprey require high gradient boulder habitat as adults in which to spawn. Given these spawning locations for adults, any sedimentation that occurs will be transported downstream relatively quickly. Lamprey larvae (ammocoetes) are often found in pockets of sediment downstream from spawning sites making sedimentation possibly beneficial to this species. Given their preference for fine sediments in stream margins and backwaters, their distribution may be related to suspended sediment levels. Changes to stream morphology may reduce pool and backwater habitat for larvae. Afforestation is likely to have little effect on lamprey.

Turbidity	Low
Sedimentation	Low
Afforestation	Low

5.18 Banded kokopu

Juvenile migrant banded kokopu avoid low levels of suspended solids, which will likely affect their migration into adult habitats (Boubee et al. 1997; Rowe et al. 2000, 2001). Their feeding ability was also reduced by an increase in turbidity (Rowe and Dean 1998). Banded kokopu are less likely to be found in turbid rivers (Rowe et al. 2009). This may also be related to their habitat (generally pools) and cover requirements that include boulders, undercut banks and woody debris dams (Rowe and Smith, 2003). Richardson and Jowett (2002) found less cover for fish such as banded kokopu in streams with high sediment loads, shallower pools, finer substrates, swifter flows and little or no in-stream debris. Reduced flows from afforestation would reduce available habitat resulting in lower abundances.

Turbidity	High
Sedimentation	High
Afforestation	Medium

5.19 Giant kokopu

There is little information on the effects of turbidity and sedimentation for giant kokopu. The closest comparable fish would be the banded kokopu, however, giant kokopu are generally found in lower gradient streams and rivers with deeper pools with less inland penetration (Baker and Smith 2007). Thus effects from turbidity, sedimentation and afforestation are likely to be similar to that of banded kokopu. However, they are likely to be more tolerant of sedimentation because of their preference for lowland habitats.

Turbidity	High
Sedimentation	Medium
Afforestation	Medium

5.20 Koaro

Koaro are relatively insensitive to elevated suspended solids (Rowe et al. 2000), and their feeding is not affected by increases in turbidity (Rowe and Dean 1998). Koaro are common in turbid rivers, and are therefore better adapted to cope with increased solids loading in rivers (Rowe et al. 2000). However, these species are generally only found in high gradient sections of streams with many runs and riffles containing a cobble/boulder substrate. These sections of streams would be regularly flushed of sediment. If substrate become choked with sediment, koaro cover, food supply and spawning habitat would likely be lost. Koaro often inhabit small ephemeral streams so reduced flows from afforestation would reduce available habitat resulting in lower abundances and possible displacement.

Turbidity	Low
Sedimentation	High
Afforestation	Medium -High

5.21 Shortjaw kokopu

There is little information on the effects of turbidity and sedimentation for shortjaw kokopu. The closest comparable fish would be the banded kokopu and these two species share some similar habitat preferences; generally pools with good amounts of cover (rocks, banks and in-stream debris) and are often found together (Goodman 2002). Their spawning habitat and timing is also similar (Charteris 2003). Thus effects from turbidity, sedimentation and afforestation are likely to be similar to that of banded kokopu.

Turbidity	High
Sedimentation	High
Afforestation	Medium

5.22 Koura

Southern koura young-of-the-year (YOY) in a study by Usio and Townsend (2000) were negatively associated with suspended solid concentrations and positively associated with coarse substrates. Cobbles provide important shelter from predators for juveniles (Reynolds & Souty-Grosset 2011) so these results are consistent with the hypotheses that koura are vulnerable to sedimentation. Koura prefer shade and seek cover during the day (Parkyn 2007, Jones 1981a). Native riparian vegetation is positively related to Southern koura presence whereas exotic riparian vegetation appears to be negatively related to crayfish presence (Jansma 1995). Similar results have been observed for Northern koura preferring habitat with good cover with adult koura associated with cobble substrate. Undercut banks, tree roots, leaf litter and woody debris were also found to be important factors in the presence –absence of koura (Jowett et al. 2007). Parkyn et al. (2002) found higher densities of koura in native forest streams, but higher growth rates and biomass of koura in pasture streams; probably due mainly to higher temperatures in unshaded pasture streams. The highest koura numbers found in Jowett's 2007 study were found in still or slow flowing water in water depths of 0.2 to 0.3 m with YOY preferring stream edge habitat. A preference for low flows and edge habitat was also suggested by Hicks (2003). Koura are a non-migratory species that prefers quieter flows and YOY would require quiet areas (stream margins, backwaters and pools) to rear. A reduction in slow flowing and edge habitat brought about by increases in sedimentation leading to changes in stream morphology would likely negatively affect this species. Koura often inhabit small ephemeral streams so reduced flows from afforestation would reduce available habitat resulting in lower abundances and possible displacement. Decreased temperatures from afforestation may also decrease growth of koura.

Turbidity	Medium
Sedimentation	High
Afforestation	Medium

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8 Appendices

8.1 Bullies (fast flow) and Torrentfish

Information	Description
Species	Bluegill bully (*Gobiomorphus hubbsi*)
Functional group	Bullies (fast flow) and Torrentfish
Conservation status	At Risk (declining)[4]
Geographic range	New Zealand wide, up to 100km inland penetration [1, 2]
Forestry regions	All
Preferred adult habitat	Fast flowing water, riffles and fast runs and associated substrate (gravel/cobble) [1, 2]
Larvae habitat	Downstream to sea
Life cycle	Diadromous[3]
Spawning habitat	Beneath instream rocks [1, 2]
Spawning range	Early Spring / Summer - September to February[3] (and likely August)
Spawning peak	Not known
Upstream migration	Juvenile
Upstream migration range	Late spring through summer [3] November – February (and likely March)
Upstream migration peak	Not known
Downstream migration	Larvae
Downstream migration range	October through February [3] (September – March in line with spawning)
Downstream migration peak	Not known
Turbidity ranking	Low
Sedimentation ranking	Medium - High
Afforestation ranking	Medium
References	1) McDowall 1990 2) McDowall 2000 3) 1995 4) Goodman et al. (2014)

