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2013 NATIONAL FISH PASSAGE MANAGEMENT SYMPOSIUM

Proceedings of a Two Day Workshop
Wellington, 26–27th November 2013

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CONTENTS

This barrier in Hamurana Spring, Bay of Plenty, was installed as a selective barrier to prevent trout access and protect kōaro populations.

NIWA – specialists in fish passage research, monitoring and solutions

We:

- provide advice on the design and monitoring of fish passage and intake solutions
- develop selective fish barriers for management of invasive fish populations
- conduct research supporting the restoration of native fish communities and habitats
- lead the development and use of telemetry methods for tracking fish movements.

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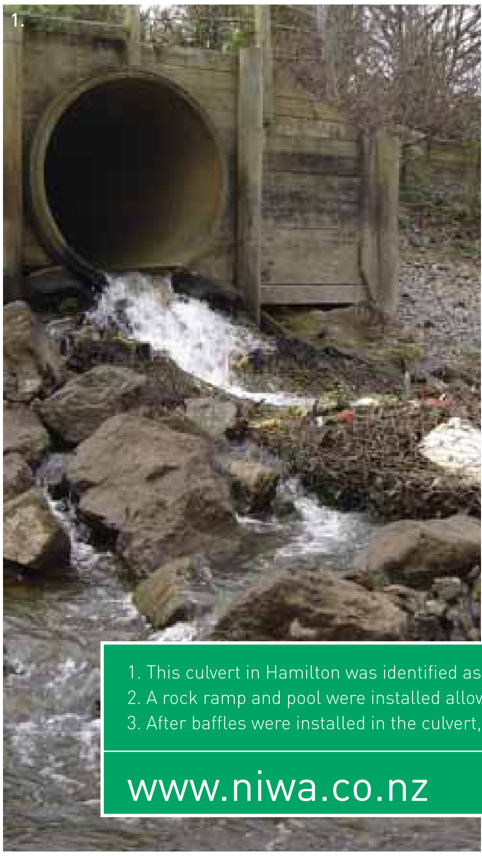

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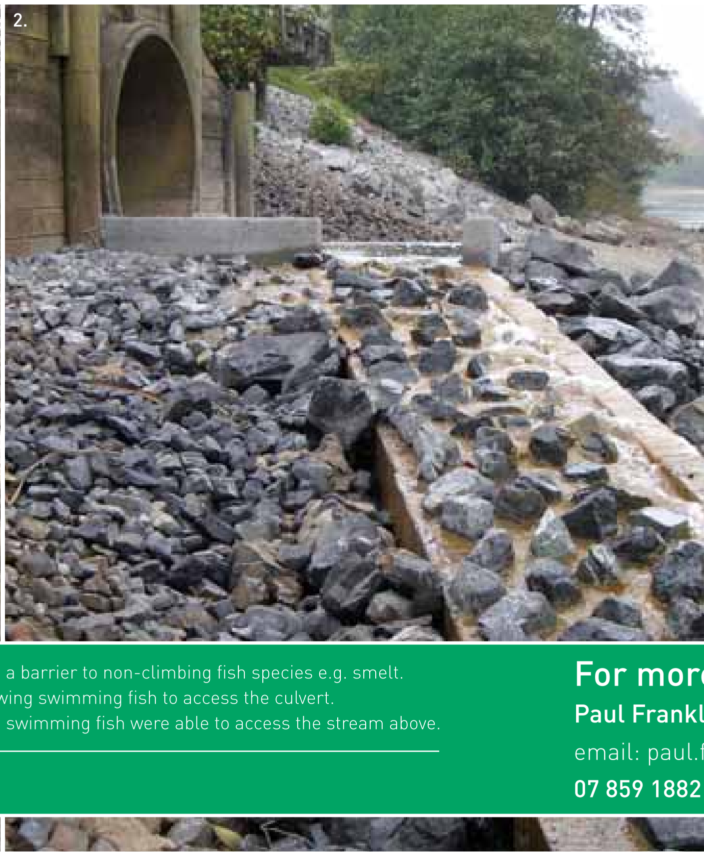

3.


1. This culvert in Hamilton was identified as a barrier to non-climbing fish species e.g. smelt.
2. A rock ramp and pool were installed allowing swimming fish to access the culvert.
3. After baffles were installed in the culvert, swimming fish were able to access the stream above.

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EXECUTIVE SUMMARY

Many of New Zealand's iconic freshwater fish species (e.g., whitebait and eels) are migratory, and require free access to and from the sea, and within waterways to complete their life-cycles. However, low-head (<4 m) structures such as tide gates, culverts, weirs and dams, which are commonly found in streams and rivers countrywide, can obstruct fish migrations. These prevent fish from reaching critical habitats, impacting on freshwater values and ultimately reducing aquatic biodiversity.

The problem of instream barriers to fish migrations needs to be better managed to protect and enhance New Zealand's freshwater fish and fisheries. To help promote and achieve this objective, experts from around New Zealand met in Wellington for the first national workshop on fish passage in November 2013. The aim of the workshop was to share and discuss the latest knowledge and research on fish passage management in New Zealand, and to share best practice solutions for reconnecting New Zealand's waterways.

These proceedings provide a summary of the presentations and discussions during the workshop. Key themes that emerged during the workshop were:

- the need for greater collaboration between ecologists and engineers in finding innovative solutions for enhancing fish passage at instream structures;
- a requirement to improve access to resources providing guidance on managing fish passage;
- the need for targeted research to fill critical knowledge gaps to support development of more robust design criteria for instream structures;
- a desire for robust testing and evaluation of fish passage solutions to ensure they are fit for purpose; and
- the need for improved and ongoing monitoring of fish communities at and around instream structures to ensure their effectiveness for maintaining fish passage.

A key outcome of the workshop has been the establishment of a working partnership between the Department of Conservation and the National Institute of Water and Atmospheric Research to collate and develop national resources to support fish passage management in New Zealand. This will be supported by a new multi-agency national fish passage advisory group.

1.
INTRODUCTION

A two day national workshop on fish passage management was organised by Sjaan Bowie (Department of Conservation (DOC)), Anna Burrows (Greater Wellington Regional Council (GWRC)), Paul Franklin (National Institute of Water and Atmospheric Research (NIWA)) and Trevor James (Tasman District Council (TDC)). The aim of the workshop was to increase national coordination and facilitate sharing of the latest research and tools available to promote effective and efficient management of fish passage in New Zealand's rivers (see Appendix 1 for programme). The workshop was held in Wellington on the 26th and 27th of November 2013, and focussed on management of fish passage at instream structures less than four metres in height.

Over 90 experts attended the workshop (Appendix 2), with engineers and scientists from over 56 different organisations represented, including Regional and District Councils, DOC, NIWA, New Zealand Transport Authority (NZTA), Kiwi Rail, Mahurangi Technical Institute, iwi, and engineering and ecological consultancies.

The first day of the workshop was targeted at scientists and ecologists, and focussed on fish passage management systems, the latest research, design standards and gaps in knowledge. This included presentations and discussions of standardised assessment forms, data collection and storage, national databases, guidance and research needs, updates of the latest research, education opportunities and examples of strategies organisations are using to manage fish passage. The second day of the workshop focussed more towards engineers and was dedicated to sharing experience and discussion.

These proceedings contain summaries of the papers that were presented at the workshop, as well as documentation of key discussions. They provide an overview of current fish passage research and management in New Zealand, and a summary of the national systems and tools required to improve future management of fish passage in New Zealand waterways. As much of this information resides outside published literature, it is hoped that these proceedings will be a valuable reference resource and useful building block for future fish passage research and management in New Zealand

2.

BACKGROUND

2.1. Why are Freshwater Fish Important?

There are a wide range of freshwater ecosystems in New Zealand, including rivers, streams, lakes and wetlands. These ecosystems provide key habitats for approximately 40 native freshwater fish species and 10 sports fish species (dependent upon regions operated by different Fish and Game Councils) (McDowall 2000). Many of these species are only found in New Zealand and therefore are of significant biodiversity value. Freshwater fish are important in New Zealand due to their status as taonga and their importance for sustaining cultural, recreational and commercial fisheries and activities. 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).

New Zealand's freshwater fish species and habitats are threatened by an increasing number of pressures including increasing demand for water, deterioration in water quality, loss and degradation of habitats, impacts of invasive species and reductions in riverine connectivity. These cumulative pressures and a lack of formal protection have had impacts on our native fish, with around 70% being classified as threatened or at risk (Allibone *et al.* 2010).

2.2. Why is Fish Passage Important?

We have changed our rivers. Structures, such as tide and flood gates, road crossings, culverts, weirs, fords and dams, are commonly found in streams and rivers throughout New Zealand and can delay or prevent fish migrations to upstream and downstream habitats (e.g., Franklin & Bartels 2012, Jellyman & Harding 2012). Fish can also be entrained into water intake structures and lost to the fishery, unless they are suitably screened (Jamieson *et al.* 2007). Barriers to migration prevent fish from reaching critical habitats required to complete their life-cycles. This can result in the gradual decline and loss of fish species from some rivers and streams. Blocking or limiting fish movements within and between waterways is therefore a significant threat to our native fish. For many native fish species protecting connectivity between habitats is as important as protecting the habitat itself.

Managing fish passage can also be important for protecting ecosystems from the effects of invasive species. While providing fish passage is advantageous for most fish, it is important to also consider the potential impacts of introducing invasive species to new areas by removing barriers. Some of our threatened native fish that live all their life in freshwater cannot compete with some of the invasive fish species, and barriers can help to protect these species. Some key locations therefore need barriers to help protect native species and ecosystems by preventing invasive fish from accessing these habitats.

Generally all fisheries in New Zealand are governed by the Conservation Act 1987, which includes the Freshwater Fisheries Regulations 1983 (section 48a Conservation Act), and the Fisheries Act 1983. In relation to fish passage, DOC's responsibilities include protecting freshwater habitats (Part 2, s. 6 (ab)), advocating for aquatic life and freshwater fisheries (s. 53 (3)(d)), and administering the fish passage provisions of the Freshwater Fisheries Regulations (Part VI). These functions are closely related to those of other agencies including the Ministry of Primary Industries, Regional councils and Fish and Game New Zealand, which also have specific functions in freshwater management (Charteris 2007).

DOC and Regional Councils have specific responsibilities to manage fish passage in New Zealand's waterways under the Freshwater Fisheries Regulations 1983 and Resource Management Act 1991 (RMA) respectively. The Freshwater Fisheries Regulations only apply for structures built after 1 January 1984. Culverts and fords may not be built in a way that impedes fish passage without approval from the Director General of Conservation, and any dam or diversion may require a fish facility. Under the RMA, Regional councils control environmental effects relating to the construction of structures including consideration of fish passage and protecting areas of significant habitats for indigenous fauna. These rules are implemented in Regional Plans.

DOC has not implemented its regulatory powers under the Freshwater Fisheries Regulations 1983 well and has ultimately relied on advocacy by regional councils under the RMA consent process. While this avoids duplication, an Environment Court ruling in 2002 (Judge Whiting decision A33 / 2002) found that there were no conflicts between the general sustainable management provisions of the RMA and the more specific fish passage protection mechanisms of the Freshwater Fisheries Regulations because they served different objectives and therefore did not override each other. DOC are consequently working on providing guidance to better implement the Department's fish passage requirements in the future.

A Cawthron freshwater scientist at work in the Travers River, St Arnaud

Cawthron scientists are the water experts. We know the rivers, lakes and seas of New Zealand from microscopic detail through to the big picture of how human activity affects our aquatic resources – and what can be done to protect them.

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2.3 What Makes a Fish Migration Barrier?

A fish migration barrier is regarded as any structure which impedes or prevents the upstream and / or downstream movement of freshwater fish. To understand what makes a barrier there is a need to understand our fish, including their distribution, habitat preferences, timing of migration and spawning, swimming ability, behaviour and size (Charteris 2007, Stevenson & Baker 2009).

Different native fish species vary in size and in their swimming and climbing abilities, e.g., inanga are weak swimmers and cannot climb, whilst young koaro whitebait and eels are adept at climbing wetted surfaces. These abilities often can vary with life stage (Charteris 2007). Fish swimming ability is an important criteria determining the ability of fish to pass a barrier. A number of studies have been carried out to investigate the swimming performance of fish species (e.g., Boubée *et al.* 1999 (Table1); Mitchell 1989). In general, water velocities of < 0.3 m s^{-1} enable most native fish to negotiate a channel. However, if the area is an important spawning or migration area for juvenile native fish the available research suggests that water velocities of < 0.1 m s^{-1} are more suitable (Table 2). Water velocities > 1.5 m s^{-1} would exclude all climbing or clinging species (Table 2). These differences in characteristics contribute to determining the biodiversity of fish communities in different habitats, e.g., coastal wetlands versus high altitude streams, and are also important in regulating which species can and cannot pass different instream barriers. Consequently, these behaviours can be exploited to improve upstream passage and to identify key design parameters for structures to ensure effective passage of fish.

There are two types of barriers:

- Unintentional barriers are those which obstruct fish movements, but were not constructed to intentionally prevent fish passage. These may include man-made structures, e.g., culverts, dams, weirs, fords (Figure 1), or natural obstructions such as waterfalls or cascades. It is the artificial barriers in this group that we most want to remediate in order to maximise fish passage, whilst ensuring the original purpose of the structure is still maintained.
- Intentional barriers include built barriers and water intakes that are designed to specifically prevent fish access. Built barriers are generally designed to exclude invasive species from gaining access to upstream areas where native fish exist that cannot cope with the presence of invasive species (Figure 2).

The combination of a barrier's characteristics and a fish's capabilities and behaviour determine the extent to which a barrier may impact on a fish community. Large fall heights, high water velocities, perched structures, low water depths and the presence of physical structures which block waterways, e.g., tide gates or dams, are all characteristics which can contribute to a barrier preventing fish movements. The swimming or climbing abilities of a fish, its size and / or the timing of migrations can, amongst other factors, impact on the ability of a fish to overcome a barrier.

There are a number of publications and resources available to help with fish passage management in New Zealand (e.g., Boubée *et al.* 1999, Stevenson & Baker 2009). However, these resources are dispersed and sometimes not widely known. Consequently, it was decided to convene a two day national workshop to gather the latest guidance on fish passage management and to make some decisions on future national needs for more coordinated fish passage management.

