THE NEW ZEALAND FISH PASSAGE GUIDELINES 2018 – RISING TO THE CHALLENGE OF RECONNECTING OUR WATERWAYS

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ABSTRACT

Introduction

Many of New Zealand's freshwater fish undertake significant migrations as part of their life-cycle. Instream structures, such as culverts, weirs and dams, can delay or prevent fish movements, reducing the distribution and abundance of some of our most iconic and valued freshwater species. Conventional approaches to designing instream infrastructure emphasise hydraulic conveyance at the expense of providing for ecological connectivity. To safeguard our aquatic biodiversity and maintain ecosystem health it is essential that this design philosophy shifts towards a situation where providing for ecological function and maintaining instream processes is central to the infrastructure design process.

All instream structures have the potential to adversely affect aquatic habitats and stream biota, but careful and considered evidence-based planning and design can be used to minimise these potential impacts. The 2018 New Zealand Fish Passage Guidelines set out best-practice approaches to designing and installing instream structures, and managing and fixing existing migration barriers, based on current state-of-the-art knowledge. It is the first comprehensive national guidance document addressing fish passage management in New Zealand and has been developed for an audience of engineers, ecologists, managers and policy makers.

Why does fish passage matter?

New Zealand's freshwater fish species and habitats are threatened by an increasing number of pressures including greater demand for water, deterioration in water quality, loss and degradation of habitats, impacts of invasive species and reductions in river connectivity. These cumulative pressures and a lack of formal protection have had impacts on our native fish, with 76% now being classified as threatened or at risk (Goodman et al. 2014).

Around one third of New Zealand's native freshwater fish spend some part of their lives at sea, which means they need free access to, from, and within freshwater habitats to successfully complete their life-cycles (McDowall 2000). River infrastructure can obstruct these movements, delaying or preventing fish from accessing critical upstream and downstream habitats (Franklin & Bartels 2012; Jellyman & Harding 2012). The result is reduced abundance and loss of some fish species from our rivers and streams.

Removing and mitigating instream barriers to migration has been shown to be one of the most cost-effective means of achieving rapid restoration of aquatic communities and ecosystem health (Roni et al. 2002). Ensuring that new instream infrastructure does not impede fish movements, and restoring passage at existing structures is, therefore, essential for maintaining river connectivity and the long-term health of New Zealand's aquatic ecosystems.

A new design philosophy for fish friendly culverts

Culverts are one of the most commonly used structures for river crossings in New Zealand, and are one of the most common impediments to fish passage. Design features of culverts that can impede fish passage include water velocities that are too fast for fish to swim against and water depths too shallow to allow swimming. In addition, poor maintenance regimes can lead to erosion downstream of culverts, creating falls that are insurmountable for upstream migrating fish. However, by considering the need to cater for fish movements from the outset of the culvert design process, it is possible to minimise the potential for impeding fish movements through culverts. Achieving this requires a paradigm shift in culvert design. Current design practices typically focus on optimising hydraulic conveyance of particular return interval events as set out in regional plan and consent rules. However, optimising hydraulic conveyance generally runs counter to providing appropriate conditions for sustaining continuity of instream habitat and maintaining unimpeded fish passage.

The 2018 New Zealand Fish Passage Guidelines set out two suitable approaches to culvert design to meet fish passage requirements; the stream simulation approach, and the hydraulic design approach.

The stream simulation approach aims to maintain continuity of physical habitat and ecosystem processes, such as transport of sediment and particulate matter (e.g. Olson et al. 2017; Timm et al. 2017). Doing so ensures that movement of fish and other organisms through the culvert will be equivalent to adjacent stream reaches, i.e. unimpeded passage. In contrast to hydraulic design approaches, stream simulation design does not target specific fish species or life stages for passage. Designers also do not have to match species-specific water velocity, depth or other hydraulic criteria. Instead, the objective is to create a continuous streambed that simulates natural channel width, depth, and slope connecting the stream reaches upstream and downstream of the structure. This maintains the natural diversity and complexity of water velocities and depths, hiding and resting areas, and edge habitats that different species use for movement. The approach begins with an initial assessment and choice of a reference reach to use as a template in creating the design reach. This is followed by a site assessment and a detailed design by a multi-disciplinary team including engineers, fish ecologists, geomorphologists and hydrologists. Critical to achieving reproduction of the full range of in-channel features is creating a structure that encompasses at least the natural bankfull width of the channel.

Culverts have traditionally been sized to maximise hydraulic conveyance while minimizing the size of the culverts and, hence, the cost. The factor missing from this optimization exercise is to also minimize the impediments to fish passing through the culvert. In the 2018 New Zealand Fish Passage Guidelines, "hydraulic design" refers to an engineering approach towards a different optimization process – one which minimizes the impediment to fish passage. While this is not mutually exclusive with a goal of ensuring adequate hydraulic conveyance to avoid road flooding due to river flow, the approach required is very different to typical culvert design. The design should consider the size of culvert necessary to convey the design flow, however, this will typically not be the limiting factor on the diameter or width of the culvert. Rather the culvert should encompass the width of the stream bed and not cause a constriction in the flow as it passes through the culvert. Conveyance calculations should then confirm that the culvert is large enough to convey the design flow. The bed slope should be close to natural bed slope and maintaining subcritical flow should be an aim. Water velocity through the culvert should not generate shear at the bed that is in excess of the critical shear stress associated with the substrate in the culvert. Effective hydraulic design of culverts requires simultaneous consideration of the hydraulic effects of culvert size, slope, material and elevation to create water depths, velocities, and a hydraulic profile suitable for fish swimming abilities (Barnard et al. 2013). It is, therefore, reliant on having a good understanding of the target fish species, sizes, swimming capabilities, and behaviour of fish requiring passage. At present, knowledge of the swimming capabilities and behaviour of most of our native fish species is poor. This presents a significant challenge to developing effective hydraulic design criteria for providing fish passage through culverts. However, the guidelines present an example of determining the maximum passable culvert water velocity for inanga, based on known swimming speeds of this species (see Figure 1).