Information	Description
Species	Redfin bully (*Gobiomorphus huttoni*)
Functional group	Bullies (fast flow) and Torrentfish
Conservation status	At Risk (declining)[4]
Geographic range	New Zealand wide (apart from Northland), up to 266km inland penetration [1, 2]
Forestry regions	All apart from Northland
Preferred adult habitat	Moderately to swift flowing water [1, 2]
Larvae habitat	Downstream to sea
Life cycle	Diadromous
Spawning habitat	Beneath in-stream rocks [2]
Spawning range	Late winter through spring August – November[3]
Spawning peak	Not known
Upstream migration	Juvenile
Upstream migration range	Late spring through summer [3] November – February (and likely March)
Upstream migration peak	Not Known
Downstream migration	Larvae
Downstream migration range	October – February[3] (and likely September in line with spawning)
Downstream migration peak	Not known
Turbidity ranking	Low
Sedimentation ranking	High
Afforestation ranking	Medium
References	1) McDowall 1990 2) McDowall 2000 3) McDowall 1995 4) Goodman et al. (2014)

Information	Description
Species	Torrentfish (*Cheimarrichthys fosteri*)
Functional group	Bullies (fast flow) and Torrentfish
Conservation status	At Risk (declining)[5]
Geographic range	Widespread North & South Is. from sea level to 235km inland. [2]
Forestry regions	All
Preferred adult habitat	Fast flowing water [1, 2]
Larvae habitat	Downstream to sea
Life cycle	Diadromous
Spawning habitat	Not known, likely gravel substrate [1, 2]
Spawning range	Summer/Autumn [2,] January to April[4,] late spring to autumn[1,] (November to May)
Spawning peak	January - April [3, 4]
Upstream migration	Juvenile
Upstream migration range	April - November[3, 4]
Upstream migration peak	Likely March - April to match with spawning peak
Downstream migration	Larvae
Downstream migration range	December – June (in line with spawning range)
Downstream migration peak	February - May[4, 3]
Turbidity ranking	Low
Sedimentation ranking	Medium
Afforestation ranking	Medium
References	1) McDowall 1990 2) McDowall 2000 3) McDowall 1995 4) Scrimgeour and Eldon 1989 5) Goodman et al. (2014)

8.2 Bullies (slow flow)

Information	Description
Species	Common bully (*Gobiomorphus cotidianus*)
Functional group	Bullies (slow flow)
Conservation status	Not Threatened[4]
Geographic range	New Zealand wide, up to 313km inland penetration[2] plus lacustrine populations
Forestry regions	All
Preferred adult habitat	Gentle flow[1,2]
Larvae habitat	Downstream to sea and lacustrine populations
Life cycle	Diadromous and lacustrine
Spawning habitat	Large in-stream rocks or aquatic vegetation and debris [2] Lake populations will spawn in lakes[7]
Spawning range	Spring / summer[2,3] September – February (and likely August)
Spawning peak	Not Known (will vary season to season)
Upstream migration	Juvenile
Upstream migration range	Summer [5,] December – February (and likely March)
Upstream migration peak	Not known (will vary season to season)
Downstream migration	Larvae
Downstream migration range	September – March (as per spawning range)
Downstream migration peak	October – November [6]
Turbidity ranking	Low - Medium
Sedimentation ranking	Low - Medium
Afforestation ranking	Medium
References	1) McDowall 1990 2) McDowall 2000 3) McDowall 1995 4) Goodman et al. 2014 5) Stancliff et al. 1988 6) Meredith et al. 1989 7) Rowe and Graynoth 2002

Information	Description
Species	Cran's bully (*Gobiomorphus basalis*)
Functional group	Bullies (slow flow)
Conservation status	Not Threatened[3]
Geographic range	North Island only
Forestry regions	NL, CNI, EC, HB, SNI
Preferred adult habitat	Still water around stream margins[2]
Larvae habitat	Gravelly substrate in still water around stream margins[1, 2]
Life cycle	Lacustrine
Spawning habitat	Beneath in-stream rocks [2]
Spawning range	Spring / summer[2,] September – February (and likely August)
Spawning peak	Not known (will vary from season to season)
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Low
Sedimentation ranking	Medium
Afforestation ranking	Medium
References	1) McDowall 1990 2) McDowall 2000 3) Goodman et al. (2014)

Information	Description
Species	Giant bully (*Gobiomorphus gobioides*)
Functional group	Bullies (slow flow)
Conservation status	Not Threatened[3]
Geographic range	New Zealand wide at low elevations up to 21km inland penetration[2]
Forestry regions	All
Preferred adult habitat	Estuaries & nearby waters [1]
Larvae habitat	Downstream to sea
Life cycle	Diadromous
Spawning habitat	Beneath large in-stream rocks[2]
Spawning range	Spring / summer[5,] September – February (and likely August)
Spawning peak	Not known (will vary from season to season)
Upstream migration	Juvenile
Upstream migration range	Not known but likely December – March [2, 4]
Upstream migration peak	Not known (will vary from season to season)
Downstream migration	Larvae
Downstream migration range	Not known but likely September – March (as per spawning range)[4]
Downstream migration peak	Not known (will vary from season to season)
Turbidity ranking	Low - Medium
Sedimentation ranking	Low
Afforestation ranking	Low
References	1) McDowall 1990 2) McDowall 2000 3) Goodman et al. (2014) 4) Franklin and Baker (pers. Comm) 5) Jellyman et al. 2000

Information	Description
Species	Tarndale bully (*Gobiomorphus alpinus*)
Functional group	Bullies (slow flow)
Conservation status	At Risk (Naturally uncommon)[3]
Geographic range	Found in only a few small sub-alpine tarns in Marlborough.
Forestry regions	NM
Preferred adult habitat	Lake margins amongst boulders and cobbles[2]
Larvae habitat	Probably pelagic in lakes[2]
Life cycle	Lacustrine
Spawning habitat	Beneath rocks[2]
Spawning range	Spring / summer[1,] September – February (and likely August)
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	Low
Afforestation ranking	Low
References	1) Rowe and Graynoth (2002) 2) McDowall 2000 3) Goodman et al. (2014)

Information	Description
Species	Upland bully (*Gobiomorphus breviceps*)
Functional group	Bullies (slow flow)
Conservation status	Not Threatened[3]
Geographic range	New Zealand wide (apart from Northland and East Coast, mainly lower North Island and South Island)[2]
Forestry regions	All apart from Northland and East Coast
Preferred adult habitat	Swift to gentle flow. Wide habitat variety[1, 2]
Larvae habitat	Stream margins and lake shallows[2]
Life cycle	Lacustrine
Spawning habitat	Beneath large in-stream rocks[2]
Spawning range	Spring / summer[2, 5] September – February (and likely August)
Spawning peak	October – December[4]
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Low - Medium
Sedimentation ranking	High
Afforestation ranking	Medium
References	1) McDowall 1990 2) McDowall 2000 3) Goodman et al. 2014 4) Staples 1975 5) McDowall and Eldon 1997