TABLE 1. Relationship between swimming speeds (VF m s^{-1}), fish length (L) and time (t secs) (Source Boubée *et al.* 1999)

	Eels	Inanga/Smelt/Bullies
Sustained VF	$1.8L^{0.5}t^{-0.13}$	$5.29L^{0.63}t^{-0.16}$
Burst VF	$5.6L^{0.5}t^{-0.33}$	$14.4L^{0.63}t^{-0.43}$

TABLE 2. Swimming performances (sustained swimming speeds) for fish species found in Canterbury waterways (m s^{-1}) (* = figures generalised from results of investigations) (Source: Charteris 2007 collated this information, original sources are detailed within the report).

Common name	Swimming velocity general (adult)	Swimming velocity general (juvenile)	Swimming velocity over <15 m (juvenile)	Swimming velocity over >15 m (juvenile)
Eels	<1.5–2.0	<0.2–0.5 Preferred <0.3		
Shortfin eel		0.15– >0.6*	<0.3	<0.25
Longfin eel		<0.15– >1.0*		
Giant kokopu	<0.1			
Shortjaw kokopu	<0.05			
Koaro	<0.8*	0.1–0.24*		
Banded kokopu	0–0.05	0.04–0.29	<0.3	<0.25
Inanga	<0.15-0.36 0.07 preferred	0.007-0.39	<0.3	<0.25
Lowland longjaw galaxias	0.1–0.5	0.1 (fry)		
Alpine galaxias		0.1 (fry)		
Canterbury galaxias	<0.15–0.6*	0.1 (fry)		
Torrentfish	0.3– <1.1*			
Common bully	0.15–0.6*	0.24–0.28	<0.3	<0.25
Upland bully	<0.15–0.7*			
Bluegill bully	0.3– >1.0*			
Redfin bully	<0.15–0.6*			
Common smelt	0.15–0.6*	0.19–0.27	<0.3	<0.25
Mean NZ species (based on observations obtained with juvenile shortfin eel, common bully, common smelt, inanga and banded kokopu)		0.2–0.32		

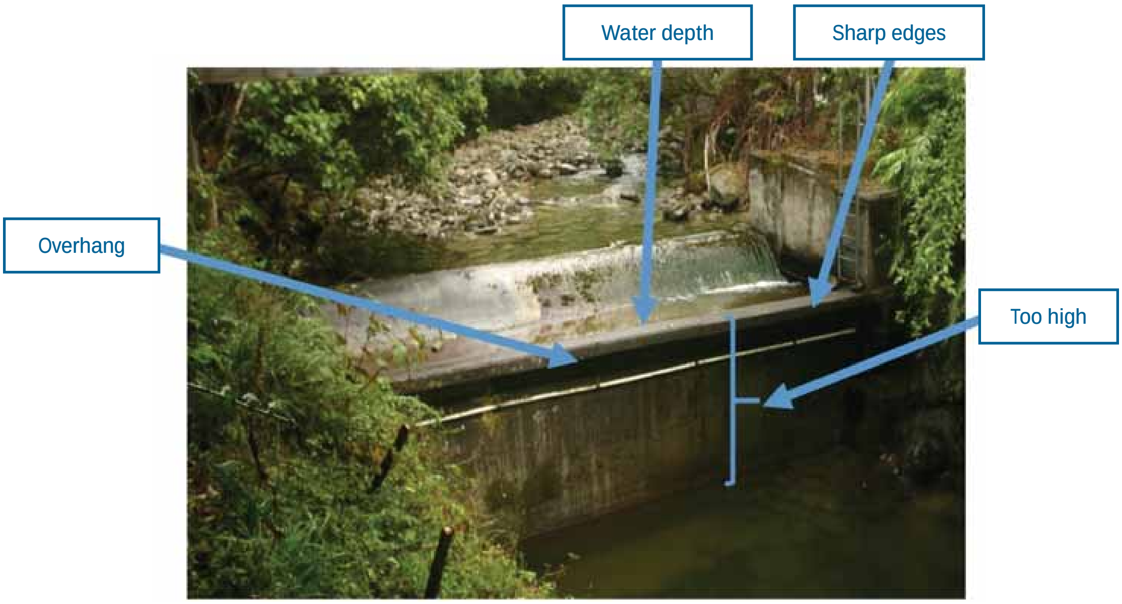

FIGURE 1: Example of a weir that is an unintentional barrier to fish migration including key characteristics that restrict fish passage.

FIGURE 2: Example of a weir that has been installed to intentionally prevent invasive species passage.

3. CONFERENCE PROCEEDINGS

Over the two days of the workshop more than twenty presentations were made, covering four main themes:

1. Data collection and storage;
2. Strategies for managing fish passage;
3. Latest research; and
4. Sharing experience.

Summaries covering the main points from each of the presentations are included below. Copies of the presentations are available from the new national fish passage website recently developed by DOC and NIWA (www.doc.govt.nz / fishpassage). This website will host the key information and guidance on fish passage management.

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3.1. Data Collection and Storage

3.1.1. National Fish Passage Survey

TREVOR JAMES Tasman District Council (TDC) &
SJAAN BOWIE Department of Conservation (DOC)

Online questionnaire about fish passage

Prior to the workshop in September 2013 an online survey was sent to all workshop participants from Regional and District councils and other organisations to get an overview of current fish passage work happening throughout New Zealand. Thirty seven respondents completed the survey, including 23 from councils, three consultants and four other organisations.

A full summary of responses has not been collated to date, however some examples of information received is provided below.

What councils undertake fish passage assessments?

All councils reported that some fish passage assessments of in-stream structures have been performed in their regions, however most have only undertaken less 50 assessments (Figure 3). Some organisations have undertaken significant assessments, with Waikato Regional Council and Tasman District Council completing 1–2000 and Auckland Council completing over 2000 assessments.

How many structures have had fish passage remediation undertaken?

Fish passage remediation is occurring in New Zealand, however most organisations have only remediated less than 10 structures to date (Figure 4). Of the respondents, five councils reported that no barriers have been remediated in their region. A few councils have made significant progress on remediating their barriers including Auckland Council with >200 sites, Tasman District Council 101–200 and Nelson City Council 50–100.

How is prioritisation of fish passage management undertaken?

Results showed that most organisations based prioritisation on the ecological value of the waterway. However, other factors were also used (number of organisations using this factor in prioritisation is marked in brackets):

- Catchments with higher fish diversity (12 organisations);
- Barriers closest to the sea (9 organisations);
- As required by condition of consent (8 organisations);
- Our own barriers (7 organisations);
- Interest from community groups (7 organisations);
- In conjunction with other works (6 organisations);
- High profile barriers (x3).

What Regional and District Plans include fish passage?

Of the Regional and District councils that responded, the majority of councils have rules in their plans that consider fish passage for new structures, while there are less councils that also have rules that consider fish passage for existing structures (Tables 3, 4 and 5). These rules vary around the country and some regions do not have current plans.

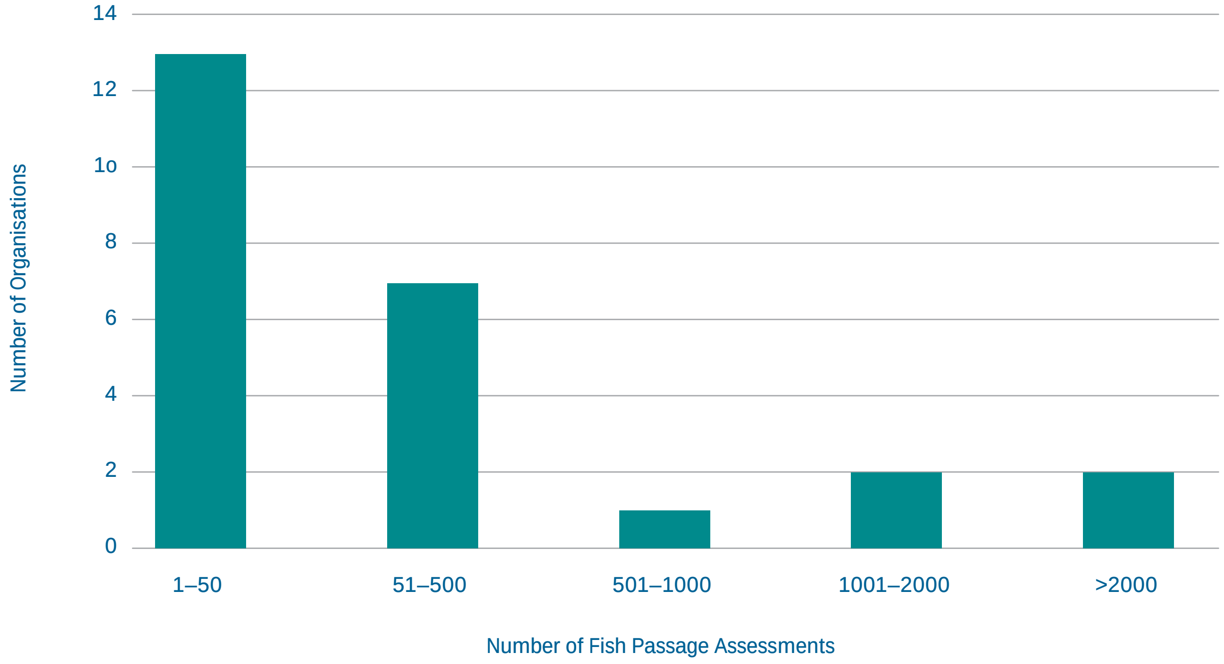

FIGURE 3: Number of fish passage assessments completed by questionnaire respondents.

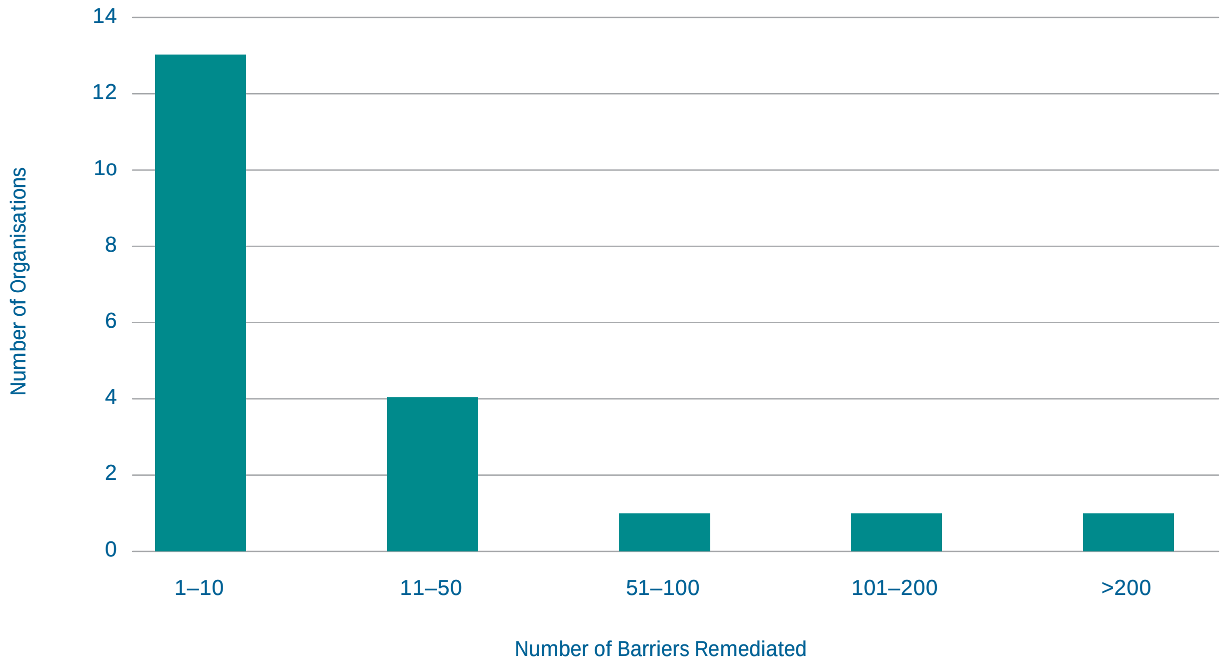

FIGURE 4: Number of barriers remediated by questionnaire respondents.

TABLE 3: Number of Councils that have rules in plans in regard to fish passage.

	Regional Councils (13)	District Councils (8)
What are the rules in your organisation's Plan for new structures?	**9** Yes **1** Developing **3** Unsure	**3** Yes **1** No **4** No answer
What are the rules in your organisation's Plan for existing structures?	**6** Yes **4** No **3** Unsure	**2** Yes **2** No **4** Unsure
Have you ever taken enforcement action to require fish passage?	**4** Yes **7** No **2** No answer	**8** No

TABLE 4: Summary of fish passage rules for new structures.

Waikato	Structures may not prevent fish passage if catchment greater than 100 ha, depth >3 m and dam does not retain >20,000 m^3
Greater Wellington, ORC	Must provide fish passage
BOP, CCC	Maintain fish passage
TRC	Shall not restrict the passage of fish
Horizons	Required for structure to meet permitted activity status
Tasman	Threshold for piping is 15 m
WCRC	Fish passage when dealing with damming and diversion (12.4)
ECAN	Differ for structures prior to 1 Nov 2010 and after (use and maintenance, reconstruction, alteration, extension, demolition, removal, erection, placement and use...)
Nelson City	Fish passage should be considered
Southland	Shall not be impeded

TABLE 5: Summary of fish passage rules for existing structures.

Northland	Maintaining life supporting capacity
Auckland	No rules to require fish ramps
Greater Wellington	New non-regulatory programme will be developed to assist with the remediation of existing barriers
TRC	Shall not restrict the passage
Horizons	In order to have permitted status, fish passage is required. Therefore by default if fish passage is not allowed for a structure it is no longer permitted and a consent / permission from DG of DOC is required
Tasman	Same as previous + those existing before Feb 2010 have 5 years from the operative date of the plan to provide for fish passage
WCRC	Damming and diversion (12.4)
ECAN	BLR4 – specific limits on length, diameters of culverts, catchment area above a dam or weir....
ORC	Must provide fish passage if it is under the permitted activity rule. If consent is required a decision on whether fish passage was needed would have been made
Wellington City	minimise / remove barriers to fish passage
Nelson	Structures can be improved if damaged; changes to the Freshwater Plan are required to deal with permitted structures (e.g., retention dams) that need fish passage improvements.

