New Zealand **Fish Passage** Advisory Group
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Fish passage research priorities for New Zealand

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Introduction & Background

The geography of New Zealand means that we have a high ratio of coastline to land mass, highly variable sea currents and conditions, comparatively short but variable sloped rivers-streams and a large range of climate, rainfall and resulting hydrological conditions. In addition, the majority of our intensification of landuse is in the lower reaches of rivers through which all migratory fish must pass. This has resulted in a complex set of natural and constructed conditions that interact with migratory fish life-cycles to challenge our understanding of fish communities and single or simple fixes of barriers to fish movements.

Globally, most fish passage research has been carried out on salmonids, which are much larger and more powerful swimmers than our migratory fish, this means research and solutions developed may not be directly applicable in New Zealand. In New Zealand, fish passage research is relatively limited and the finer details of how to get native fish past in-stream structures are still largely unknown. This is compounded by the high proportion of migratory fish in our lowland fish communities and the correspondingly large variation in the timing, behaviour and size of fish species migrating from or to the sea. Previous research has focused on select species, life stages, and structure types, but we need a broader understanding of the impacts of fish barriers and how to construct practical solutions. In the absence of detailed knowledge of the needs of different groups of fish, recommendations can only be made based on what is known about some fish and then generalised to the others. The current limitations of our knowledge make it difficult to provide robust design criteria and ensure the successful passage of our fish species past instream obstacles.

It is important that future research focuses on a broad variety of fish species, body shapes and sizes, abilities and life stages. When comparing abilities, there are those that adhere to a wetted surface and wriggle to climb (e.g. juvenile eels and juveniles of some galaxiid species), attach to a wetted surface and jump (e.g. lamprey and redfin bullies), and capable of leaping out of the water (e.g. trout and salmon), while others can only swim past obstacles using short bursts of speed (e.g. inanga and common bullies). Examining the subtle differences between similar species is less useful at this stage when more broad knowledge is needed. Thus, although inanga and smelt are only distantly related, they are both small-bodied, pelagic, burst swimmers without climbing ability. It would be better to compare one of these with redfin bullies, which are benthic fish that can climb the wetter margins of obstacles but are considered a poorer climber than eels or climbing galaxiids. Therefore, focusing research on representative fish species can be beneficial to designing fish passes that can cater for a wide range of fish species.

It is also important to design a fish pass for the target fish species present upstream of the barrier, and this can vary depending on altitude and distance inland. In general, fish passes situated in lowland areas will need to cater for a wide range of species with varying swimming abilities. However, with distance inland and increasing altitude, fish diversity decreases, and it is usually the species capable of climbing (e.g. juvenile eels, large galaxiid whitebait species, adult lamprey) that fish passes would need to target.

The New Zealand Fish Passage Advisory Group (NZFPAG) has undertaken a process to identify and prioritise key fish passage research questions. This document provides a summary of these key priority research questions. It is hoped this document can be used by government agencies, non-government organisations, universities and consultants to provide an overview of the important knowledge gaps that should be promoted to improve fish passage management in New Zealand and enable more robust recommendations for effective fish passage.

Priority Research Questions

Part A: Fish abilities

Behaviour and physiology

Much about the behaviour and physiology of our native fish is unknown or based on extrapolation from a few observations or related species. With respect to movement, we know that flow rate and time of the day affects the migrations of certain native fish species, but generally only species of commercial interest (e.g. whitebait and eels). It is likely that other species are also stimulated to move in response to these and other environmental factors. This could change how effective fish passes are under different conditions. For example, a particular fish pass might work best during base flows, but key migrations could be happening during high flows.

In addition, understanding the hydraulic features of the flow that fish are looking for during migration is an important consideration in designing effective fish passes. This is because behavioural and motivational factors can reduce the passage of fish over structures even though the water velocities may be within their swimming ability. Here, if we understand what attracts fish to a fish pass and then motivates them to migrate past we can design more effective solutions.

Research questions:

Highest priority

1. How do fish respond to different hydraulic characteristics of flow over and at entrances to constructed fish passes? In particular varying turbulence, water velocities, and attraction flows. Presently, this knowledge gap needs addressing for all native freshwater fish species and life stages.
2. How does stream flow (variability in discharge) affect upstream and downstream migrations of different fish species?