8.3 Eels

Information	Description
Species	Longfin eel (*Anguilla dieffenbachii*)
Functional group	Eels
Conservation status	At Risk (declining)[4]
Geographic range	New Zealand wide, strong inland penetration[2]
Forestry regions	All
Preferred adult habitat	Faster-flowing stony streams and rivers [1]
Larvae habitat	Sea
Life cycle	Diadromous
Spawning habitat	Migrates to sea to spawn [2]
Spawning range	Not known
Spawning peak	Not known
Upstream migration	Glass eels and elvers
Upstream migration range	Glass eels (estuary and lower river) July to November, elvers November to April [1, 3]
Upstream migration peak	Glass eels August to October and elvers December to March [1, 3]
Downstream migration	Adults
Downstream migration range	Autumn – March to May [2, 3]
Downstream migration peak	Flood events during autumn[5]
Turbidity ranking	Low
Sedimentation ranking	Medium - Low
Afforestation ranking	Low
References	1) Jellyman et al. 1999 2) McDowall 2000 3) Boubee et al. 2000 4) Goodman et al. (2014) 5) Boubee at al. 2001

Information	Description
Species	Shortfin eel (*Anguilla australis*)
Functional group	Eels
Conservation status	Not Threatened[4]
Geographic range	New Zealand wide, up to 292 km inland penetration[2]
Forestry regions	All
Preferred adult habitat	Wetlands, low elevation rivers and streams [2]
Larvae habitat	Sea
Life cycle	Diadromous
Spawning habitat	Migrates to sea to spawn [2]
Spawning range	Not known
Spawning peak	Not known
Upstream migration	Glass eels and elvers
Upstream migration range	Glass eels (estuary & lower river) August to December, elvers November to April [1, 3]
Upstream migration peak	Glass eels September to November and elvers December to March [1, 3]
Downstream migration	Adults
Downstream migration range	Late summer / Autumn – February to March [2, 3]
Downstream migration peak	Flood events during late summer and autumn[5]
Turbidity ranking	Medium
Sedimentation ranking	Low
Afforestation ranking	Low
References	1) Jellyman et al. 1999 2) McDowall 2000 3) Boubee et al. 2000 4) Goodman et al. 2014 5) Boubee at al 2001

8.4 Inanga and smelt

Information	Description
Species	Common smelt (*Retropinna retropinna*)
Functional group	Inanga and smelt
Conservation status	Not Threatened[4]
Geographic range	New Zealand wide at low elevations up to 236 km inland penetration, plus landlocked populations[2]
Forestry regions	All
Preferred adult habitat	Still / gently flowing water in streams and rivers. Open waters and margins of lakes [2]
Larvae habitat	Sea/lakes
Life cycle	Diadromous and lacustrine
Spawning habitat	Sand banks [2]
Spawning range	December to July for sea run fish [1, 5] Spring (and likely August) and summer for landlocked populations[6]
Spawning peak	Autumn - March to May [3] and June [7]
Upstream migration	Juveniles (some adult lake fish may move into streams) [6]
Upstream migration range	August to November [1, 3], (spring to summer for some adult lake fish) [6]
Upstream migration peak	September to November [1, 3, 7]
Downstream migration	Larvae
Downstream migration range	January to August (to match spawning range)
Downstream migration peak	April to June (to match spawning peak)
Turbidity ranking	Low - Medium
Sedimentation ranking	Low - Medium
Afforestation ranking	Medium
References	1) McDowall 1990 2) McDowall 2000 3) Stancliff et al. 1988 4) Goodman et al. 2014 5) Ward at al 2005 6) Rowe and Graynoth 2002 7) Baker pers comm.

Information	Description
Species	Inanga (*Galaxias maculatus*)
Functional group	Inanga and smelt
Conservation status	At Risk (declining)[4]
Geographic range	Found widely at low elevations and near coast of New Zealand [2], a handful of landlocked populations occur in Northland [8].
Forestry regions	All
Preferred adult habitat	Gently flowing and still water [1, 2]
Larvae habitat	Sea
Life cycle	Diadromous (with a few small lacustrine populations)
Spawning habitat	Migrates downstream to estuaries[2] and lower river reaches [5] Spawns in intertidal vegetation
Spawning range	September to June [7]
Spawning peak	Autumn - March to April [7] and May, June [5]
Upstream migration	Juveniles
Upstream migration range	May to December [1, 3, 5]
Upstream migration peak	August to October [7] plus November [5]
Downstream migration	Larvae
Downstream migration range	October to August (to match spawning range)
Downstream migration peak	April to July (to match spawning peak)
Turbidity ranking	Low - Medium
Sedimentation ranking	Medium
Afforestation ranking	Low
References	1) McDowall 1990 2) McDowall 2000 3) Stancliff et al. 1988 4) Goodman et al. 2014 5) Franklin and Baker (pers. com) 6) Wilding 2000 (and references therein) 7) McDowall 1995 8) Rowe and Graynoth 2002

Information	Description
Species	Stokell's smelt (*Stokellia anisodon*)
Functional group	Inanga and smelt
Conservation status	At Risk (naturally uncommon)[4]
Geographic range	Found only in Canterbury rivers at low elevations and no further inland than 12 km.[2]
Forestry regions	CAN
Preferred adult habitat	Lives entirely at sea apart from spawning and egg development [2]
Larvae habitat	Sea
Life cycle	Diadromous
Spawning habitat	Spawns over estuarine/river gravels [2]
Spawning range	Spring / Summer, September to February [1, 2] (and likely August)
Spawning peak	December to January [3]
Upstream migration	Adult
Upstream migration range	October to March [3]
Upstream migration peak	November to December [5]
Downstream migration	Larvae
Downstream migration range	September to March (to match spawning range)
Downstream migration peak	January to February (to match spawning peak)
Turbidity ranking	Low - Medium
Sedimentation ranking	Low - Medium
Afforestation ranking	Medium
References	1) McDowall 1990 2) McDowall 2000 3) McDowall 1995 4) Goodman et al. 2014 5) Eldon and Greager 1983

8.5 Lamprey

Information	Description
Species	Lamprey (*Geotria australis*)
Functional group	Lamprey
Conservation status	Threatened, Nationally Vulnerable[4]
Geographic range	NZ wide, including Stuart and Chatham Islands[2]
Forestry regions	All
Preferred adult habitat	Boulder aggregations[2]
Ammocoete habitat	Sandy/silty margins and backwaters[2]
Life cycle	Diadromous
Spawning habitat	Under large instream boulders[5]
Spawning range	Spring/early summer (August to December)[5]
Spawning peak	October[5] (Okuti catchment may vary in others)
Upstream migration	Adult
Upstream migration range	Autumn through spring, April to November[6]
Upstream migration peak	June to September [5]
Downstream migration	Macropthalmia
Downstream migration range	All year round - up to four years from hatching[2]
Downstream migration peak	No known peak – long term migration
Turbidity ranking	Low
Sedimentation ranking	Low
Afforestation ranking	Low
References	1) McDowall 1990 2) McDowall 2000 3) McDowall 1995 4) Goodman et al. 2014 5) C. Baker pers. comm. 2014