3.1.2. National fish passage assessment protocol and migration barrier database

PAUL FRANKLIN National Institute of Water & Atmospheric Research (NIWA)

Background

There are currently many different assessment protocols used by different regions and agencies for evaluating fish migration barriers. There is also no central repository for the data collected. This makes it difficult to create a nationally consistent picture of how big the fish passage problem is in New Zealand. As a consequence, it is difficult to gain support for more coordinated action at a national level to improve management of this problem.

A national fish passage assessment protocol would deliver consistency in the evaluation of migration barriers and is an essential foundation for developing a national database. In combination, a national protocol and database would enhance our ability to develop a national picture of the problem, assist with prioritisation and management, and support restoration efforts.

Requirements for fish passage data collection and storage

A review of assessment methodologies currently in use by Regional councils, Department of Conservation and others indicated that most are focused on culverts and are based on the assessment sheet used by Kelly & Collier (2006). However, there are many inconsistencies in how data is collected, what measurements are taken, and how to evaluate the degree of impediment created by each structure. Key requirements of a national assessment protocol should include:

- all main structure types i.e., culverts, flood / tide gates, weirs etc.;
- a hierarchical format integrating both a rapid assessment method and a protocol for collecting more detailed information about barriers to inform management actions;
- an assessment of the degree of impediment created by a structure for target fish species; and
- be intuitive, objective and quick to complete.

A draft assessment protocol was presented for discussion. Feedback was obtained on what fields were thought to be most useful, fields that were unnecessary, the structure of the protocol and what path future development of the protocol should take. The subjective nature of assessing how passable a structure is, and for which species, was investigated and preferred approaches for data collection were discussed.

It was highlighted that the fundamental basis of an efficient and useful national database must be data collected in a consistent manner. If this is achieved, construction of a national database is a relatively straightforward process. Options for data management, data presentation, accessibility and the potential for linking to prioritisation methods were discussed.

Key requirements of a national barrier database include:

- consistency in data collection;
- easy to input data;
- easy to retrieve data in an accessible format; and
- data quality management.

Summary

A nationally standardised fish passage assessment methodology would help improve consistency in the management of fish migration barriers between regions and is an essential foundation for a national fish migration barrier database.

Data collected in a consistent and standardised way will allow a more robust understanding of how river connectivity is impacted by human infrastructure and therefore how these activities should be managed to reduce adverse effects on fish communities.

The development of a standardised national fish passage assessment protocol will require input from a range of practitioners to ensure it is fit for purpose.

3.2. Strategies for Managing Fish Passage

3.2.1. Prioritisation tools and systems for remediating, maintaining or creating fish barriers

DAVE WEST Department of Conservation (DOC)

Background

There are a large number and range of barriers to fish passage in New Zealand river systems. While many may only be partial barriers, there remains a significant challenge in prioritising sites for survey and fish barrier remediation. In addition, some barriers may be protecting remnant native fish populations from invasive fish and should be maintained.

Using a number of existing and new spatial features, along with infrastructure and other information such as works' schedules, management agencies can efficiently prioritise fish passage management to maximise gains to freshwater fish populations.

Migratory fish species

To manage and remediate barriers to ensure migratory fish can complete their lifecycles, the following key steps can be used:

1. Collate a map of known structures from all sources available, e.g., Regional Councils, NZTA, DOC
2. Map freshwater values to identify important catchments and reaches including;
    - Unique and high value catchments using FENZ_v1 river planning unit ranks (Leathwick *et al.* 2010).
    - Use of predicted diadromous species richness to identify reaches requiring unrestricted passage.
    - Threatened fish species using New Zealand Freshwater Fish Database (NZFFD) records.
    - Key inanga spawning locations (or adult distribution) as they are weak swimmers and favour low altitude habitats.
    - Other prioritised catchments / sites, e.g., vicinity to prioritised sites, active restoration sites, schedules of important sites.
    - Land ownership – best to focus on public ownership, before private.
    - Other important values, e.g., key mahinga kai sites.
3. Add consideration of practical aspects including:
    - Start downstream first, and check no other barriers downstream.
    - Start downstream complete barriers, before partial barriers upstream.
    - Barrier design, i.e., some floodgates easier to retrofit and repair than others.
    - Take advantage of maintenance or replacement schedules to address barrier issues.
    - Look for multiple benefits from single barrier fix, e.g., floodplain reconnection.
    - Tackle local government barriers first.
4. Finally intersecting barriers, values and practice:
    - Start focussing on areas with important values; don't get side-tracked by easy fixes in less important places.
    - Look for multiple beneficial outcomes, i.e., local government asset management and conservation outcomes.
    - Capture barrier data in a manner so that others can fix their barriers, even if your organisation chooses not to.
    - Consider overlaying relevant combination of value and pressures, e.g., whitebait spawning sites and bad floodgates.
    - Amount of habitat upstream, i.e., if there is not much habitat upstream of the barrier it may not be a priority to remediate.

Key non-migratory fish hotspots

To ensure barriers are established and maintained to protect key non-migratory locations and prevent invasive species access the following steps can be considered:

1. Map known barriers and natural barriers e.g., waterfalls
2. Map freshwater values to identify important catchments and reaches including:
    - Locations of threatened non-migratory fish species.
    - Catchments identified as key hot spots or optimised management sites.
    - Good habitat for threatened native species (e.g., predicted fish distributions (FENZ), potential translocation sites).
    - Where invasive species are absent.
    - Other prioritised catchments / sites, e.g., vicinity to prioritised sites, active restoration sites, schedules of important sites.
    - Land ownership – best to focus on public ownership, before private.
3. Add consideration of practical aspects including:
    - Take advantage of maintenance or replacement schedules to address barrier protection at key native fish locations.
    - Using artificial structures, such as culverts or weirs, or natural waterfalls or chutes that can be enhanced as barriers.
    - Reaches with high slopes can establish effective barriers.
4. Finally intersecting barriers, values and practice:
    - Start focussing on areas with important values; don't get side-tracked by easy fixes in less important places.
    - Look for multiple beneficial outcomes, i.e., local government asset management and conservation outcomes.
    - Capture barrier data in a manner so that others can fix their barriers, even if your organisation chooses not to.
    - Consider overlaying relevant combination of value and pressures, e.g., non-migratory galaxiid key hot spots and trout distribution.
    - Amount of habitat upstream, i.e., if there is not much habitat upstream of the barrier it may not be a priority to remediate.

Summary

A number of features and values (for example Freshwater Environments of New Zealand Geodatabse (FENZ_v1 ranks)) ranging from catchment to stream reach and point records can be used to prioritise fish passage management effort. Key agencies need to work together in regions to ensure most effective gains can be made. This comprehensive value mapping enables robust setting of objectives at scales appropriate to the goals of rehabilitation.

The benefits of co-ordinating remediation with existing asset maintenance schedules is high, but care also needs to be taken that limited fish passage technical expertise is not used up on convenient rather than priority fixes.

More exploratory use of FENZ_v1 features, such as predicted stream slopes, could speed identification of likely natural barriers and those that could be enhanced to prevent expansion of invasive exotic fish into threatened native fish habitats.

3.2.2. Development of the Greater Wellington Regional Council Fish Passage Programme

ANNA BURROWS Greater Wellington Regional Council (GWRC)

Background

The Greater Wellington Regional Council (GWRC) Biodiversity Department was formed in 2011 to lead GWRC's strategic approach to biodiversity management. The GWRC Fish Passage Programme intends to manage one of the threats to freshwater biodiversity by removing impediments to the free movement of fish along waterways.

This presentation summarises the evolution of the GWRC Fish Passage Programme over the last few years, and will be of interest to other organisations going through similar development processes.

As part of the GWRC Fish Passage Programme, a number of structures in streams have been assessed and / or modified to provide fish passage. The details of this assessment and remediation work have not been included in this presentation summary, which focuses purely on the programme development.

Collating existing information

The first step in the development of the GWRC Fish Passage Programme was to understand the extent of the problem.

Existing spatial information showing the location of structures in streams across the region was collated, and a master GIS layer of potential barriers to fish passage was created. A number of different organisations and other GWRC departments contributed to the creation of this layer.

Other GIS resources, including "Point-Click-Fish[1]", the NZ Freshwater Fish Database, and several freshwater ecological prioritisation datasets (Leathwick *et al.* 2010) were also gathered together to create a geodatabase of fish passage resources.

Developing a strategic approach

With information on structures in streams in the Wellington region collated, the next step was to decide on a strategic approach to regional fish passage remediation. The departmental objective was to ensure that the limited resources available were used for maximum ecological gain.

A document entitled "A Strategy for Providing Fish Passage in the Wellington Region" (Butler 2011) was produced to identify the region's "high value" catchments and make recommendations for the programme's implementation approach.

It was agreed that the fish passage restoration effort would be focused in these catchments.

Implementation "fine-tuning"

Following the recommendations of Butler (2011) several attempts to restore fish passage at key structures in the "high value" catchments were made. However it became clear that an unsustainable level of staff resources was needed to discuss the programme with the structure's owner, get permission to proceed, talk to stakeholders, identify the affected species, design solutions and implement them. The Biodiversity Department didn't have the capacity to do this detailed operational work for each structure. In addition concerns were raised about where the responsibility for the ongoing maintenance costs associated with this work would lie. As a consequence of these concerns, it was agreed that the programme's approach would be reviewed.

1 Point-Click-Fish is a predictive model of fish occurrence.

Focusing on our own structures

Following the decision to review the earlier approach taken by the programme, it was decided to shift the focus of the GWRC Fish Passage Programme to GWRC owned or managed structures.

GWRC manages over 50,000 ha of land (including Regional Parks, Water Catchment Areas and Forestry Blocks) and this land includes a number of structures in streams that may be barriers to fish passage. Most of these areas also have dedicated operational staff associated with them.

This new approach aimed to utilise staff from other departments to deliver operational fish passage work with guidance from the GWRC Biodiversity Department. It fitted well with the legal requirements of GWRC to provide fish passage over the structures it owns and manages, and with the first goal of the GWRC Biodiversity Strategy 2011–21 to "demonstrate leadership in biodiversity management" (GWRC 2011).

Using this modified approach the majority of structures in streams on GWRC park land have now been assessed for their potential as barriers to fish passage.

Summary

After some initial "fine-tuning" the GWRC Fish Passage Programme is now well underway with some additional improvements and updates already in the pipeline.

A new non-regulatory method ("Method M15: GWRC will provide support and guidance on methods and locations for restoring fish passage") is currently part of the Greater Wellington Regional Plan "working document for discussion" (the early draft of the second generation Regional Plan)(GWRC 2014). If this method is approved it will provide a stronger mandate for the continuation of this work and potentially a strong argument for increasing the resources allocated to this programme.

Building on the "focus on our own land first" approach it has been agreed that increasing GWRC staff's understanding of fish passage issues and how to fix them is likely to provide good value for money, and ideas for workshops and fish passage related presentations and resources are being developed.

Once all the GWRC owned and managed structures have been assessed and, wherever possible, fish passage has been restored GWRC will have a good understanding of the costs involved (both initial and on-going) of such work. This information will be used to determine an approach to dealing with the many structures in streams in high value catchments not under GWRC control, as part of an on-going programme.

3.2.3. Tasman District Council – Practical prioritisation

TREVOR JAMES Tasman District Council (TDC)

Assessments

Tasman District Council started their fish passage programme by concentrating on assessments of in-stream structures associated with main highways and Council roads, starting with coastal areas and then moving inland. All of Golden Bay and about 30 km inland in Tasman Bay have been completed. Work still to be completed includes the furthest inland areas of the region, e.g., Upper Buller catchment. These areas have non-migratory galaxiids and so we have to be careful about allowing greater predation by trout. Assessments were done as a stand-alone project (not linked with restoration) on public roads as it was more a one-person job and vehicle set up with a "road inspection" sign and flashing lights.

Tasman District Council is currently undertaking assessments and remediation on farms in Golden Bay. Structures are remediated on the same day as the assessment unless it is a big job. This is because it takes more effort to arrange subsequent visits with the landowner.

University students undertook this work over 25 days during the summer months (2–3 days per week for 11 weeks), and they achieved 250–300 assessments. Council staff have spent an additional 10 days per year doing assessments and managing the database. The need for good photos was emphasised, and to do this students were supplied with hedge clippers so barriers were not obscured by vegetation. At least 6 photos per site were required, including a view at the inlet looking upstream and downstream, view at outlet looking upstream and downstream, and views of the outlet and inlet taken at 90 degrees to the flow. Photos have proven invaluable when it came to planning assessments.

Restoration/remediation

Some obvious priority structures were easily identified in the first year or so after the assessments began. It is suggested that doing a few pilot assessments before doing the bigger campaigns 4–5 years after starting the assessments is worthwhile.

Again students were used, this time with a practical bent, as well as a few week-long campaigns with Kelly Hughes from ATS Environmental.

This work was started with a budget of $6000 per year for remediation (along with donated materials) and looking back, it is amazing what was achieved.

Using conveyor and spat rope, five to eight culverts per day and about 50 sites per year were remediated. Around 10 days per year were spent managing the remediation (half of which was in the field). Additional time has been spent working with owners of structures who are unwilling to contribute or are trying to do the restoration themselves but to a poor standard. In most cases Tasman District Council have found that it is easier to do the remediation themselves. At one site, the remediation work could have been done twice over in the time it took to work with the three owners of the structure.

We started with restoration of publically-owned structures, i.e., Council and NZTA roads, as well as hydrology and tide gate structures, and then moved on to private land. We found that it was good to tie in with dairy farm compliance visits.

When it came to the debate about how to regulate existing fish passage barriers Tasman District Council councillors were happy to offer a service to landowners to fix them instead of creating strong rules requiring restoration of fish passage. Tasman District Council also does have a rule requiring restoration of the barrier within five years of Council being made aware of it.

Summary

From the experiences of Tasman District Council, it is worth not spending too much time and money developing elaborate prioritisation systems, as other non-ecological factors come in that often over-rides the process. Site by site prioritisation was undertaken, but this was generally not worth the time. Using broad ecological priorities, rather than catchment by catchment or site by site priorities, were deemed more effective. For the Tasman area priority locations were all of our coastal areas to 10 km inland and then worked inland. Golden Bay got the highest priority with generally the best habitat upstream. In addition, it was decided to focus on remediating most, or all, structures (including the low priority sites) in an area, particularly if remote locations.