Other key questions

3. What are the seasonal or daily patterns in the migrations of juvenile fish?
4. Does delay of fish at instream structures limit the effectiveness of subsequent fish ways and impacts on natural migration patterns? Causal factors for this could include a reduction in rheotaxis, motivation or behaviour/physiological changes.

Physiological capabilities

Generally, only the swimming and climbing abilities of certain life stages have been studied. However, fish of all sizes are moving past obstacles and the abilities of all life stages need to be understood to provide sufficient passage to maintain healthy upstream populations/ecosystems. We need a better understanding of the swimming and climbing capabilities of most of our fish species and how these vary across different life stages.

In addition, it is generally assumed that climbing fish don't jump. However, some fish species such as banded kōkopu have been observed jumping at the start of their climb. Therefore, it may be possible for these fish to jump into a perched culvert.

Research questions:

Highest priority

1. What are the swimming (burst & sustained) and climbing capabilities of different fish species and how do these vary between life stages? Key species identified are inanga, smelt, redfin bully, banded kōkopu, torrentfish, lamprey, Canterbury galaxias, dwarf galaxias.

Other key questions

2. Can whitebait species with climbing abilities jump into a perched culvert? If so, how does perch height and body size affect the proportion of fish successfully jumping?

Part B: Effectiveness of current solutions

There are many commercial products currently available to remediate existing barriers. These aim to provide successful fish passage. However, there has been little to no laboratory testing of these designs to see if they are effective, and in situ monitoring over time is rare. The lack of design standards, uncertain effectiveness of the different options and variation in cost are barriers to implementation, with managers reluctant to spend money on unproven designs. We need to know the key design principles of different commercially available fish pass solutions and assess their effectiveness in different types of waterway and under different flow conditions.

Research questions:

Highest priority

1. How effective are the different types of fish pass solutions currently being implemented or sold commercially? In particular, those targeting remediation of perched culverts (e.g. ramps) and improving passage through the culvert barrel (e.g. baffles).

Other key questions

2. What is the effect on fish passage of the following design criteria: length of the fish pass, Manning's N, water velocity, substrates and does this change with gradient, water depth, and baffles (spacing, size and shape).

Technical fish passes

Technical fish passes use engineered designs to create specific flow patterns, rather than mimicking natural features of a waterway. These are often made of concrete and involve constructed baffles, weirs and pools stepped up a slope. Common designs include pool/weir passes, vertical slot passes, and Denil passes.

Most research on these designs has been carried out on salmonids and they have been fine-tuned for their strong swimming abilities. Our native fish are much smaller than salmonids and are not such powerful swimmers or jumpers, so technical passes may not work for some New Zealand species. However, there may be aspects of technical fish passes that could be adapted for native fish and useful research would look at how to modify different passes so that they are suitable for native fish passage. There are few if any fishways that have been designed, implemented and monitored for migrating native fish communities or species. Most situations where fish passage is considered default to various implementations of a catch and carry system that while practical has inherent limitations in reinstating conditions that facilitate migration of all members of the fish community. A fishway appropriate for native fish communities needs to be developed and tested.

Research questions:

Highest priority

1. What is an appropriate fishway design for upstream and downstream migrating native fish? Pool/weir and vertical slot designs are of particular interest.

Other key questions

2. Can fish passage in technical fish passes be enhanced by adding different types of substrates? This includes examining different substrate shapes, sizes and spatial arrangements.

Selective and built barriers

Selective barriers allow certain fish species to pass upstream or downstream but exclude others. These are used to prevent invasive or predatory species from accessing upstream or downstream habitats and protect sensitive native species. Recently, selective barriers have been built to prevent the movement of invasive species such as trout, perch and koi carp but allow the passage of native fish capable of climbing. With the continued spread of some invasive fish species, selective barriers will become increasingly important for protecting important native fish populations.