8.6 Large Galaxiids

Information	Description
Species	Banded kokopu (*Galaxias fasciatus)*
Functional group	Large galaxiids
Conservation status	Not Threatened[4]
Geographic range	Widespread throughout New Zealand penetrates well inland to 177km, some landlocked populations[2] (Lakes Ototoa (NL), Kaihoka (NM), Hunua and Waitakere lakes (NL)and several lakes in the Wellington region (SNI)) [7]
Forestry regions	All
Preferred adult habitat	Generally small pools in small rocky streams [1, 2]
Larvae habitat	Sea/lakes
Life cycle	Diadromous with several lacustrine populations
Spawning habitat	Forest litter along stream margins at flood [2, 5] including lake populations (using streams flowing into lakes)[7]
Spawning range	Autumn/Winter for sea run fish[2] unknown for landlocked populations
Spawning peak	May to June [5] (sea run fish)
Upstream migration	Juvenile
Upstream migration range	August to December (sea run fish)
Upstream migration peak	September to October [6] (sea run fish)
Downstream migration	Larvae
Downstream migration range	April to September for sea run fish (to match spawning range)
Downstream migration peak	June to July for sea run fish [3] (to match spawning peak)
Turbidity ranking	High
Sedimentation ranking	High
Afforestation ranking	Medium
References	1) McDowall 1990 2) McDowall 2000 3) McDowall 1995 4) Goodman et al. 2014 5) Charteris et al. 2003 6) Wilding 2000 (and references therein) 7) Rowe and Graynoth 2002

Information	Description
Species	Giant kokopu (*Galaxias fasciatus)*
Functional group	Large galaxiids
Conservation status	At Risk (declining) [4]
Geographic range	Widespread throughout New Zealand at low elevations but rare East Cape to Otago Peninsula. Penetrates well inland to 170km, some landlocked lake populations on the West Coast, Bay of Plenty and Lower North Island [2]
Forestry regions	All, apart from Hawkes Bay
Preferred adult habitat	Gently flowing weedy/boggy streams, swampy lagoons and lake margins [1, 2]
Larvae habitat	Sea/lakes
Life cycle	Diadromous with several lacustrine populations
Spawning habitat	Stream/river margins at flood [5] including lake populations (using streams flowing into lakes)[8]
Spawning range	April to July[5] and August [3, 7] for sea run fish, unknown for landlocked populations
Spawning peak	May to June [5]
Upstream migration	Juvenile
Upstream migration range	October to December [3]
Upstream migration peak	November[6]
Downstream migration	Larvae
Downstream migration range	May to September (to match spawning range)
Downstream migration peak	June to July [5] (to match spawning peak)
Turbidity ranking	High
Sedimentation ranking	Medium
Afforestation ranking	Medium
References	1) McDowall 1990 2) McDowall 2000 3) McDowall 1995 4) Goodman et al. 2014 5) Franklin et al. 2014 6) McDowall and Eldon 1980 7) McDowall and Kelly 1999 8) Franklin pers. comm. 2014

Information	Description
Species	Koaro (*Galaxias brevipinnis)*
Functional group	Large galaxiids
Conservation status	At Risk (declining)[4]
Geographic range	Widespread throughout New Zealand with good inland penetration, also landlocked populations in many lakes [2]
Forestry regions	All
Preferred adult habitat	Swift boulder-cobble streams [1, 2]
Larvae habitat	Sea/lakes
Life cycle	Diadromous with multiple lacustrine populations
Spawning habitat	Marginal gravels and litter during elevated flows [2, 5] including lake populations (using streams flowing into lakes) spawning may occur in tarns with no inlet streams[7]
Spawning range	Late Autumn - Winter [3] April to August. Summer and autumn for landlocked popuations[7], (including November)[10]
Spawning peak	April – May for sea run fish [5] and November to March for lacustrine populations [10]
Upstream migration	Juveniles - for all populations and adults for lacustrine populations
Upstream migration range	September to November for sea run juveniles[3, 6] landlocked fish August to February for juveniles[9] and September to April for landlocked adult fish[7]
Upstream migration peak	September to October for sea run fish [8] and December for juvenile lacustrine fish [9], and November to March for adult landlocked fish [10]
Downstream migration	Larvae
Downstream migration range	May to September for sea run fish and January to August for landlocked populations (to match spawning ranges)
Downstream migration peak	May to June for sea run fish [5] (to match spawning peak)
Turbidity ranking	Low
Sedimentation ranking	High
Afforestation ranking	Medium - High
References	1) McDowall 1990 2) McDowall 2000 3) McDowall 1995 4) Goodman et al. 2014 5) Allibone and Caskey 2000 6) McDowall and Eldon 1980 7) Stancliff et al. 1988 8) Wilding 2000 (and references therein) 9) Kusabs 1989 10) Rowe and Graynoth 2002

Information	Description
Species	Shortjaw kokopu (*Galaxias postvectis)*
Functional group	Large galaxiids
Conservation status	Threatened (nationally vulnerable)[4]
Geographic range	Low to moderate elevations up to 206km inland penetration in both North and South Islands, not found in the Hawkes Bay and Canterbury [2] landlocked population in Lake Mangatawhiri (Auckland)[7]
Forestry regions	NL, CNI, EC, SNI, NM, WC , OS
Preferred adult habitat	Generally small bouldery streams enclosed within dense podocarp forest [1, 2]
Larvae habitat	Sea/lake
Life cycle	Diadromous with one known lacustrine population
Spawning habitat	Marginal gravels and litter during elevated flows [5] including lake population (using streams flowing into lakes)[6]
Spawning range	May to June [5] plus one month either side as spawning is likely to occur either side of this range [6] making range April to July. Ripe males found in March for the Lake Mangatawhiri population making spawning range similar for this lake population[7].
Spawning peak	May to June [5]
Upstream migration	Juvenile
Upstream migration range	Spring - September to November[3, 2]
Upstream migration peak	Not Known
Downstream migration	Larvae
Downstream migration range	May to August (to match spawning range)
Downstream migration peak	June [5] to July (to match spawning peak)
Turbidity ranking	High
Sedimentation ranking	High
Afforestation ranking	Medium
References	1) McDowall 1990 2) McDowall 2000 3) McDowall 1995 4) Goodman et al. 2014 5) Charteris et al. 2003 6) Franklin and Baker (pers. com) 7) Smith et al. 2012