Therefore the main criteria used to prioritise remediation were:

- Quantity of habitat upstream.
- Quality of habitat upstream.
- Fish community value – using ‘proximity to coast’.
- Concentrate on Council roads that were accessible first, then move to private land.
- Undertake all remediation in remote locations whilst there.
- “Severity of fish passage restriction” and working from the bottom of the catchment upstream were two key factors used to prioritise those larger more expensive remediation jobs.
- “Fitting in with programmed works” where possible.

The presence of a community group really wanting to improve the health of ‘their’ waterway can make a real difference.

3.2.4. Assessing barriers to fish passage in the Canterbury region

DAVE KELLY Environment Canterbury (ECan)

Background

Freshwater fish are an important component of Canterbury's biodiversity. Thirty three of the 58 species of freshwater fish present in New Zealand occur in Canterbury. Seventeen of the fish species found in Canterbury are diadromous and thus undergo migrations between marine and freshwater. Migration often occurs between critical habitats for feeding (e.g., migratory galaxiids), and / or spawning (e.g., eel and salmon). Thus, the presence of impassable artificial structures is a significant factor in the decline of freshwater fish populations in the region.

A number of directives / policies promote the protection of fish passage. In Canterbury, the proposed Canterbury Land and Water Regional Plan, The Canterbury Water Management Strategy (CWMS), and the Canterbury Biodiversity Strategy identify priorities or set regional rules. Although some policies have been in effect for over 20 years, many structures have been in place either long before such policies were in effect or during periods when planning rules were less stringent. Thus, a potentially large number of structures in Canterbury may fail to provide adequate passage for fish. The extent and distribution of existing potential migration barriers is largely unknown and no assessment or mapping has been undertaken. Establishing where barriers exist is the first step in considering mitigation options.

Under the CWMS Immediate Steps Biodiversity Fund, up to $450,000 is potentially available over the next five years to support fish habitat and passage projects in Canterbury. A programme to facilitate fish passage in the Canterbury Region was initiated by Environment Canterbury with the following key aims / goals:

- Desktop assessment to pre-identify sites with potential barriers to fish passage was carried out. This was achieved by intersecting the River Environment Classification (REC) river network with road crossings.
- Data was stratified by distance from coast, with ones closest to the coast identified as being a priority for assessment.
- In-situ assessments were undertaken using Boubée *et al.* (1999) and categorised as low, medium or high priority.
- "Ground-truth" (fish and habitat surveys) areas upstream and downstream of candidate barriers for verification.
- Develop an inventory of potential barriers to fish passage to assist in the planning of stream restoration projects for biodiversity enhancement.
- Assist in the identification and prioritisation of sites for modification or removal of barriers.

Summary

Although the programme is on-going (as of February 2014), the desktop survey identified 192 Environment Canterbury managed flood protection structures in Canterbury. From November 2010 through to February 2014, in-situ assessments have been conducted at 856 public road crossing sites across four water management zones covering the Waimakariri, Selwyn, Waihora, Opihi / Orari and Wainono catchments. Of the 856 visited, 112 were categorised as candidate barriers to fish passage. In order to "ground-truth" these candidate barriers, intensive fish surveys upstream and downstream of the barrier are planned for the summer of 2013 / 14. From these surveys, barrier sites will be prioritised for modification and / or removal.

3.3. Latest Research in Fish Passage Restoration and Management

3.3.1. Being baffled at barriers

CINDY BAKER & PAUL FRANKLIN NIWA

Background

Many of the migratory fish species in New Zealand appear to be declining in both abundance and distribution across their ranges (Allibone *et al.* 2010). Habitat loss from low-head migration barriers, such as culverts and weirs, has been recognised as one of the key drivers of migratory fish species decline. As such, remediation of migration barriers to restore longitudinal habitat connectivity and to re-establish fish populations is an integral component of river restoration.

Most conventional fish passes are designed to accommodate species with strong swimming abilities, such as adult salmonids. To date, few fish passes have been designed to target amphidromous or catadromous fish species. These species undertake extensive upstream migrations during their juvenile life-stages and therefore do not possess the strong swimming and jumping abilities of adult salmonids.

Baker and Boubée (2006) evaluated 15° and 30° fish ramps, with different baffled substrates, as a means for increasing the passage success of inanga (*Galaxias maculatus*) and redfin bullies (*Gobiomorphus huttoni*) over low-head obstacles. Key design features of the ramp passes were: a) the presence of a wetted margin for successful passage of fish capable of climbing obstacles (e.g., redfin bullies); and b) a low velocity margin for successful passage of swimming fish species unable to climb. For all substrates tested, passage success for both species declined with increasing ramp slope. A baffled drainage product, Miradrain®, allowed the greatest passage success for both species.

Utilising the Miradrain® substrate, current NIWA research is evaluating the effects of altering ramp design and hydraulic conditions on native and exotic fish passage.

Targeted design of fish passes

The effectiveness of any fish pass is dependent on a wide variety of factors such as physical design, slope, length, water depth, and hydraulic conditions at the entrance. The relative contribution of each factor is difficult to differentiate, but the interaction of slope and length are important design considerations when developing appropriate passage structures for low-head obstacles.

Baker (2014) investigated the effect of increasing ramp length (3, 4.5 & 6 m) on native fish passage over a Miradrain® ramp with 15° and 30° gradients. As slope and ramp length increased, passage success decreased for inanga and common bullies (*Gobiomorphus cotidianus*). However, passage success of redfin bullies, a species capable of climbing the wetted margin of the ramps, was reduced by increased ramp slope, but was not influenced by increasing ramp length up to the maximum tested. Based on the swimming abilities of inanga (Boubée *et al.* 1999) and common bullies (Mitchell 1989), higher passage success than 64% and 14%, respectively, over the 15° ramp was expected. It was speculated that the low passage rates may have reflected behavioural and motivational factors rather than physiological abilities. Thus understanding the hydraulic features fish seek during migration is an important consideration in designing effective fish passes.

On-going research

In order to effectively accommodate the different climbing and swimming behaviours of fish species, 15° and 30° Miradrain® ramps based on a modified 'V' notch crump weir are currently being evaluated for native and exotic fish passage (inanga, redfin bullies, common bullies, rainbow trout (*Oncorhynchus mykiss*), rudd (*Scardinius* *erythropthalmus*), koi carp (*Cyprinus carpio*), perch (*Perca fluviatilis*) and gambusia (*Gambusia affinis*)). Ramp weirs have a maximum head differential of 1 m and length of <3 m. As hydraulic conditions have been shown to influence behavioural and physiological performances of fish, their passage at both high and low flows is being investigated.

Although studies are on-going, initial findings have shown that with a 15° gradient, juvenile and adult inanga passage increased with increased water flow. The opposite effect was seen with juvenile trout. No effect of flow was seen on the passage success of trout or inanga with a 30° gradient. Redfin bully passage was unaffected by flow on either ramp. These results highlight the importance of understanding the hydraulic conditions driving upstream movement of the target species to ensure high passage success at fishways. Further, initial results suggest that manipulating design features and hydraulic conditions could enhance native fish passage whilst decreasing passage of exotic / pest fish species. Therefore, further research into the hydraulic characteristics that depress and promote passage of target fish species at fishways is necessary.

Selective barriers

Presently, there are few mitigation tools to manage the spread of invasive fish species. Controlling invasive fish populations is currently limited to preventing their spread, focusing largely on physical removal or piscicides. Development of an in-stream structure that will allow passage of both swimming and climbing native fish species, but restrict invasive fish movement could provide an innovative but cost-effective solution to reducing and controlling the spread of undesirable fish species. Future research hopes to exploit the unique capabilities of many of our native fish species to utilise specific hydraulic conditions that could minimise larger bodied and less agile invasive species.

Summary

- Baffled ramps offer a cost-effective solution for re-establishing fish communities upstream of low head obstacles. The key design features are the presence of smooth wetted margins to facilitate passage of climbing fish species, and low velocity water necessary for swimming fish passage.
- Fish seek specific cues from flow and water velocity gradients. Therefore, understanding the physiological abilities and hydraulic conditions driving upstream movement of the target species is essential in ensuring high passage success at fishways. However, this is currently a significant knowledge gap.
- Future research hopes to exploit unique features of the swimming and climbing behaviours of native fish to create passes which enhance native fish passage but minimise exotic fish passage.

3.3.2 Utility of mussel spat ropes for improving passage past culverts – summary to date and future development

BRUNO DAVID Waikato Regional Council

Background

Culvert pipes are regularly used around the world for conveying stream flows underground, through embankments or under road crossings. Installation of these features can have significant negative effects on the passage of freshwater biota and potentially exclude many species from large areas of river networks. We investigated the installation of mussel spat ropes as a potentially rapid and cost effective tool for improving passage of freshwater biota through perched and narrow, difficult to access culvert pipes where internal barrel conditions impeded passage. This talk covered two primary aspects for rope use:

1. Their potential for improving access for 'climbing' fish species past perched culverts – this was demonstrated through initial laboratory trials with banded kokopu and then via a before after control treatment experiment where use of this tool was examined in two high energy Coromandel streams; and
2. Their use for enabling passage of 'non-climbing' aquatic species through long culverts posing a hydraulic barrier – this aspect was demonstrated through another laboratory trial where aspects of water velocity, barrel gradient and length were specifically investigated for two fish and one shrimp species.

Perched culverts

Laboratory experiments with banded kokopu (*Galaxias fasciatus*) demonstrated that this fish was easily capable of negotiating 0.5 m perched culverts by climbing vertically up the ropes (David *et al.* 2009). In the field investigation, ropes were fitted to a 2.4 m high perched culvert and results indicated a significant improvement in passage success for young of the year banded kokopu relative to a nearby control stream but no change for redfin bullies (*Gobiomorphus huttoni*) and inconclusive results for longfin (*Anguilla dieffenbachii*) and shortfin eels (*Anguilla australis*) which were naturally uncommon in both streams (David & Hamer 2012). It was concluded that use of this tool for addressing passage past significantly perched culverts should only be used where species with excellent climbing abilities would be expected to occur upstream.

Long culverts posing a hydraulic barrier

We assessed passage success for two fish species, juvenile rainbow trout (*Oncorhynchus mykiss*) and adult inanga (*Galaxias maculatus*), and one migratory shrimp (*Paratya curvirostris*) through culverts of differing length (3 and 6 m), slope (1.5 and 3°) and flow (0.24 and 0.75 $L\ s^{-1}$). We hypothesized that ropes would enhance the passage success of these three species but success rates would differ between species and trial combinations.

Ropes resulted in reduced water velocity within culvert barrels and significantly improved passage success for all three species. Shrimp benefited most by the presence of ropes, being unable to negotiate any of the pipe combinations in their absence, but exhibiting varying rates of success across all combinations with their presence. Both inanga and rainbow trout were able to negotiate some of the non-roped pipe combinations, but as the level of difficulty increased, successful passage was only achieved with ropes present (David *et al.* 2014).

Summary

We conclude that this relatively inexpensive and easy to install tool has potential to substantially improve passage for a range of aquatic biota through various culvert scenarios. We consider that this tool would be particularly useful in situations where internal culvert access is difficult and where various culvert parameters (slope, flow, length) result in internal barrel hydraulics that would normally limit or exclude passage of aquatic biota.

3.3.3 Swimming against the tide gates

PAUL FRANKLIN NIWA

Background

Flood and tide gates are widely used throughout the world to allow drainage of lowland areas, whilst still providing protection to valuable agricultural land and infrastructure. However, these gates can also act as barriers to migratory fish species and influence the physical, chemical and biological character of upstream habitats.

The infrastructure associated with extensive land drainage in many lowland areas of New Zealand has potentially limited fish access to many kilometres of productive freshwater habitats. In the lower catchment of the Waikato River, for example, approximately 1900 km or 20% the total length of rivers and streams, are located upstream of flood or tide gates.

New Zealand's native fish fauna is characterised by a relatively high proportion of diadromous species (McDowall 1990), meaning that fish community structure is sensitive to the presence of migration barriers such as flood and tide gates. The proliferation of anthropogenic barriers over the last 50 years is therefore likely to have had a significant effect on the distribution of diadromous fish populations, as well as community structure and functioning in some rivers and streams. As the desire to restore waterways and preserve native flora and fauna increases, there is a need for improved understanding of how flood and tide gates impact fish communities and how their effects can be mitigated.

How do tide gates affect fish?

Closed tide gates are a physical barrier to the upstream and downstream movement of fish. This can prevent fish from reaching habitats critical to the successful completion of their life cycle. As a consequence, both the abundance and diversity of fish species in a community may be altered through limitations on recruitment success.

Tide gates also have a significant influence on the physical stream environment. This can include the reduction or loss of tidal water level fluctuations in upstream habitats, and the alteration of water chemistry e.g., reduced salinity, and changes in water depth, velocity and substrate. These modifications of instream habitats can change the suitability of the habitat for different aquatic species.

There has been relatively little research or monitoring of the effects of tide gates on the migration of native fish species in New Zealand. Doehring *et al.* (2011) demonstrated that the number of fish passing a gated culvert in the Motueka estuary was 75% lower than for an ungated culvert, but that some fish were still able to pass at low tide. Franklin and Hodges (2012) also showed that some fish were able to pass into a tide gated tributary of the Waihou River, however, the presence of the tide gates significantly modified the physico-chemical characteristics of the instream habitat in the low gradient reaches immediately upstream of the tide gates. These conditions were sub-optimal for native species typical of lowland reaches such as inanga (*Galaxias maculatus*), but favoured more tolerant introduced species such as tench (*Tinca tinca*) and catfish (*Ameriurus nebulosus*).

Restoration options

The best solution for restoring fish passage at tide gates is their complete removal. However, there is a need to balance the potential biodiversity gains with the requirements to protect land and property from flooding. This means that removal may not always be an option. An alternative is to leave the gates open for as long as possible to maximise the opportunity for fish to pass the structure and to reduce the impact on upstream habitats. Franklin and Hodges (2012) investigated the short-term effects on instream habitat of leaving a tide gate partially open. The consequence was reintroduction of tidal fluctuations upstream of the gates and improvements in dissolved oxygen and water temperature. In the long-term it was expected that this would benefit native fish communities by increasing the suitability of instream habitats and enhancing fish passage. Other restoration options include alternative tide gate designs including side-hung gates and 'fish friendly' tide gates.