Some built barriers exclude the upstream passage of all fish species. In New Zealand, these have mainly been used to stop trout and kōaro from predating and out-competing, respectively, non-migratory galaxiid species. Although kōaro are native, human activities have made it possible for them to penetrate much further inland than was previously possible, bringing them into contact with threatened populations of non-migratory galaxiids. In practice, eliminating the passage of both a powerful jumper and a determined climber has proved more difficult than expected.

Some success has been seen for built barriers for preventing invasive species access, however this has often seen other issues like sedimentation and macrophyte invasion increase.

Therefore, both selective and built barriers need further development and testing of key design features to ensure they function in a wide range of situations and flow regimes, while not creating or increasing other pressures on important habitats e.g. sediment.

Research questions:

Highest priority

1. What are the effective barrier designs criteria that prevent invasive species access, while not increasing other pressures and protecting key biodiversity hotspots for low gradient situations where limited head differences exist?
2. What barrier height is needed to exclude key invasive species?

Other key questions

3. The most effective design of the apron below the barrier to prevent erosion whilst still preventing passage of the target species.
4. Can passage of native swimming species (e.g. inanga and smelt) be provided whilst preventing invasive swimming species (e.g. koi carp, perch, rudd and catfish)?
5. What is the minimum receiving pool depth that prevents leaping fish from jumping over the barrier? The different life stages of all undesirable species need considering.
6. Effective designs that prevents both climbers and jumpers

Water intakes

Water intakes divert water from a waterway for another purpose, such as irrigation, stock and human drinking water, pumping for water level control and to run hydroelectric turbines. These intakes require screens and other devices to prevent fish and other objects from being sucked through the intake. In poorly designed intakes, fish may be sucked in (entrained) or trapped against (impinged) and damaged by the intake screens.

Development and testing of intake screen designs to protect New Zealand fish species is needed to understand the key design criteria that will protect native and sports fish from water intakes. Particular focus is needed on the location of the intake, effective approach and sweep velocity, the effects of mesh size on impingement and escapement rates of larger fish and entrainment of larvae and juveniles, the effectiveness of bypass or guidance devices and maintenance and operation. These should be tested under different water velocities and using a range of representative fish species and life stages, including those that migrate past and those that reside in reaches with intakes. Key species identified are inanga, Canterbury galaxias, dwarf galaxias, longfin eel, bullies, torrentfish, banded kōkopu, trout and salmon.

Research questions:

Highest priority

1. There are seven design criteria currently recommended for protecting native and sports fish from water intakes. How effective are these and which are the most important criteria for protecting target species?
2. What are effective water intake designs for small, medium and large takes that prevent impingement and entrainment of fish?

Other key questions

3. What are the effects of different mesh sizes and different water velocities on impingement of native fish species?
4. How effective are different screening devices in preventing or minimising the entrainment of fish larvae and juveniles?
5. Are gravel bunds and rock groynes effective for guiding fish away from intakes?

Engineering structures

Flood and tide gates

Flood and tide gates are used to prevent water from penetrating or backing up into waterways during floods and high tides, protecting the land behind them from inundation. These gates are essentially a 'door' opening downstream. Normally they are open, allowing water to flow through them, but during a tide, the water rises on the downstream side and the pressure pushes the 'door' shut.

Certain native species migrate during high water levels, such as whitebait entering rivers, inanga spawning in response to the peak of king tides, floods prompting adult lamprey to move upstream and migrant adult eels to move downstream. Flood and tide gates can restrict access for these species during these important migration times. They can also affect hydrology and water quality (especially temperature and oxygen levels) by reducing flushing flows, increasing retention time, and changing the salinity. 'Fish friendly' gates have been developed that hold the gate open for longer, but these have not been adequately tested for New Zealand fish.

Different floodgate designs need to be tested to understand how fish use them, and the effects of the size and shape of the opening, whether the gate is hinged at the top or sides, and how long the gates are open for on each tide or flood.

Research questions:

Highest priority

1. How effective are 'fish-friendly' flood gates, both in terms of the abundance and diversity of fish as well as effects of the gate on water quality, especially dissolved oxygen and temperature.
2. Is the tidal inundation through a 'fish-friendly' gate sufficient to prompt inanga spawning?