8.7 Mudfish

Information	Description
Species	Black mudfish (*Neochanna diversus*)
Functional group	Mudfish
Conservation status	At Risk (declining) [4]
Geographic range	Widespread in northern North Island [2]
Forestry regions	NL, CNI
Preferred adult habitat	Stationary water, shallow pools, wetlands[1, 2]
Larvae habitat	Near adult habitats [2]
Life cycle	Lacustrine
Spawning habitat	Near adult habitat in stationary water, shallow pools, wetlands[2]
Spawning range	Autumn – Spring, April to October[2, 3, 5]
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Low - Medium
Sedimentation ranking	Low - Medium
Afforestation ranking	High
References	1) McDowall 1990 2) McDowall 2000 3) Barrier and Hicks 1994 4) Goodman et al. 2014 5) Thomson 1987

Information	Description
Species	Brown mudfish (*Neochanna apoda*)
Functional group	Mudfish
Conservation status	At Risk (declining) [4]
Geographic range	Widespread in southern North Island and west coast of the South Island[1, 2]
Forestry regions	CNI, WC
Preferred adult habitat	Weedy shingly springs and margins of wetlands [2]
Larvae habitat	Near adult habitats [2]
Life cycle	Lacustrine
Spawning habitat	Near adult habitat in stationary water, often in old root holes when water returns [2]
Spawning range	Autumn after dry period [2,] Autumn or early winter[3]
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Low - Medium
Sedimentation ranking	Low - Medium
Afforestation ranking	High
References	1) McDowall 1990 2) McDowall 2000 3) Ling 2001 4) Goodman et al. 2014

Information	Description
Species	Canterbury mudfish (*Neochanna burrowsius*)
Functional group	Mudfish
Conservation status	At Risk (declining) [3]
Geographic range	Low elevations in Canterbury area [2]
Forestry regions	CAN
Preferred adult habitat	Slow flowing weedy/overgrown springs, creeks and wetland margins[2]
Larvae habitat	Near adult habitats [2]
Life cycle	Lacustrine
Spawning habitat	Near adult habitat in stationary water, amongst aquatic debris and vegetation [2]
Spawning range	Late winter and spring [1,2]
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Low - Medium
Sedimentation ranking	Low - Medium
Afforestation ranking	High
References	1) McDowall 1990 2) McDowall 2000 3) Goodman et al. 2014

Information	Description
Species	Northland mudfish (*Neochanna heleios*)
Functional group	Mudfish
Conservation status	Threatened (nationally vulnerable) [3]
Geographic range	Found in wetland sites on Kerikeri volcanic plateau at elevations of 200m [1]
Forestry regions	NL
Preferred adult habitat	Ephemeral wetlands on peaty soil [1]
Larvae habitat	Near adult habitats
Life cycle	Lacustrine
Spawning habitat	Not known - likely similar to black mudfish - near adult habitat in shallow pools and wetlands
Spawning range	Not known – likely similar to black mudfish - Autumn to Spring and as late as December if conditions allow[4]
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Low - Medium
Sedimentation ranking	Low - Medium
Afforestation ranking	High
References	1) Ling and Gleeson 2001 2) McDowall 2000 3) Goodman et al. 2014 4) Ling pers. comm. 2014

8.8 Non-Migratory Galaxias

Information	Description
Species	Alpine galaxias (*Galaxias paucispondylu*)
Functional group	Non-migratory galaxias
Conservation status	At Risk (naturally uncommon)[7]
Geographic range	East Coast South Island high country
Forestry regions	CAN, OS
Preferred adult habitat	Swift broken water and riffles[3]
Larvae habitat	Larvae maybe found in slow flowing stream margins / backwaters[8]
Life cycle	Non migratory
Spawning habitat	Habitat not discovered, but likely near home range[3] possibly in backwaters[7]
Spawning range	Spring, ripe fish found in October[1,] spring [2] October to November (and likely August)
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	High - Susceptible to lost habitat (cover[4], spawning) and food supply[5]
Afforestation ranking	High - Susceptible to a reduction in available habitat[6]
References	1) McDowall 1990 2) McDowall 2000 3) Goodman et al. 2014 4) Jowett and Boustead 2001 5) Ryan 1991 6) Fahey 1994 7) Dunn and O'Brien 2007 8) Jellyman and McIntosh 2008

Information	Description
Species	Bignose galaxias (*Galaxias macronasus*)
Functional group	Non-migratory galaxias
Conservation status	Threatened (nationally vulnerable)[2]
Geographic range	McKenzie Basin (Canterbury)
Forestry regions	CAN
Preferred adult habitat	Small riffle run habitat[1]
Larvae habitat	Larvae maybe found in slow flowing stream margins / backwaters[6]
Life cycle	Non migratory
Spawning habitat	Not known but likely in-stream under larger rocks similar to Canterbury galaxias
Spawning range	Probably winter[1] June to August (and possibly September)
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	High - Susceptible to lost habitat (cover[4], spawning) and food supply[5]
Afforestation ranking	High - Susceptible to a reduction in available habitat[6]
References	1) McDowall and Waters 2003 2) Goodman et al. 2014 3) Jowett and Boustead 2001 4) Ryan 1991 5) Fahey 1994 6) Jellyman and McIntosh 2008

Information	Description
Species	Canterbury galaxias (*Galaxias vulgaris*)
Functional group	Non-migratory galaxias
Conservation status	At Risk (declining)[3]
Geographic range	Throughout Canterbury and parts of Marlborough and Otago[2]
Forestry regions	NM, CAN, OS
Preferred adult habitat	Swift flowing streams – cobble[2]
Larvae habitat	Larvae maybe found in slow flowing stream margins / backwaters[7]
Life cycle	Non migratory
Spawning habitat	Beneath a large riffle boulders[1]
Spawning range	September to November[2], July to September[1,] July to November
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	Medium - Susceptible to lost habitat (cover[4], spawning) and food supply[5] but inhabit lowland sites reasonably well[8]
Afforestation ranking	High - Susceptible to a reduction in available habitat[6]
References	1) Calwallader 1976 2) McDowall 2000 3) Goodman et al. 2014 4) Jowett and Boustead 2001 5) Ryan 1991 6) Fahey 1994 7) Jellyman and McIntosh 2008 8) P. Jellyman pers. Comm. 2014