Research needs

There is a significant research gap around the impact of tide gates on native fish communities. There is a need to improve understanding of how different gate types / configurations impact fish passage and instream habitat conditions, and what characteristics of these structures have greatest influence on fish passage and habitat. There is also a need to understand how we can design effective retrofit solutions and improve current management practices. All of this requires better understanding of fish life-cycles, behaviour, physiology and habitat requirements.

Summary

- Tide gates are a physical barrier to migrating fish, and modify instream habitat altering its suitability for different fish species.
- There is a need for improved understanding of how flood and tide gates impact on fish communities and how their effects can be mitigated.
- Better understanding of fish life-cycles, behaviour, physiology and habitat requirements are needed to inform the design of tide gates and restoration efforts.
- The best solution is to not have tide gates, or at least leave them open as long as possible.

3.3.4 New Engineering Ideas: "Fish passage design & development"

KELLY HUGHES ATS Environmental

Background

There are a large variety of structures in various waterways affecting the migration of native fish. Each species has different capabilities with respect to the physical challenges they may face trying to enter and pass on, through, or over structures.

Ongoing development of low-cost solutions to improve fish passage at structures is needed.

Summary

There are many practical challenges to remediating fish passage at some structures, for example culverts that are too small to physically work within. To address these challenges some novel engineering solutions are being developed.

Current development is focussing on:

- Targeting longer ramps and culverts that are too small to work in i.e., <900 mm diameter;
- Swimming species up ramps;
- Vertical culverts;
- Fish lifts at pump stations.

Engineering solutions have been developed (e.g., Figure 5) using the following considerations:

- Functionality for fish;
- Function of the structure;
- Material cost;
- Installation e.g., cost / skill set required;
- Life expectancy;
- Aesthetics;
- Carbon footprint e.g., recycled materials.

In some cases the idea is to take advantage of the engineering elements of the existing structure by fixing modules to the concrete aprons to thereby divert water or create resting pools. Field tests of these novel solutions are needed.

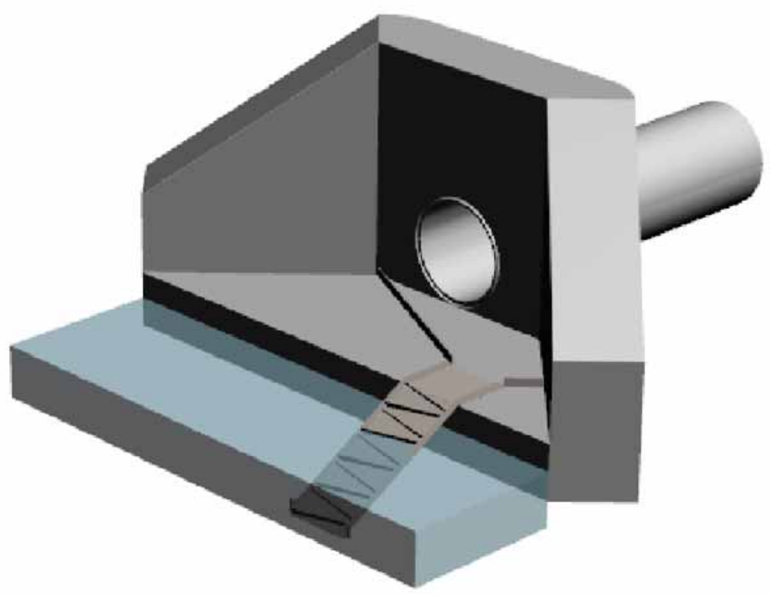

FIGURE 5: Example of a fish passage remediation option

3.4 Sharing Experience

3.4.1 Integrating science and practical solutions for enhancing river connectivity

PAUL FRANKLIN & CINDY BAKER NIWA

Background

Apart from the degradation of adult habitats, one of the most significant causes of the decline in freshwater fish populations in New Zealand is the construction of instream structures such as culverts, weirs and tide gates that prevent migratory fish from accessing critical upstream habitats. Consequently, there is a requirement to ensure these structures are designed and installed in a way to avoid impeding fish migrations. Understanding fish life cycles and behaviours, and their habitat requirements are essential to achieving this goal.

Understanding the fish

Many of New Zealand's iconic fish species, such as eels and whitebait, undertake significant migrations between the sea and freshwater as part of their life cycle. It is important to understand when these migrations occur, where they occur and what habitat fish are trying to move from and to, so that these pathways remain unimpeded. It is also necessary to understand how different fish move (swimmers v. climbers) and their behaviour when faced with different conditions to ensure that instream structures are designed and installed to meet these capabilities.

Many of New Zealand's fish species undertake their main upriver migrations as juveniles, meaning that they are relatively small and weak. They therefore require different solutions to those widely tried and tested for the stronger swimming Northern Hemisphere species, such as salmon and trout, which migrate upriver as adults. A range of scientific studies have been carried out to support the design of instream structures suitable for passing New Zealand fish species.

Baker (2003) investigated the effects of fall height and weir notch shape on the passage of inanga (*Galaxias maculatus*) and common bullies (*Gobiomorphus cotidianus*). It was demonstrated that adult inanga were unable to pass fall heights of >20 cm and that juvenile inanga and common bullies failed to pass fall heights of >10 cm. A v-shaped notch provided the greatest passage success for both species.

Baker and Boubée (2006) evaluated the effect of ramp slope and substrate on passage success of inanga and redfin bullies (*Gobiomorphus huttoni*). Passage success declined for both species with increasing ramp slope for all substrates tested. A baffled drainage product, Miradrain®, allowed greatest passage success for both species.

Baker (2014) showed that increasing slope and length of a ramp baffled with Miradrain® reduced passage success for inanga and common bullies. However, passage success of redfin bullies, a species capable of climbing, was reduced by increasing ramp slope, but not by ramp length up to the maximum tested (6 m).

David *et al.* (2014) demonstrated that the installation of mussel spat ropes inside culverts can reduce water velocities and enhance the passage of juvenile rainbow trout (*Oncorhynchus mykiss*), inanga and shrimp (*Paratya curvirostris*) through culverts.

Transferring the science to practical solutions

A critical step for enhancing management of fish migration barriers is the transfer of scientific knowledge into practical solutions. There are relatively few well documented examples of where this has been undertaken in New Zealand. However, David and Hamer (2012) demonstrated that mussel spat ropes installed at a perched culvert increased the upstream passage of banded kokopu (*Galaxias fasciatus*), but not elvers (*Anguilla sp.*) or redfin bullies. Franklin and Bartels (2012) also showed that retrofitting a perched culvert, with a rock ramp and baffling inside the culvert barrel, increased fish abundance and diversity upstream of the culvert, by allowing passage of smelt (*Retropinna retropinna*), inanga and common bullies.

There are also, however, many examples where the science and engineering have been poorly integrated resulting in ineffective solutions being installed. A range of examples were demonstrated from around New Zealand. There are also a range of innovative and cost-effective solutions being developed and implemented, but with little monitoring or testing to ensure that they meet best practice guidelines such as those provided by Stevenson and Baker (2009).

Research needs

There is a clear need for better understanding of fish behaviour, physiology and habitat requirements to inform the design of instream structures in New Zealand. In particular, there is an absence of information about how fish behave at obstructions and their response to turbulence and other hydraulic characteristics. This requires better integration between the ecological and engineering disciplines.

The relative capabilities of native versus exotic fish species is also a valuable area of research. The spread of exotic species can impact negatively on aquatic ecosystems and native fish communities. Developing structures that allow passage of native species, but prevent the spread of undesirable species would therefore be beneficial.

Studies to evaluate the effectiveness of new solutions are required prior to field installation. Significant investment is often required to implement retrofit options and therefore it is important to ensure that solutions are likely to be effective in restoring passage for the target fish species.

In all cases, even when best practice guidelines are followed, it is important to adopt a maintenance and monitoring programme to ensure the structure or channel is operating as designed and continues to do so.
The recommended approach to monitoring would be to utilise a before-after-control-impact (BACI) survey design, whereby surveys are undertaken both before and after remediation is carried out (ideally at the same time of year), both downstream (control) and upstream (impact) of the structure.

Summary

Poorly designed and installed instream structures can have a significant impact on aquatic communities.
The most effective solution to this problem is to avoid installation of structures in waterways that are a barrier to fish movements. This can be accomplished by understanding the fish and ensuring that the design of structures and retrofits are informed by science and meet best practice guidelines. To achieve this goal it is critical that ecologists and engineers work together.

3.4.2 Lessons from remediation of fish migration barriers in the Tasman region

TREVOR JAMES Tasman District Council (TDC)

Background

Tasman District Council has learnt the following lessons through undertaking remediation:

- Keeping costs low:
  - Using summer students
  - Concentrated restoration campaigns
  - Using low or no-cost materials;
- Teamwork with roading & stormwater engineers;
- Getting budget set aside;
- Having a good database (including links to photo archive);
- Important to identify and manage for occupational health and safety considerations including:
  - **Flash floods** – Stop work in heavy rain or rising water levels.
  - **Falling down a steep bank** – Care at all times. Use ropes where necessary.
  - **Slipping in a stream or in culverts due to slimy growth** – Use footwear with good grip and take care when entering and exiting culverts.
  - **Traffic hazards** – Wear high viz, put hazard lights at key locations and take care crossing roads.
  - **Electrocution** (from using electric drills) – Use certified leads, prevent damage, ensure leads and generators are secured away from water, and wear rubber boots or waders.
  - **Cuts** – Ensure straps are well secured before drilling into them.
  - **Toxic vapour from generator or glue** – Place in the open air, not in a confined space.

Key tips for efficiency

- 'Campaigns' of several days or a week to undertake remediation are most efficient overall. Using Kelly Hughes in these campaigns alongside staff achieved a lot, as Council staff did not always have the tools or practical experience of remediation.
- Complete all the more simple remediation work (i.e., those that can be completed within an hour or two) within a catchment in the one go. Detailed prioritisation on a structure by structure basis (using variables like habitat quantity and quality) is best saved for those needing a more expensive fix.
- Try and keep it simple. Avoid needing diggers and trucks of rock where possible, use materials that can be handled by 2 persons and take cordless power tools.
- Staying overnight on campaigns to reduce travel time and efficient operation work.

Useful remediation materials

- Conveyor belts: wood processing plants, quarries;
- Mussel spat ropes: Big waste product from farms in the Marlborough Sounds;
- Stainless fixings (all 316): Fixings from Blacks or Anzor. Mushroom spikes;
- Sealant to reduce potential for corrosion of culvert reinforcing.
- For concrete – used mooring chain & fibreglass reinforcing (e.g.www.forta-ferro.com).

When building concrete ramps, Tasman District Council found a number of issues including:

- Cement is very toxic to fish.
- Fine sediment causes adverse effects.
- Flow on the surface, not into a rock sieve.
- Pay particular attention to the foundation and top & bottom ends.
- Use geotextile and reinforce so it lasts.

To mitigate these issues it is important to always undertake work in the dry and ensure fish recovery of dried reaches is undertaken. Installing a larger pipe or bridge is always best where achievable.

When installing new culverts the following design criteria should be used where possible:

- Wider than stream.
- Climbing medium should be installed to create a rough and continuous wetted margin.
- Water velocity (0.3 m s^{-1}).
- Shallow water (500 mm for larger native fish).
- Culvert floor is below stream bed level.
- Resting eddies / pools in the culvert floor.
- Erosion protection (particularly at outlet).
- Not too long (<100x wetted width).
- For box culverts: provide a deeper, low flow channel.

An example of a more complex remediation is shown in Figure 6.

FIGURE 6: This weir was constructed with large boulders in a medium-size river (annual flood flow of 180 cumecs). This structure was found to be a barrier to common smelt and inanga. Several thousand common smelt were recorded below the weir but only three were ever found upstream. The highly turbulent flow between the boulders appeared to be the cause of the restriction to these fish. The first option used was to pack 20–50 mm crushed rock material between the boulder but that got reamed out by floods. After this it was felt that concrete was the only option (given that the basic structure had to stay). The photo is of the weir with a lower gradient (zig-zag) concreted ramp installed. In building the ramp 4 m3 of 'manhandlable' angular rock was slotted in all the larger voids and 4 m3 of 30 MPa 8 mm block fill concrete was used to build the ramp. We are yet to do a fish survey to confirm that this rock ramp has been successful at providing fish passage.

3.4.3 Lessons from remediation of fish migration barriers in the Horizons (Manawatu-Whanganui) Region

LOGAN BROWN Horizons

Background

Identification of fish barriers and attempts to remedy them though non-regulatory and regulatory measures has been on Horizons Regional Councils radar since 2008. The focus over the last two years has moved from identifying these barriers to remediation of them. The information below provides a very brief outline of the work to date.

Identifying the problem

Initial survey work was undertaken by Massey University via an Envirolink funded project to find barriers on roading networks within the Upper Manawatu catchment and provide recommendations to Horizons on the priority for fixes (James & Joy 2008). The focus has changed in recent years with work being undertaken in-house and the focus being on walking entire streams (finishing at DOC boundaries) to find barriers present throughout catchments. Catchments with high native fish biodiversity values have been the first to be sampled.

Prioritising the barriers and their fixes

Using the data collected, a decision tree (Figure 7) was used to determine which barriers had highest priority for remediation.

The carrot and stick approach to fixes

The Horizons One Plan and its predecessors required that instream structures must allow for fish passage if they were to be a permitted activity, otherwise a resource consent was required (in addition to permission required by DOC under the Freshwater Fisheries Regulations 1983).

In the Manawatu catchment, funding through the Manawatu Clean up fund is allowing co-funding of some remediation works. Outside of the Manawatu catchment, subsidies from Horizons can be made depending on the value of the waterway. These subsidies do not always involve monetary payments to the project, but may involve staff hours designing the fix, organising contractors, or reduced consent fees (if one is required). This allows us to both require fixes of fish barriers, and to supply an incentive of partial funding.

What we found

Stream walking has resulted in a number of barriers being found, including all of the normal suspects, i.e., perched and undersized culverts, weirs, etc. Structures were found to be owned by a number of parties.

Early attempts

Through this programme Horizons Regional Council have had some successes and learnt some useful lessons. For example:

- In some situations the structure causing the issue is no longer required for any purpose. Consequently, in consultation with the structure owner, removal was identified as the most cost effective and successful solution.
- It is really important to match the solution to the instream conditions. Take into consideration large flood events and whether a certain fix will be able to withstand the elements.