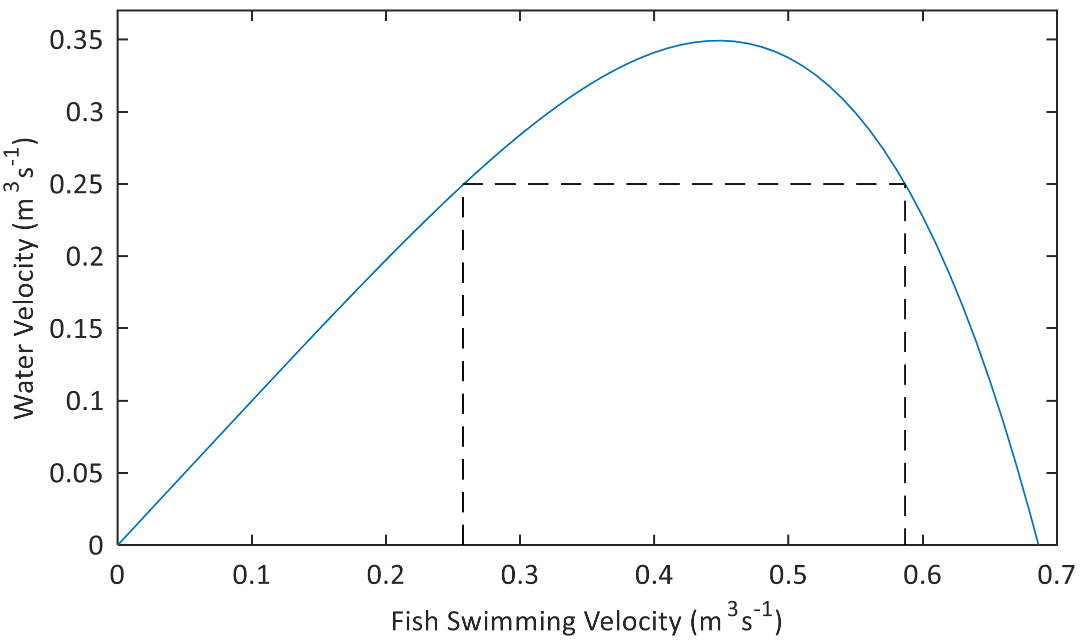

Figure 1: Relationship between design water velocity (Uw) and fish swimming velocity (Uf) for a 75 mm inanga in a 10 m culvert. Data based on Nikora et al. (2003).

Tackling the challenge of restoring fish passage at existing structures

There are many existing instream structures in New Zealand's waterways that impede fish migrations. Overcoming this legacy of poorly installed and/or maintained structures is a significant challenge, but also offers the potential for rapid and significant gains for native aquatic biodiversity. The 2018 New Zealand Fish Passage Guidelines provides a guide to current best-practice options for remediating fish passage at instream structures with a focus on highlighting the key design principles necessary for developing site and structure specific remediation solutions. In all cases, solutions should be developed in consultation with a suitably qualified fish ecologist and engineer.

The first step in developing appropriate remediation strategies for existing structures is to evaluate to what extent and why they are not fulfilling the relevant ecological objectives and performance standards. This may be achieved through visual assessments, routine and/or targeted monitoring. Once the extent and cause of the failure are identified (e.g.

fish passage success is too low because of high water velocities in the structure), appropriate remediation options can be identified, implemented and the structure re-evaluated. Table 1 gives some examples of how to prioritise structures for remediation.

Table 1: Examples of some possible ecological prioritisation criteria for fixing instream barriers. Multiple factors may influence the priority of works to restore connectivity. This includes not only ecological criteria, but also economic, social and logistical criteria. Adapted from Franklin et al. (2014).

Criteria	Explanation
Proximity to coast	Barriers that are closer to the coast not only block access to a greater proportion of upstream habitat, but they also generally block a larger number of fish species.
Potential habitat gain	The greater the total length of accessible river upstream of the barrier, the greater the potential habitat gain.
Habitat quality	Restoring access to higher quality instream habitat should be prioritised over providing access to degraded sites.
Proximity to protected areas	Connection with protected area networks may provide added benefits (e.g. constraints on fishing).
Number of species likely to benefit	Some sites are expected to naturally support a greater number of species than others, e.g. sites at low elevation close to the coast. Sites that are expected to support many species may be of higher priority than those expected to support few species.
Conservation status of species	Sites expected to support species with a higher conservation status may be of higher priority for restoration of connectivity.
Preventing spread of exotic species	Maintaining boundaries on the spread of exotic species may be a desirable outcome of retaining barriers and should also be considered in prioritising restoration actions.
Protects threatened species	Barriers may protect populations of threatened fish species by preventing access to competing species, e.g. trout. Existence and protection of threatened fish populations should also be considered.

Conclusions

The Freshwater Fisheries Regulations require that culverts (new or existing) must not impede the movement of fish unless approval (in the form of a permit) is received from the Department of Conservation. Unfortunately, inappropriate design and inadequate maintenance mean that many culverts do not comply with the requirements of the Freshwater Fisheries Regulations. The resulting fragmentation of our rivers and streams has significant consequences for native biodiversity and ecosystem health – a compulsory national value under the National Policy Statement for Freshwater Management. Reducing the impact of culverts on our waterways requires a new approach to culvert design that places catering for the movement of organisms at the centre of the design process. The 2018 New Zealand Fish Passage Guidelines set out a framework for achieving this.

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KEYWORDS

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