Information	Description
Species	Dusky galaxias (*Galaxias pullus*)
Functional group	Non-migratory galaxias
Conservation status	Threatened (nationally endangered)[1]
Geographic range	Inland Eastern Otago
Forestry regions	OS
Preferred adult habitat	Small swift flowing streams -boulder- cobble[2]
Larvae habitat	Larvae maybe found in slow flowing stream margins during spring and summer[3]
Life cycle	Non migratory
Spawning habitat	Roots of riparian tussock and shrubs that overhang riffles[2]
Spawning range	Spring - September to November[2] (and likely August)
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	High - Susceptible to lost habitat (cover[4], spawning) and food supply[5]
Afforestation ranking	High - Susceptible to a reduction in available habitat[6]
References	1) Goodman et al. 2014 2) McDowall 2000 3) Jellyman and McIntosh 2008 4) Jowett and Boustead 2001 5) Ryan 1991 6) Fahey 1994

Information	Description
Species	Dwarf galaxias (*Galaxias divergens*)
Functional group	Non-migratory galaxias
Conservation status	At Risk (declining)[2]
Geographic range	Intermittent North Island south of Matamata, common lower North and upper South Island
Forestry regions	CNI, HB,SNI,NM,WC CAN
Preferred adult habitat	Riffley marginal shallows of large rivers and cobble riffles of smaller streams[1]
Larvae habitat	Larvae maybe found in slow flowing stream margins[3]
Life cycle	Non migratory
Spawning habitat	Unknown, likely instream under larger rocks or stream margins
Spawning range	Spring - September to November (and likely August)[1]
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	High - Susceptible to lost habitat (cover[4], spawning) and food supply[5]
Afforestation ranking	High - Susceptible to a reduction in available habitat[6, 7]
References	1) McDowall 2000 2) Goodman et al. 2014 3) Jellyman and McIntosh 2008 4) Jowett and Boustead 2001 5) Ryan 1991 6) Fahey 1994 7) Hay 2009

Information	Description
Species	Eldon's galaxias (*Galaxias eldoni*)
Functional group	Non-migratory galaxias
Conservation status	Threatened (Nationally endangered)[2]
Geographic range	Eastern Otago
Forestry regions	OS
Preferred adult habitat	Riffles in small gravel/cobble/boulder streams[1]
Larvae habitat	Larvae maybe found in slow flowing stream margins[1, 3]
Life cycle	Non migratory
Spawning habitat	Within coarse cobble boulder substrate at riffle edge[1]
Spawning range	Spring - September to November[2] (and likely August)
Spawning peak	Not Known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	Medium - High - Susceptible to lost habitat (cover[4], spawning) and food supply[5] though can inhabit similar stream types to Canterbury galaxias[7]
Afforestation ranking	High - Susceptible to a reduction in available habitat[6]
References	1) McDowall 2000 2) Goodman et al. 2014 3) Jellyman and McIntosh 2008 4) Jowett and Boustead 2001 5) Ryan 1991 6) Fahey 1994 7) P. Jellyman pers.comm. 2014

Information	Description
Species	Gollum galaxias (*Galaxias gollumoides*)
Functional group	Non-migratory galaxias
Conservation status	Threatened (nationally vulnerable)[1]
Geographic range	Otago and Southland including Stuart Island
Forestry regions	OS
Preferred adult habitat	Boggy swamps and streams[2]
Larvae habitat	Larvae maybe found in slow flowing stream margins and backwaters for stream fish[2, 3]
Life cycle	Non migratory
Spawning habitat	Beneath cobbles / boulders for streams fish and vegetation for wetland fish
Spawning range	Spring - September to November for stream fish and August to October for wetland fish [4]
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	Medium – High - Susceptible to lost habitat (cover[5], spawning) and food supply[6] though wetland fish would be lest susceptible[4]
Afforestation ranking	High - Susceptible to a reduction in available habitat[7]
References	1) Goodman et al. 2014 2) McDowall & Chadderton 1999 3) Jellyman and McIntosh 2008 4) Dunn 2012 5) Jowett and Boustead 2001 6) Ryan 1991 7) Fahey 1994

Information	Description
Species	Taieri flathead galaxias (*Galaxias depressiceps*)
Functional group	Non-migratory galaxias
Conservation status	Threatened (nationally vulnerable)[2]
Geographic range	Otago and Southland including Stuart Island
Forestry regions	OS
Preferred adult habitat	Swift flowing streams - cobble/boulder[1]
Larvae habitat	Larvae maybe found in slow flowing stream margins[3]
Life cycle	Non migratory
Spawning habitat	Beneath cobbles / boulders in runs and riffles[1]
Spawning range	Spring - September to November[1] (and likely August)
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	Medium – High - Susceptible to lost habitat (cover[4], spawning) and food supply[5] though can inhabit similar stream types to Canterbury galaxias[7]
Afforestation ranking	High - Susceptible to a reduction in available habitat[6]
References	1) McDowall 2000 2) Goodman et al. 2014 3) Jellyman and McIntosh 2008 4) Jowett and Boustead 2001 5) Ryan 1991 6) Fahey 1994

Information	Description
Species	Upland longjaw galaxias (*Galaxias prognathus*)
Functional group	Non-migratory galaxias
Conservation status	Threatened (Nationally Vulnerable)[1]
Geographic range	Inland Canterbury
Forestry regions	CAN
Preferred adult habitat	Marginal shallows of swift flowing streams[2]
Larvae habitat	Larvae maybe found in slow flowing stream margins / backwaters[2]
Life cycle	Non migratory
Spawning habitat	Not Known, likely in-stream under larger rocks or stream margins
Spawning range	Spring - September to November[2] (and likely August)
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	High - Susceptible to lost habitat (cover[3], spawning) and food supply[4]
Afforestation ranking	High - Susceptible to a reduction in available habitat[5]
References	1) Goodman et al. 2014 2) McDowall 2000 3) Jowett and Boustead 2001 4) Ryan 1991 5) Fahey 1994

Information	Description
Species	Lowland longjaw galaxias (*Galaxias cobitinis*)
Functional group	Non-migratory galaxias
Conservation status	Threatened (Nationally Critical)[1]
Geographic range	McKenzie Basin and North Otago
Forestry regions	CAN, OS
Preferred adult habitat	Margins of riffles and runs[2]
Larvae habitat	Larvae are found in backwaters and side braids from October to January[2]
Life cycle	Non migratory
Spawning habitat	Not known but likely beneath cobbles / boulders in runs and riffles
Spawning range	Late winter and early summer - August to December[2]
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	High - Susceptible to lost habitat (cover[3], spawning) and food supply[4]
Afforestation ranking	High - Susceptible to a reduction in available habitat[5]
References	1) Goodman et al. 2014 2) McDowall and Waters 2002 3) Jowett and Boustead 2001 4) Ryan 1991 5) Fahey 1994