New approach

This year will see the construction of 8 fish passes in the region (6 in the Manawatu and 2 in the Whanganui catchments). This work is being undertaken with landowners, district councils, NZTA and Horizons, and involves remediation of culverts by placing fish passes on them with the fish pass design being based on the species expected to be found upstream of the barrier.

Baseline monitoring

To date no monitoring has been undertaken of the fish passage solutions that have been trialled. However, as part of the work being undertaken this year a number of remediation sites are to have pre- and post-survey work completed. The exact format of this monitoring is still to be finalised.

Summary

Horizons Regional Council is actively involved in the identification of fish barriers and prioritizing those for remedial action. Mechanisms for remediation have been both non-regulatory and regulatory with both methods involving all parties working closely together. A number of remediation options have been trialled in the region and it has become clear that when choosing appropriate solutions, careful consideration must be given to the environment in which they are to be placed to ensure that they endure.

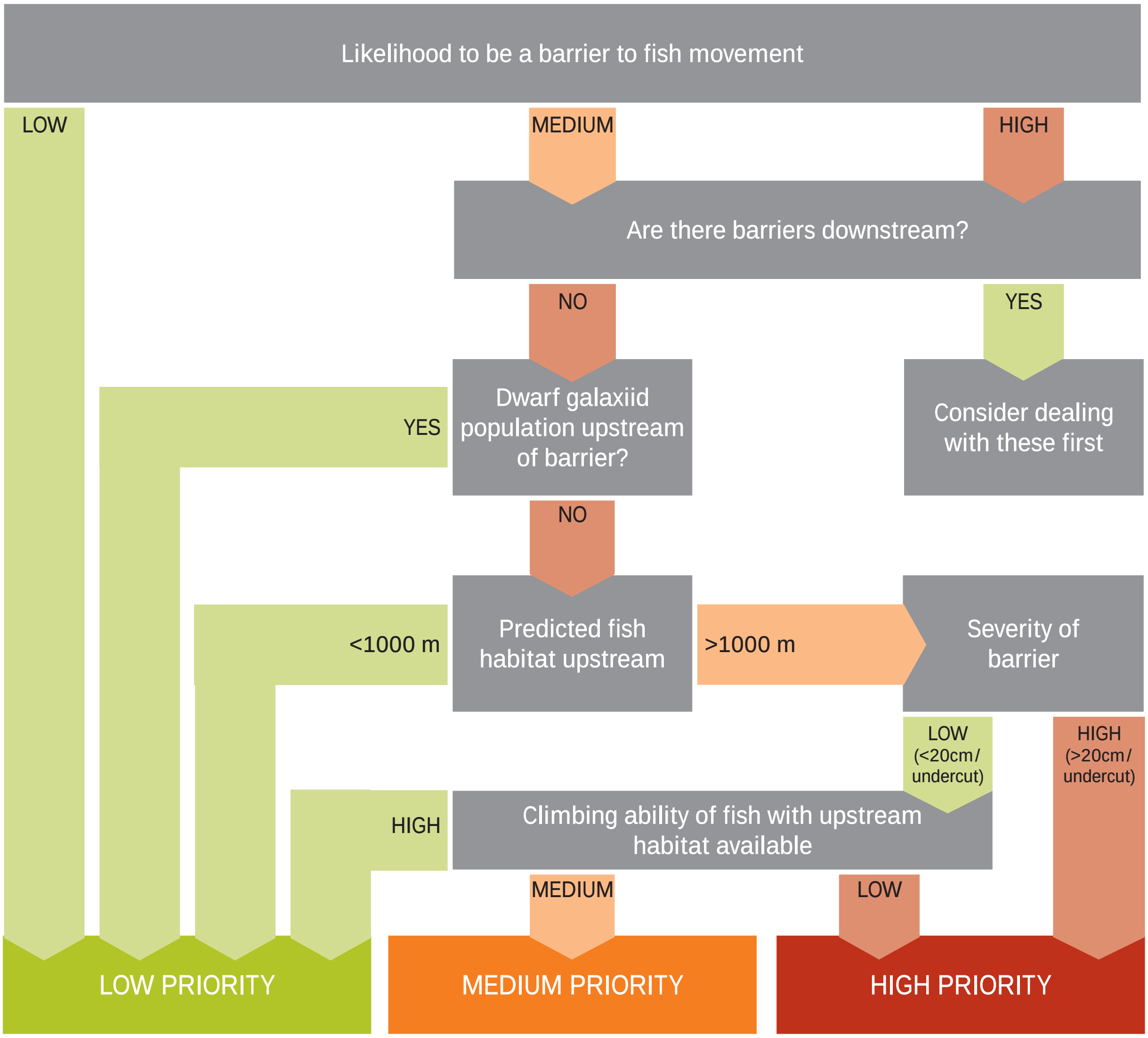

FIGURE 7: Decision tree used by Horizons Regional Council to determine which barriers had highest priority for remediation. Revised from James and Joy (2008).

3.4.4 Lessons from remediation of fish migration barriers in the Auckland region

MATT BLOXHAM Auckland Council

Background

Streams of the Auckland isthmus are typically short, small streams that climb steeply from the coast and contain limited low elevation habitat. These streams are dominated by migratory fish species. However, Auckland shares the national phenomenon of having many poorly configured culvert crossings resulting in catchment-scale impacts on stream ecology. North Shore City Council began investigating culverts for fish passage protection a number of years ago, prior to the amalgamation of its boundaries with the remainder of the Auckland Region.

Quantifying the size of the fish barrier problem in Auckland

As a way of quantifying the size and extent of the fish barrier problem in Auckland, stream walks were conducted in major North Shore streams and an inventory complied on all instream modifications including culverts. After amalgamation, fish passage survey work was extended to the Rodney District, and Great Barrier and Waiheke Islands. Auckland Council have thus far surveyed and identified around 360 manmade fish barriers in the Auckland region, and culverts have been recorded as the single most common fish passage barrier type.

However, substantially less than half of all urban streams have been surveyed (pers. comm. Tom Mansell) in Auckland's metropolitan area. There is estimated to be around 700 existing barriers in Auckland's built environment alone.

If the cost to mitigate each barrier (the majority of which are culverts) is averaged across the region (at around $2,500 per culvert), that amounts to a cost to Council (to Auckland rate payers) of $1,750,000, just to rehabilitate existing barriers in Auckland's built environment and on some of its islands. With this in mind it is critical to ensure any new structures are installed correctly to allow for fish passage.

Planning considerations

The costing above does not take into account:

- The nearly ten kilometres of stream lost annually to consented stream piping / infilling. Infill piping, where remaining open stream between piped lengths are progressively in filled, can create unavoidably long culverts that are unable to be scaled by fish.
- The presently incalculable stream length lost to culvert crossings covered by permitted activity rules.

Only with further stream walks will the full extent of Auckland's fish passage problem be revealed. Barriers able to be investigated are typically those that traverse public land or those administered by roading agencies including the NZTA and Auckland Transport. Culvert fish barriers on private land are less easily quantified because there is little recourse for Council to ensure new culverts are sized appropriately or installed properly in rural areas (as required in Resource Consent conditions).

This is unlikely to change with the launch of the Unitary Plan as, while it contains more stringent rules relating to the piping of streams, such as for reclamations, it again classifies culverts used for crossings as a permitted activity. There is general agreement that the problem of defective rural culverts is widespread, but treating culvert crossings as a permitted activity, and one not requiring council notification, makes deriving absolute numbers of barriers problematic. It also limits opportunities for remediating existing or future culverts on rural properties.

Installation of new culverts

It is far more effective, from a fish passage performance standpoint, installing culverts correctly in the first place than rehabilitating culverts to provide for fish passage retrospectively. There are a range of performance standards needing to be satisfied, but generally using an oversize culvert (relative to the active stream channel) from the outset and installing it so a minimum of 20%

of the culvert's diameter is sunk into the stream bed (throughout its entire length) will provide for fish passage and help limit erosion and flooding. Burying the culvert also allows natural bed material to accumulate in the base (invert) of the culvert and this improves fish passage conditions.

Fish passage remediation at existing culverts

Auckland Council began prioritising fish passage management with the low hanging fruit and easy wins. For example:

- Where culverts traverse, reserves or parkland;
- Council owned, redundant, or outmoded structures;
- Where roading is associated with island roading networks – Waiheke and Great Barrier Island.

With Great Barrier Island, for example, there was a reasonable expectation that few barriers exist upstream of the roading network. The Island's overall steepness also means that roading often tracks close to the coast. This creates constraints where stream crossings associated with roading don't provide for fish passage, but it also creates opportunities because the roading network is not extensive and the hinterland beyond transitions fairly quickly from pasture into bush. A survey of the Island was completed in 2012. The Great Barrier Island survey revealed that 24 out of 71 culverts (34%) assessed formed partial or complete fish passage barriers. Their remediation will regain just less than 40 km of upstream habitat.

Auckland Council fish passage survey requires completion of a standard Auckland Council evaluation sheet for fish passage. Our main areas of interest include culvert perch height, flow and streambed attributes. Remediation approaches are decided on by surveyors at the time of the culvert investigation. As well as expediting the process, this gives contractors certainty over resourcing requirements. There is flexibility on technical design details, but also an expectation that a basic approach will be adhered to. For example, where a barrier required remediation for non-climbing species (as well as for climbers) and sufficient upstream habitat exists for non-climbing fauna, a fish ladder or a tailwater control, which lifts downstream water levels to reduce the perch height allowing swimming access, is always the stated goal. Which of the two are adopted generally depends on the downstream gradient. Where the streambed below the perched outlet is generally flat, a tailwater control is usually chosen because it provides room for incrementally building up the water level, it also serves the double function of creating an impoundment through the floor of the culvert thus reducing water velocities. If however the gradient is too steep, or the downstream section too short to accept a series of tailwater controls (effectively small check dams), a fish ladder is generally chosen.

Culvert remediation approaches are generally less expensive and more easily implemented where climbing access is all that is required. For example, a case may be made for installing mussel spat rope or other climbing surfaces to help upstream migrants exploit the last 200 metres of a stream as the cost is relatively small. However, for a fish ladder to be installed, there needs to be reasonable certainty that upstream habitat is both extensive and accessible to the widest range of species, both climbing and non-climbing species. Fitting spat rope as the only solution for culverts will lead to non-climbers being compromised in some systems. Current thinking is that one will generally create passage for a wider variety of climbing species if the spat rope remains in contact with a backing surface (i.e., so that it is not free hanging and climbing species can insert themselves between the rope and backing surface). This may be achieved by using rope and rubber sheets in combination to overcome a culvert perch.

In using spat rope there is certainty regarding cost. However, fish passes and baffles available take radically different approaches and costs differ also. Nationally we need proper design standards so projects can be tendered competitively. Auckland Council, currently spends $80,000 annually on fish passage remediation and could potentially spend more, but not without greater design certainty and standardised approaches. Councils are more likely to commit budget if the 'solution' can be tendered competitively and fairly.

3.4.5 Lessons from remediation of fish migration barriers in the Waikato region

BRUNO DAVID Waikato Regional Council

Background

This presentation covered general current issues regarding fish passage in the Waikato Region. Topics discussed included: management of fish passage structures with respect to native and invasive fish access in lowland areas; installation of culverts as part of consenting processes including mitigation offset options and appropriate monitoring requirements; compliance with permitted activity rules; and issues and possible solutions to ensure compliance of structures over time. Another key issue discussed was the general paucity of knowledge regarding the actual impacts of various structures on native fish passage.

Summary

- Invasive fish may be an important consideration when assessing structures to promote or limit fish access. A sound understanding of key migration times and fish size and behaviour is required (in a local context) to maximise benefits for native species while limiting access to invasive species, e.g., ongoing research at Lake Waikare fish pass.
- There is still a paucity of knowledge regarding the effectiveness of different fish passage options, particularly for supporting upstream fish communities.
- Appropriate mitigation and monitoring targets / conditions should be part of any Resource consent but would be assisted through some standardisation, rather than regional inconsistency.
- It is important to recognise that incremental loss of the river network occurs when uniform inert structures (e.g., pipes) are placed on river beds. These features may not only create a barrier, but can also result in a loss of previously productive river bed. Consideration should be given to offsetting this loss by ensuring that habitat loss (in addition to passage) is also addressed.
- National standardisation of effort and methods for monitoring would enable more robust and effective assessment of structures and their relative effects on fish communities. With sufficient information of this type it may then be possible to more effectively treat similar structures elsewhere, possibly without the need for intense monitoring.
- Structures can change (physically) over time so repeated monitoring and reporting should be considered to ensure long-term performance of structures for passage, e.g., 5 year assessment (especially for permitted structures in high risk areas and high value sites).
- Confirming passage through the structure may in itself not be sufficient to confirm the effectiveness of a structure. For important sites it may be necessary to evaluate persistence of upstream fish communities as the main focus of monitoring.
- Involving engineers early in process / pathway to build relationships and allowing for greater information transfer prior to consents being lodged would be a more effective strategy for improving passage efficacy regionally, e.g., the Te Awa O Katapaki River Road culvert replacement project.

3.4.6 Getting the job done: Practical, cost effective solutions to restoring river connectivity

KELLY HUGHES ATS Environmental Ltd

Background

Fish passage can be restricted by physical elements such as closed tide gates and perched culverts. High water velocity, smooth surfaces and shallow water can also inhibit passage. A variety of methods have been developed to improve fish passage through tide gates and culverts over the past few years, including fish-friendly flood gates, culvert ramps and baffles, mussel spat ropes and downstream landscaping.

Summary

The materials used include rubber, stainless steel and recycled mussel spat rope. The focus is on keeping both the material and installation costs to a minimum while delivering effective mitigation. The solutions covered generally require only basic skills and standard equipment (e.g., D-ring and clasp, mushroom spikes and spat rope) without the need to stop or divert flows during installation. An important consideration in any installation is the health and safety requirements.

3.4.7 Fish passage guidance for state highways – an overview

CRAIG REDMOND
New Zealand Transport Agency (NZTA)

Background

In 2008 / 2009, the NZ Transport Agency (NZTA) enlisted Opus International Consultants (Opus) to assist in responding to the Waikato Regional Council (WRC) legislative requirements with respect to the retrofitting of existing culverts for fish passage in the most cost effective and practical manner.