Other key questions

3. How do fish approach and exit through the gates? Here, acoustic imaging or biotelemetry could be used to examine small and large bodied species.
4. What is the effect of the shape of the flood & tide gate opening on fish passage?

It is important that the tide and flood gates are examined during the night as well as during the day, to see if fish species move differently or at different times.

Fords

Fords may look merely like a more vehicle-friendly area of stream, but they often share many of the characteristics that make culverts into barriers. Fords usually have less substrate complexity, which increases the speed of water. Some fords have concrete bases, which reduce disturbance from vehicles driving through the water or from floods rearranging the shape of the ford. However, these concrete bases reduce flow heterogeneity and water velocity even further and remove resting places for fish, while often adding extra challenges in the form of steep downstream approaches and sharp crests, or vertical surfaces and perches as they erode.

Nothing is known about how fish navigate fords. Guidelines are needed on when a ford is appropriate for a waterway and how can these be built to enable fish unrestricted passage up and downstream. In addition, temporary fords are frequently used in forestry. To determine the best practice designs of temporary fords, these need to be tested for their effectiveness at promoting successful fish passage.

Research questions:

As fords are not recommended structures for maintaining and enhancing fish passage, these questions are considered lower priority to the knowledge gaps outlined in all other categories.

1. A range of ford types need to be tested for passage, using both mark and recapture studies and comparing upstream/downstream fish assemblages.
2. Different temporary ford designs need to be tested to determine best practice solutions for maximising fish passage.

Other areas

Downstream passage for eels

Most fish passage discussion focuses on the upstream movement of juvenile fish, however, eels also face barriers when the adults migrate downstream to sea to spawn. They may find their path blocked by hydroelectric dams and pump stations, where passing through the structure typically results in death or injury. Eels may easily find their way over the top of vertical weirs, but some will land on hard concrete surfaces rather than into a deep pool, and these manmade structures can affect the survival of the fish.

In particular, telemetry studies are needed to better understand eel movements, especially how eels approach and attempt to pass these structures. This research should help to identify where and how to build bypasses, and if we can guide their movements towards and through the pass. For hydrodams, we need to know if the size of a reservoir affects the ability of eels to find a bypass, and if there are ways of attracting them to it.

Research questions:

Highest priority

1. What is the most effective passage solutions for migrant adult eels moving downstream? Particularly for hydroelectric dams, pump stations and weirs.
2. How do apron or sills below the structure impact downstream moving eels compared with receiving pools?
3. Can eels be guided towards or attracted to a bypass?

Other key questions

4. Do weirs with sluice gates (which releases water underneath the gate) adversely impact downstream passage compared to weirs where the water (and eels) pass over top?
5. Does reservoir size and the subsequent surface area of the dam wall affect the ability of eels to find a bypass?
6. What happens when eels go over the top of high weirs without receiving pools?

What is 'effective passage'?

We need clearer definitions of what constitutes 'effective passage', and especially if this definition changes with the location of the barrier.

Not all migrating fish species travel far inland – the greatest diversity and abundances of fish are found in lowland areas. Thus, the definition of 'effective passage' may change depending how far inland the structure is. It may be more important for structures further inland to pass a greater percentage of fish attempting it than one closer to the sea, since far fewer fish reach the inland barrier. There is also the effect of altitude, since low gradient streams often have a greater diversity of fish further inland than steeper streams.

As the fish move upstream they are growing, so perhaps fish passes further inland may need to be designed to cater for adults and larger juveniles, while lowland passes focus just on juveniles. While non-climbing fish will make their way far inland if the gradient is low, they do not usually proceed far if the gradient is steep.

Growth rates and reproductive output could also be considered, as the few large fish upstream of a barrier may have less competition for small invertebrate foods but also less opportunity to eat other fish.

Research questions:

Highest priority

1. What constitutes 'effective passage' at a fish pass for upstream migrating juvenile fish, and for species who migrate upstream as adults (e.g. lamprey, adult galaxiids, adult Chinook salmon)?

Other key questions

2. What are the effects of cumulative fish passes on fish populations?
3. Does distance inland or altitude change how effective the pass needs to be in order to maintain healthy populations upstream?