Information	Description
Species	Roundhead galaxias (*Galaxias anomalus*)
Functional group	Non-migratory galaxias
Conservation status	Threatened (Nationally Endangered)[1]
Geographic range	Southern South Island
Forestry regions	OS
Preferred adult habitat	Low-gradient shingly creeks with cover[2]
Larvae habitat	Juveniles maybe found in slow flowing stream margins[2]
Life cycle	Non migratory
Spawning habitat	Amongst porous gravel at outflows of ground water or the head of braids[2]
Spawning range	Spring - September to November[2,] (and likely August)
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	High - Susceptible to lost habitat (cover[3], spawning) and food supply[4]
Afforestation ranking	High - Susceptible to a reduction in available habitat[5]
References	1) Goodman et al. 2014 2) McDowall 2000 3) Jowett and Boustead 2001 4) Ryan 1991 5) Fahey 1994

Information	Description
Species	Dwarf inanga (*Galaxias gracilis*)
Functional group	Non-migratory galaxias
Conservation status	At Risk (declining)[1]
Geographic range	Selective Northland Lakes
Forestry regions	NL
Preferred adult habitat	Open water and margins of lakes[2]
Larvae habitat	Pelagic in lakes[2]
Life cycle	Non migratory
Spawning habitat	Unknown
Spawning range	Little known - possibly summer - autumn[2]
Spawning peak	Not known
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	Low – medium - siltation may affect egg mortality, prey species and increases in turbidity may affect visual feeding[3]
Afforestation ranking	Low - unlikely to affect lake levels
References	1) Goodman et al. 2014 2) McDowall 2000 3) Rowe and Graynoth 2002

8.9 Salmonid Sportsfish

Information	Description
Species	Atlantic salmon (*Salmo salar*)
Functional group	Salmonid Sportsfish
Conservation status	Introduced and naturalised [1]
Geographic range	Only in upper lakes of Waiau River system[2]
Forestry regions	OS
Preferred adult habitat	Open waters of lakes [2]
Fry habitat	Lakes
Life cycle	Lacustrine
Spawning habitat	Swift-flowing, shallow, gravelly runs (possibly only in the stream between lakes Gunn and Fergus in the upper Eglinton Valley) [2]
Spawning range	Autumn or early winter [2]
Spawning peak	May/June[3]
Upstream migration	Adult
Upstream migration range	Summer/autumn[2]
Upstream migration peak	Not known
Downstream migration	Fry/juveniles (limited, many juveniles will remain in streams)[3]
Downstream migration range	May to August[2]
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	High - Susceptible to lost habitat (cover[7], spawning[4]) and food supply[5]
Afforestation ranking	High - Susceptible to a reduction in available habitat[6]
References	1) Goodman et al. 2014 2) McDowall 2000 3) McDowall 1990 4) Alabaster and Lloyd 1982 5) Ryan 1991 6) Fahey 1994 7) Bjornn 1971

Information	Description
Species	Brook char (*Salvelinus fontinalis*)
Functional group	Salmonid Sportsfish
Conservation status	Introduced and naturalised [1]
Geographic range	Widely in eastern South Island, intermittent populations central North Island[2]
Forestry regions	CNI, CAN OS
Preferred adult habitat	Small tributary streams often less than a metre, also in open waters of a few high country lakes[2]
Fry habitat	Lakes
Life cycle	Lacustrine
Spawning habitat	Gravelly streams or around lake shore [2]
Spawning range	Autumn or early winter [2]
Spawning peak	May/June[3]
Upstream migration	Adult (limited, some remain in lakes to spawn)[2]
Upstream migration range	Summer/autumn[2]
Upstream migration peak	Not known
Downstream migration	Fry/juveniles (limited, many juveniles will remain in streams)[2]
Downstream migration range	May to August[2]
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	High **-** Susceptible to lost habitat (cover[7], spawning[4]) and food supply[5]
Afforestation ranking	High - Susceptible to a reduction in available habitat[6]
References	1) Goodman et al. 2014 2) McDowall 2000 3) McDowall 1990 4) Alabaster and Lloyd 1982 5) Ryan 1991 6) Fahey 1994 7) Bjornn 1971

Information	Description
Species	Brown trout (*Salmo trutta*)
Functional group	Salmonid Sportsfish
Conservation status	Introduced and naturalised [1]
Geographic range	Widespread from Waikato and Coromandel southwards [2]
Forestry regions	All apart from Northland
Preferred adult habitat	Diverse habitats, from estuaries to high country streams and lakes [2]
Fry habitat	Mainly stream margins some to sea and lakes [2, 3]
Life cycle	Mainly lacustrine but some diadromous
Spawning habitat	Gravelly headwater streams [2]
Spawning range	Autumn or early winter – March to July [2]
Spawning peak	May/June[3]
Upstream migration	Adult
Upstream migration range	Summer/autumn[2]
Upstream migration peak	Autumn[3]
Downstream migration	Fry/juveniles (limited, most juveniles will remain in streams, some back to sea or lakes)[2, 3]
Downstream migration range	Fish will be moving all year round, varies from a few month old to up to three years[3]
Downstream migration peak	Varies from a few month old to up to three years[3]
Turbidity ranking	Medium
Sedimentation ranking	High - Susceptible to lost habitat (cover[7], spawning[4]) and food supply[5]
Afforestation ranking	High - Susceptible to a reduction in available habitat[6]
References	1) Goodman et al. 2014 2) McDowall 2000 3) McDowall 1990 4) Alabaster and Lloyd 1982 5) Ryan 1991 6) Fahey 1994 7) Bjornn 1971

Information	Description
Species	Chinook salmon (*Oncorhynchus tshawytscha*)
Functional group	Salmonid Sportsfish
Conservation status	Introduced and naturalised [1]
Geographic range	Mainly Eastern South Island occasionally West coast, rare in North Island, some landlocked populations in high elevation lakes [2]
Forestry regions	CAN, WC, OS
Preferred adult habitat	Deeper pools and runs [2]
Fry habitat	To sea / lake
Life cycle	Diadromous and lacustrine
Spawning habitat	Clear, gravelly, upstream tributaries [2]
Spawning range	March to June[3]
Spawning peak	April/May[3]
Upstream migration	Adult
Upstream migration range	Summer/autumn[2] and early Winter[3]
Upstream migration peak	April/May[3]
Downstream migration	Fry/juveniles (limited, some juveniles will remain in streams for up to a year)[2]
Downstream migration range	May to October[3]
Downstream migration peak	August/September[3]
Turbidity ranking	Medium
Sedimentation ranking	High **-** Susceptible to lost habitat (cover[7], spawning[4]) and food supply[5]
Afforestation ranking	High - Susceptible to a reduction in available habitat[6]
References	1) Goodman et al. 2014 2) McDowall 2000 3) McDowall 1990 4) Alabaster and Lloyd 1982 5) Ryan 1991 6) Fahey 1994 7) Bjornn 1971