A number of techniques to retrofit structures to provide for fish passage were formulated with the WRC. Rope, ramp and altering the downstream habitat to remove barriers to fish passage were used at five different sites on SH25 in the Coromandel Region. The sites were selected due to their habitat quality upstream, the degree of the obstacle for fish passage and the practicality of a retrofit. The Opus report *Culvert retrofit – fish passage East Waikato network* (Eastham 2009) provides more detail regarding the site selection and constructed works.

One of the recommendations from Eastham (2009) was that “on-going monitoring of these sites is undertaken over the next 12 months by Opus Consultants, consisting of a visual evaluation once every six months. This would ideally be followed by a similar interval of inspection by NZTA as the owner of these structures. This will provide an excellent base from which to assess the success and robustness of these cost effective designs for future retrofitting work”.

The NZTA Environment and Urban Design Team inspected four of the five sites on 22 December 2009 and 16 September 2013. The Kuaotuna Stream was not located on either site visit, and therefore not inspected.

A comparison of the physical condition of the retrofit works between the two site inspections on 22 December 2009 and 16 September 2013 is described.

Culvert retrofit assessment

The Waipapa Stream, Petote Stream, Kaitemako Stream and Waitekuri Stream fish passage retrofits where the streams dissect SH25 were inspected on 22 December 2009 and on 16 September 2013 to assess the physical condition of the retrofit solutions.

The original works on the Waipapa Stream involved installing gabion baskets filled with stone at the base of the culvert outlet, sloping from the end of the pool up to the culvert outlet. The design aimed to maintain flow from the culvert to the stream without a perch in all tidal conditions. The concrete lining the left hand side of the bank has been scoured out. This is causing a new flow path off the side of the gabion baskets which has the potential to establish a perch and further stream bank erosion. The gabions are still in good condition showing little to no sign of deterioration.

The original works at Petote Stream involved building a ramp, from the culvert outfall concrete apron down to the stream bed, removing the perch and allowing passage for all fish species. Latest observations saw that the toe of the ramp has been damaged resulting in a small perch, so fish passage remediation is not fully effective at this site to date.

The original works at Kaitemako Stream involved the installation of mussel spat rope instead of a ramp, due to the steep nature of the catchment upstream likely to only support climbing species of fish, and the historical damage caused by forestry debris at this culvert location in high rainfall events. The rope at the culvert outfall has snapped or been dislodged and has been washed downstream of the culvert. The rope is still clearly visible just downstream of the outfall as it has been tangled amongst branches and other material in the streambed. At the culvert inlet, the rope is still looped around the two culverts, which indicates the rope has snapped inside the culverts.

The original works in the Waitekuri Stream involved the construction of a ramp to assist climbing species in accessing habitat above the culvert, as they had previously been found to exist below the culvert, but not above. The ramp was designed to overcome the perch at the end of the apron and the culvert. The ramp is in the same good condition as it was in 2009.

Summary

Three of the four sites require repair to ensure the fish passage remediation continues to function as designed. The repairs of the ramps may be difficult due to the fact they are constructed of concrete, and concreting within a stream bed is a high risk environmental activity that will require stream diversions to be put in place prior to concreting works commencing. Other options should be explored that may result in a longer lasting retrofit.

The fact that three of the four sites require maintenance / repair to the degree that they do after five years of operation indicates that preventative maintenance and a sound design is critically important for fish passage retrofits. However, it does demonstrate the difficulties in retrofitting, indicating just how important it is to ensure fish passage is considered in the original design and installation of culverts.

3.4.8 An engineering perspective

BRYN QUILTER Tonkin & Taylor Ltd

Background

This summary paper discusses the author's, and Tonkin & Taylor's experience in fish passage design and engineering. This paper summarises engineering issues related to retro-fitting fish passage at existing barriers and incorporating fish passage facilities for new in-stream structures at the design stage.

The paper also summarises the author's experience in working with ecologists to develop design criteria and what information the science community needs to provide to engineers / designers to enable good design and successful outcomes. A proposed pro-forma for communicating design criteria was also presented but is not included here.

Common fish passage design concepts for culverts, weirs, ramps and culvert gates are summarised, and an overview of design issues and possible design solutions are provided.

Communication

- Key criteria need to be discussed and agreed.
- Establishment of key criteria can make it easier for an engineer to design works and improve outcomes.
- Reporting of constraints, issues and successes can be more clear.
- Key design criteria include:
  - Flow range & target flows.
  - Burst / prolonged fish swim speed criteria.
  - 'Functional range' of design, i.e., the range of flow conditions that are suitable for fish passage.
  - Tidal access limitations.
  - Stream access upstream and downstream.

Common structures

- Culverts and mussel spat rope.
  - Suitable for pipes < 1.8 m, i.e., install & maintenance access issues are eliminated.
  - Good for mitigation in disjointed pipes.
  - Lead-in and exit lengths to extend beyond channel constrictions, often 5–10x pipe size.
  - Long lead-in and exit lengths can cause rope to lift out of flow.
  - Fix rope at key points to prevent lifting.
- Culverts and baffle / rock substrates
  - Suitable for pipes > 1.8 m, i.e., install & maintenance access issues are less significant.
  - Baffle insert and maintenance access are still quite constrained in pipes < 2.3 m.
  - Fixing and sealing of baffles to prevent underflow and eventual uplift an issue.
  - Manning's roughness changes with depth, limited good design.
  - Consider apron lead-in and lead-out details.
- Weirs
  - Low flow small diameter culverts can often be used below weir overtopping height – need to assess how culvert discharge affects water levels.
  - Smooth transition roll-over type weir design is required to avoid 'water falls' and reduce velocity step changes.
  - Weirs are similar to Ramps.
- Ramps
  - 'Ramps' and 'ladders' are called channels in an engineer's world.
  - Providing flow depth and low velocity for swimming species is challenging.
  - Asymmetric channels can provide a trade off in achieving flow depth, low velocity zones and a wet margin.
  - Substrate choice significantly affects calculations.
  - Manning's roughness numbers can change significantly with depth.
  - Manning *n* (trapezoidal channel) with rock up to 150 mm and depth up to 300 mm = 0.11 to 0.16, manning's number can be much higher than engineers normally work with.

- Flood / flap gates – hinged
  - Again need to look at functional range.
  - Key issues are velocity, water depth, opening size and time open.
  - Water depth and velocity can be managed by looking at:
    - Outlet water level control, i.e., weirs.
    - Low flow bypass using small diameter culverts or ramps.
    - Operational range of stored water level may be critical.
    - Water retaining structures, e.g., dams, may require floating, pumping or siphon flow intakes for ramps.
- Flood / flap gates – balanced / tensioned
  - Counter-weight mass or spring / strap tension is critical – monitor / adjust after installation
  - Build up and release of flow can cause cycling of system and can lead to mechanical fatigue

Health and safety, and maintenance

- Current proposed legislation indicates that all parties involved MUST consider through all stages 'safety in design'.
- Confined space (e.g., small culvert and manhole) entries may be 'notifiable hazards'.
- Culverts with substrate installation MUST consider practicalities of culvert size in construction, inspection and maintenance.

Summary

A key learning is that: *designing for fish passage is complex and the need for scientist-engineer interaction from concept, to detailed design, to construction supervision, is important in achieving successful fish passage outcomes.*

Scientist-engineer communication and interaction is critical and:

- Key criteria need to be discussed and agreed.
- Establishment of key criteria can make it easier for engineer to design works and improve outcomes.
- Reporting of constraints, issues and successs can be clearer.
- Design discussion and review needed throughout project life.
- Design team needs to consider the "functional range" of the device using multiple flow points to better understand operational behaviour and thus enable optimisation for improved outcomes
- Culverts with substrate installation MUST consider practicalities of culvert size in construction, inspection and maintenance
- Design detailing is very important but 'tweaking' of design during and after installation is often required and can significantly improve likelihood of successful outcomes.

3.4.9 River mouth openings and engineered manipulations for fish passage

ADRIAN MEREDITH Environment Canterbury (ECan)

Background

Fish passage along rivers is important for achieving connectivity, and giving effect to the principle of Ki uta ki tai ("mountains to the sea"). While much current effort is spent on raising awareness and finding solutions for structural barriers at points in a river network, it should be acknowledged that there are also more fundamental natural features such as intermittently flowing reaches and river mouth blockages that can restrict fish migration. Facilitating the opportunities to manipulate river mouth conditions can be a very important step in achieving open fish passage through river systems.

Incidence of issue in New Zealand

East coast rivers in New Zealand frequently have mouth blockage issues associated with gravel barrier beaches. These form hapua, waituna or estuaries. Canterbury has an 800 km coastline with intermittently blocked gravel river mouths every 12–16 km.

River mouth opening purposes

Most current river mouth opening activities are associated with flood hazard avoidance or threats to infrastructure. Ecological (fish passage requirement) purposes are seldom specified or available and so should be integrated with these current engineering purposes.

Planning and consenting

New and re-consented regulatory processes pose the greatest opportunity to integrate hazard management and ecological requirements for river mouth management. Fish passage requirements should therefore be included with river engineering requirements.

Ecological justifications

Characterise types and value of fish communities in rivers, and determine necessary opening regime requirements (seasonal, annual, intermittent (2 to 3 years), etc.).

Outcomes

Facilitate ecological opportunities for river mouth management by removing regulatory impediments (consenting or planning requirements), integrating with current river engineering and identifying fish passage needs on a river type basis. Or facilitate softer approach of approval mechanisms for simply lowering beach crests to facilitate higher likelihood of natural river mouth openings.

Summary

River mouth closures were recognised as a major impediment to achieving unrestricted fish passage in east coast gravel rivers. The integration of existing river hazard management works with ecological requirements were identified as the most beneficial steps to removing regulatory impediments to action.

3.4.10 Fish passage at water intake infrastructure

SJAAN BOWIE Department of Conservation (DOC)

Background

Water being taken from our waterways for irrigation and other purposes in New Zealand has increased at a considerable rate over the past few years. The designs of these water intakes ("screens") varies throughout the country and have predominantly been approved on a consent by consent basis, as there is limited best practice or guidance about what would best protect our native and sports fish.

Poor water intake design is an issue, as it can lead to deterioration or loss of habitat, diversion into unscreened or poorly screened intakes (entrainment) and / or physical damage or death on poorly operating screens (impingement). Many of our freshwater fish migrate between freshwater habitats and / or between freshwater and the sea to complete their lifecycles. So if they are entrained or impinged on screens, then they are lost to the fishery. For some fish this could have devastating results for future survival of the species.

Extensive research has been undertaken overseas, as well as a few investigations in New Zealand, on water intake requirements to protect sports fish, however not a lot is known about design criteria to best protect our native fish.

In 2004 Fish and Game undertook a review of water intakes in North Canterbury and found that most water intakes are likely to be impacting on freshwater fish, due to poor design and lack of ongoing maintenance (Hardy 2004). As a result of this study Environment Canterbury convened a multi-agency working party in 2005 to develop good practice guidelines and criteria.

Development of good practice guidelines and key criteria

Environment Canterbury, Fish and Game, Irrigation New Zealand and the Department of Conservation gained funding and used the knowledge and experience of the group to undertake reviews of sports fish (Bejakovich 2007) and native fish (Charteris 2007) requirements. The aims were to identify key criteria that were thought to protect them from intake screens and to produce a review of structural options and good practice guidelines for Canterbury (Jamieson *et al.* 2007).

All freshwater species are important and it would be ideal if all freshwater fish were protected from being entrained and impinged. However, due to their requirements and life cycles the following species were identified as at highest risk or concern:

- Sports fish
  - Downstream migrating juvenile, and post spawning and upstream migrating spawning adults of Chinook salmon, brown and rainbow trout.
- Native fish
  - Downstream migrating juveniles (e.g., lamprey);
  - Downstream migrating larvae (e.g., banded kokopu, shortjaw kokopu, giant kokopu);
  - Upstream migrating juveniles (e.g., elvers, bluegill bully, redfin bully, torrentfish);
  - Threatened non-migratory galaxiids (e.g., lowland longjaw galaxias, bignose galaxias, upland longjaw galaxias, northern flathead galaxias).

The sports and native fish reports collated all known information on fish values, size, migration timing, swimming ability, life cycle, habitat and water column use. Using this fish information, structure placement, water velocity requirements at intakes, effective bypass and escape routes, maximum material opening size and monitoring and maintenance were identified, and criteria set as key design parameters that would protect freshwater fish. There are gaps in knowledge of native fish, nevertheless similar criteria were identified that would protect native and sports fish.

Jamieson *et al.* (2007) concluded there was a need for a "whole of intake design" if fish are to be efficiently and effectively diverted without damage from intakes. So to ensure an effective water intake and fish screen is designed, all of the following key design criteria were identified as needing to be satisfied:

- **Location**

  Designed to minimise exposure of fish to fish screen structure and minimises length of channel affected. To minimise entrainment, the location should be at, or as close as practical, to the point of diversion or positioned flush to banks of the river where possible.

- **Approach velocity**

  The velocity through the screen needs to be slow enough to allow fish to escape entrainment and therefore match the swimming ability of the weakest fish likely to encounter the screen. Designing structures to have an approach velocity of ≤ 0.1 m s^{-1} (Table 6) was identified to prevent entrainment of most freshwater fish in New Zealand.

- **Sweep velocity**

  The velocity of water sweeping past screens or water intakes needs to be sufficient to sweep the fish past the intake promptly. Sweep velocity was identified as needing to be higher than approach velocity to minimize exposure of fish to the screen face. Velocities of 0.5 m s^{-1} (Table 6) have been found to deter most species, so sweep velocity greater than this is optimal.

- **Bypass**

  The bypass entrance needs to be easy to find by fish so that if they do get entrained into the water intake area they can escape.

- **Connectivity**

  An effective escape route (*bypass*) needs to ensure fish are returned undamaged to an actively flowing main stem (*connectivity*).

- **Screen material opening size**

  Screening material on the screens needs to have openings with a maximum screen material opening size to exclude fish and be smooth enough to prevent any damage to the fish. Minimum fish size and shape of sports fish (25–20 mm) and native fish (3–20 mm), along with information from international studies (Table 7) were used to identify that a material opening size of 2–3 mm is likely to be effective at excluding fish.

TABLE 6: Approach and sweep water velocities identified using information on swimming abilities and speeds, required to protect freshwater fish at water intakes (Source Bejakovich 2007 and Charteris 2007).