Information	Description
Species	Mackinaw (*Salvelinus namaycush*)
Functional group	Salmonid Sportsfish
Conservation status	Introduced and naturalised [1]
Geographic range	Only in Lake Pearson, inland Canterbury [2]
Forestry regions	CAN
Preferred adult habitat	Deeper parts of the lake during summer, rest of the lake for the remainder of the year [2]
Fry habitat	Lake
Life cycle	Lacustrine
Spawning habitat	Likely boulder shoals on lake bed [2]
Spawning range	Not known in New Zealand but likely February to June[3]
Spawning peak	Not known in New Zealand but likely April to May[3]
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	Low - entire life cycle in a lake
Afforestation ranking	Low - entire life cycle in a lake
References	1) Goodman et al. 2014 2) McDowall 2000 3) McDowall 1990

Information	Description
Species	Rainbow trout (*Oncorhynchus mykiss*)
Functional group	Salmonid Sportsfish
Conservation status	Introduced and naturalised [1]
Geographic range	New Zealand wide mainly central North Island [2]
Forestry regions	All
Preferred adult habitat	Mostly in lakes or rivers associated with lakes, river fish inhabit fast-flowing bouldery headwaters [2]
Fry habitat	Mainly stream margins some to lakes [2, 3]
Life cycle	Lacustrine
Spawning habitat	Gravelly headwater streams [2,] small amount of spawning within lakes where there are no suitable streams [3]
Spawning range	May to September[2,] (can be all year round in parts of the Lake Taupo catchment) [4]
Spawning peak	July- July[3] (August to October for most of the Taupo fishery) [4]
Upstream migration	Adult
Upstream migration range	May to September[3] (can be all year round in parts of the Lake Taupo catchment)[4]
Upstream migration peak	Usually July- August[3] (April to October for most of the Taupo fishery) [4, 5]
Downstream migration	Fry/juveniles (limited, most juveniles will remain in streams, some back to lakes) [2, 3]
Downstream migration range	Fish will be moving all year round, varies from a few month old to up to three years[3]
Downstream migration peak	Varies from a few month old to up to three years [3], peak December to March for lake fish [6]
Turbidity ranking	Medium
Sedimentation ranking	High - Susceptible to lost habitat (cover[7], spawning[8]) and food supply[9]
Afforestation ranking	High - Susceptible to a reduction in available habitat[6]
References	1) Goodman et al. 2014 2) McDowall 2000 3) McDowall 1990 4) Hamer 2007 (and references therein) 5) Dedual and Jowett 1999 6) Rowe and Graynoth 2002 7) Bjornn 1971 8) Alabaster and Lloyd 1982 9) Ryan 1991 10) Fahey 1994

Information	Description
Species	Sockeye salmon (*Oncorhynchus nerka*)
Functional group	Salmonid Sportsfish
Conservation status	Introduced and naturalised [1]
Geographic range	Only In Waitaki River valley Lakes[2]
Forestry regions	CAN, OS
Preferred adult habitat	Open waters of lakes [2]
Fry habitat	Stream margins at first and then downstream to lakes [2, 3]
Life cycle	Lacustrine
Spawning habitat	Streams with swift flowing shallow, sandy/gravelly runs[2]
Spawning range	March to May [2, 3]
Spawning peak	March[3]
Upstream migration	Adult
Upstream migration range	March[3]
Upstream migration peak	March[3]
Downstream migration	Fry
Downstream migration range	April to June[3]
Downstream migration peak	Likely May to match peak spawning
Turbidity ranking	Medium
Sedimentation ranking	High - Susceptible to lost habitat (cover[7], spawning[4]) and food supply[5]
Afforestation ranking	High - Susceptible to a reduction in available habitat[6]
References	1) Goodman et al. 2014 2) McDowall 2000 3) McDowall 1990 4) Alabaster and Lloyd 1982 5) Ryan 1991 6) Fahey 1994 7) Bjornn 1971

8.10 Koura

Information	Description
Species	Northern Koura (*Paranephrops planifrons*)
Functional group	Koura
Conservation status	Not Threatened [5]
Geographic range	North Island and northwest South Island [1]
Forestry regions	NL, CNI, EC, HB, SNI, NM, WC
Preferred adult habitat	Cobble substrate, with good cover (undercut banks, leaf litter, woody debris), slow flows and pool habitat depths between 0.2 – 0.3 meters [2]
juvenile habitat	Fine substrates (associated with slow flows) good cover, shallow depths – often stream edge [2]
Life cycle	Lacustrine
Spawning habitat	Females carry eggs
Spawning range	April to December for stream populations[3] and April to July (main season) and October to January (second breeding period) for lake koura[4]
Females with young	September to December for stream populations[3], and also January to March for lake koura[4]
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	High
Afforestation ranking	Medium
References	1) McDowell 2005 2) Jowett 2007 3) Hopkins 1967 4) Devcich 1979 5) Grainger et al. 2014

Information	Description
Species	Southern Koura (*Paranephrops zealandicus*)
Functional group	Koura
Conservation status	Declining [5]
Geographic range	Canterbury and lower South Island. [1]
Forestry regions	CAN, OS
Preferred adult habitat	Likely similar to Northern koura - cobble substrate, with good cover (undercut banks, leaf litter, woody debris) [2], slow flows and pool habitat[3] depths between 0.2 – 0.3 meters [2]. Prefers native riparian vegetation [4]
Juvenile habitat	Likely similar to Northern koura - fine substrates (associated with slow flows) good cover, shallow depths – often stream edge [2]
Life cycle	Lacustrine
Spawning habitat	Females carry eggs
Spawning range	All year (a minimum of 60 weeks)[3]
Females with young	December to April[3]
Upstream migration	None
Upstream migration range	None
Upstream migration peak	None
Downstream migration	None
Downstream migration range	None
Downstream migration peak	None
Turbidity ranking	Medium
Sedimentation ranking	High
Afforestation ranking	Medium
References	1) McDowell 2005 2) Jowett 2007 3) Whitmore 1999 4) Whitmore et al. 2000 5) Grainger et al. 2014