	Approach velocity	Sweep velocity
Native fish – general	<0.3 m s^{-1}	>0.5 m s^{-1}
Native fish – important spawning or migration pathway	≤0.1 m s^{-1}	
Sports fish	≤0.12 m s^{-1}	>0.24 m s^{-1}

TABLE 7: Material opening size required to prevent entrainment (Source Jamieson *et al.* 2007).

Group	Mesh size (mm)	Profile bar	Perforated plate
Native larval fish	0.3		
Whitebait (banded kokopu, inanga), common bully, shrimp	2.0		
Canterbury mudfish	2.0		
Glass eels / elvers	1.5		
Eels (adults)	20–25		
Juvenile sports fish	3	2	3.2

- **Maintenance and Operation**

  As fish are moving in the water column and waterways 24 hours a day, intakes need to be kept operating to a consistent, appropriate standard with effective *maintenance and operation*. Regular monitoring is critical.

Field investigations of water intakes in Canterbury

Since 2010, the water intake working party has gained funding from the Sustainable Farming Fund to undertake a number of field investigations of a range of water intakes in Canterbury. The aim was to assess the water intake designs and test the success in relation to the suitability and effectiveness of the criteria identified in Jamieson *et al.* (2007). Electric fishing of intake and bypass locations was undertaken where possible to gain information on what species were found in the areas, and of those species which were entrained under normal operating conditions. Traps were then set in the intake and bypass areas, and juvenile salmon and trout were released and traps monitored over a set time period. Juvenile Chinook salmon and rainbow trout were used as the indicator species for fish exclusion tests predominantly, as they are one of the species most at risk of impingement and entrainment, good numbers were available, and it was found that many requirements for Chinook salmon were similar to that of other sports fish and native fish (Bejakovich 2007, Charteris 2007).

Preliminary results were presented for field investigations undertaken at a vertical flat plate screen, inclined flat screen, buried infiltration gallery, rotating mesh drum, and a rock bund water intake (Bonnett *et al.* In prep). Useful information was gained from these investigations, but unfortunately not one water intake could not be found that met all seven criteria.

All field investigations reported some entrainment, however this was lower when there was an effective bypass, and when approach and sweep velocity was appropriate. Also where screen material opening size was 5 mm, entrainment was recorded.

Vertical flat plate screens showed some promise, however the screen material opening size needed to be consistently 3 mm and the sweep velocity needed to be higher to ensure greater sweep of fish into the bypass.

Buried infiltration gallery and permeable rock bunds demonstrated they exclude juvenile salmon, however they are less effective for very small salmon and some native fish, e.g., bluegill bully.

At a number of the sites investigated maintenance was found to be lacking (e.g., gaps in seals, bypass was closed or not connected), and as a result the testing could not draw conclusions on some key criteria. However, some useful information was gained that will enable better design and protection of freshwater fish at water intakes in the future.

Summary

Overall, the findings from these investigations of fish screens have shown that the criteria identified in Jamieson *et al.* (2007) are appropriate for protecting freshwater fish in our rivers, with effective bypass and connectivity, and maintenance and operation being identified as critical.

So when designing a water intake it is important to identify the freshwater fish values of the area, and consider all seven key design criteria to best protect freshwater fish.

3.4.11 Building barriers: Saving our natives

FRANCES CHARTERS [1], SJAAN BOWIE [2], DAVE WEST [2] & AISLING O'SULLIVAN [1]
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Background

New Zealand has around 51 species of native freshwater fish, with an additional 3 colonist species and 20 introduced species that are now considered naturalised in New Zealand waters (Allibone *et al*. 2010). Some of New Zealand's native fish are vulnerable to direct predation and / or competition by introduced, invasive species, as well as the adverse changes to aquatic habitat caused by these introduced species (Rowe & Dean-Speirs 2009).

Many of our native fish are diadromous, moving between freshwater and saltwater during their life cycle, and the ability to migrate between streams, lakes and the sea is vitally important to their population health and future species survival (McDowall 2000). The remaining native fish are non-diadromous, living their whole lives in freshwater, with some only being found in very specific types of freshwater habitats and locations.

It has long been recognised that dams prevent fish migration and consequently there has been much research conducted into overcoming these barriers to ensure fish passage (Katopodis & Williams 2012, Schilt 2007). However, the vulnerability of New Zealand's native fish and other aquatic values, e.g., macrophytes, to invasive species suggests some barriers, whether natural or built, could be used to create protected habitats for some native species.

This research reviewed national and international design and effectiveness of waterway barriers to prevent the spread of introduced fish species, for the purpose of providing guidance on future effective barrier design in New Zealand.

Methods

A literature review was undertaken of the following sources:

- International and New Zealand peer-reviewed literature;
- Publicly available monitoring and construction reports of existing barriers;
- Department of Conservation internal reports;
- Department of Conservation natural barrier evaluations.

The case studies were summarised in terms of design criteria, implemented design features, barrier performance and lessons learnt.

A compilation of electronic files was produced from this review which collectively summarise current knowledge of waterway barriers and provide guidance to those looking to design an effective waterway barrier in New Zealand (Table 8). This resource was developed with the hope that the Department of Conservation would maintain and use it to help guide their and others work on using barriers as a tool to protect threatened native fish in key locations.

Results

Barriers can be both natural and built. Natural barriers include waterfalls, swamps, dry stream beds and zones of species-specific uninhabitable conditions (such as low water levels or low dissolved oxygen concentrations). Built barriers can be categorised as physical or non-physical. Physical barriers include weirs, overhangs, high velocity chutes and screens[1]; they are designed to exceed the invasive fishes' ability to swim, jump or climb past the barrier. Non-physical types include acoustic and air bubble barriers, electric fields and strobe lighting; they work by stimulating an avoidance response in fish.

1 Screen barriers such as water intakes are not included in the database at present as information on these barriers in place in New Zealand is not currently available.

TABLE 8: Waterway Barrier Design Files

File name	Brief Description of Contents and Purpose
Review report	This report collates the findings of the literature review, including case studies from New Zealand and overseas. It also includes a flowchart (see Figure 8) showing how the Waterway Barrier Design Files can be used as part of the design process of a waterway barrier.
Database	The database summarises known characteristics and design details of Otago natural barriers (as this region has recently completed a series of natural barrier assessments) and a selection of built barrier case studies from New Zealand and overseas. This database needs to be updated as more information is gained.
EndNote Library	This library (created in EndNote version X6) holds copies of relevant literature. The user can search within the library by keywords (refer to tab in Database titled 'EndNote Library Keywords').
Photo and Drawings Library	Photos and design drawings of natural and built barriers are linked from the Waterway Barriers Database, where available.
Design Review Checklist	This file includes a checklist to define the barrier objectives (as the basis of design) and a checklist of design factors that should be considered.

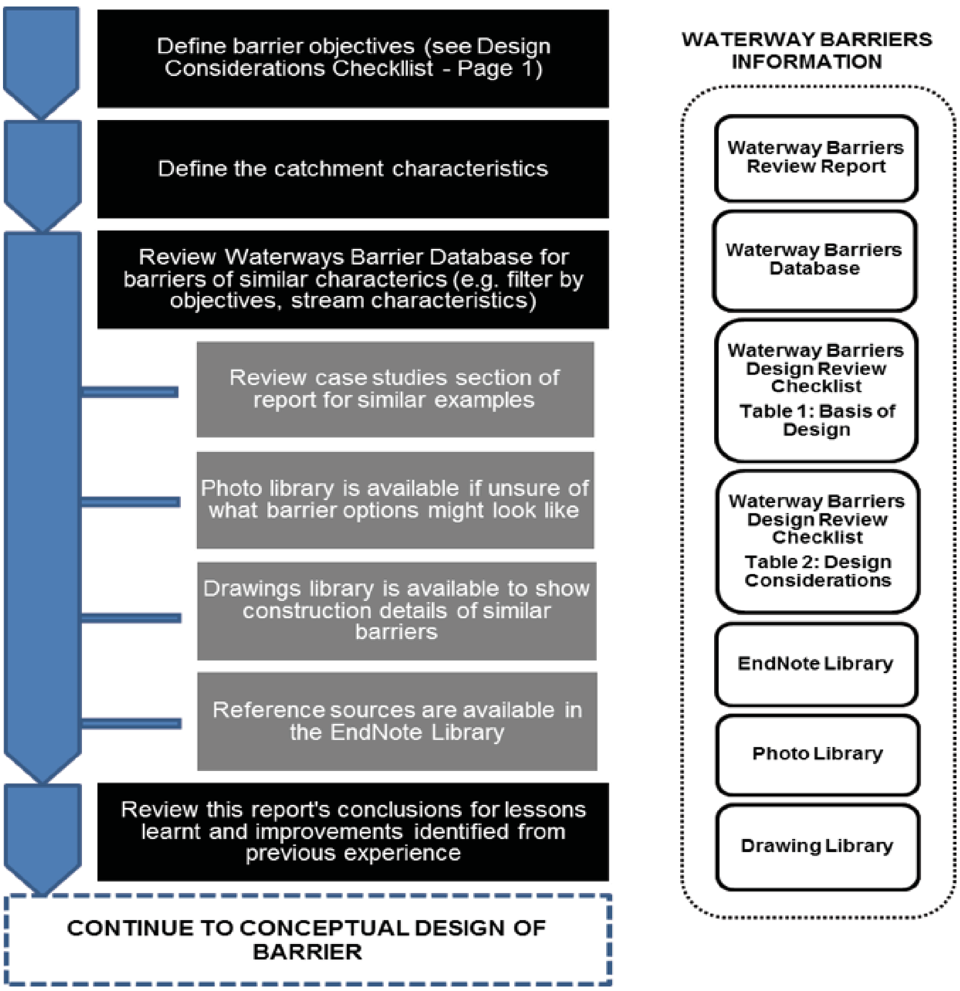

FIGURE 8: Flowchart of suggested process for using water barrier design files in planning and design of new waterway barriers.

There are numerous effective waterfall barriers in the Otago region, owing to the prevalence of bedrock outcrops. Of the 69 natural barriers evaluated to date in Otago by Department of Conservation staff, 61 did not have invasive species recorded upstream of them, indicating effective barrier characteristics.

Effectiveness of a barrier can depend on behavioural or hydrological factors, including a fish's swimming, jumping and climbing ability, fish age and size, barrier height, water velocity and downstream water depth. To date non-physical barriers were consistently found to be ineffective as full exclusion barriers for trout and salmon species in the examples found, although they have been effective at excluding carp. Of greater potential for the New Zealand situation, however, are physical barriers. Physical barriers have successfully resulted in the protection of key non-migratory galaxiid locations, when combined with invasive species removal operations (e.g., Akatore Creek in Otago or Fraser Spring in Canterbury (Figure 9)). Table 9 summarises the primary design criteria and considerations for built physical barriers identified from the review of national and international case studies that could apply to New Zealand.

Summary

The strong swimming and jumping ability of invasive fish, coupled with the predatory nature of many of these species, mean that a full exclusion barrier is required to provide adequate protection for some New Zealand native species. This is especially applicable for non-migratory galaxiids that are at risk of extinction without control or eradication of brown trout in select places.

Several native species are moderate to strong climbers. This attribute can be exploited by incorporating grates and overhang features on physical barriers, which inhibit jumping but allow climbers to pass upstream through the barrier. Ongoing research into linking specific design criteria with most effective barrier outcomes is helping to restore native fish to New Zealand waterways.

TABLE 9: Summary of design considerations for built physical barriers

Design feature	Design criteria	Design considerations
Barrier location	• Barrier placed in a stable section of streambed, with a moderate slope	• Minimise upstream backwater effects including loss of riffle zones, flooding by placing barrier in section of reasonable gradien
Barrier height	• Drops ≥1.5 m are effective exclusion barriers. However, small drops (i.e.1.5–2.5 m) should be used in combination with other barrier types, such as a shallow, high velocity chute.	• Minimising upstream backwater effects by restricting barrier height while still achieving barrier effectiveness • Change in sediment transport within stream
Barrier profile	• Existing weir barriers can use V-notch profiles to maintain a concentrated, high velocity body of flow under low flow conditions • Existing barriers have successfully used ≥500 mm overhangs to inhibit jumping	• Minimise upstream backwater effects by using a shallower upstream face profile • Grated overhangs have been used to allow climbers to pass up through barrier
Design flow	• Existing barriers (in the US) have used 1:100 year flood flows as the maximum design flow for full exclusion	• Hydraulic profile over weir crest under varying flows • Anchoring of weir structure to prevent overturning, sliding, scour • Protection of abutments
Downstream zone	• Downstream apron (>2 m length) to create a high velocity and shallow water zone that inhibits jumping and swimming	• Scour protection on sides of apron • Scour protection downstream of apron

Future research of effective barrier design and function is also recommended, including laboratory trials to test key design parameters, such as minimum barrier height and downstream water velocities required to inhibit jumping by invasive species. Also recommended is the extension of natural barrier assessments to other areas in New Zealand (e.g., Canterbury, where there are rare non-migratory galaxiid locations), with the collected data added to the existing database set up for the Otago natural barrier assessment information.

Your role in enhancing the waterway barriers design database

The Waterway Barrier Design files are intended as live documents and it is essential that the information in the database is updated as more barriers are established and more monitoring information on existing barriers is gathered. Please contact Sjaan Bowie (sjaanbowie@doc.govt.nz) and Dave West (dwest@doc.govt.nz) at the Department of Conservation, with any information you have about the design and performance of waterway barriers. This information will help continue to build the database of information on the effective design of waterway barriers for protection of New Zealand's aquatic values.

FIGURE 9 Built barrier installed at Fraser Spring, Twizel in the Waitaki catchment to prevent trout accessing bignose galaxias and lowland longjaw galaxias habitat.

3.4.12 World Fish Migration Day 2014

SJAAN BOWIE Department of Conservation (DOC)

Background

Information on an upcoming advocacy opportunity for New Zealand was presented (www.worldfishmigration day.com). Participants were invited to take part in World Fish Migration Day 2014 on the 24th of May, as this event was seen as a great opportunity for ecologists, planners, engineers and educators to work together to promote the importance of fish passage and was a great next step from the workshop.

This international event calls attention to the need to safeguard free flowing rivers and to restore the connections in rivers for migratory fish. World Fish Migration Day 2014 aims to raise global attention for endangered migratory fish that are threatened by barriers such as weirs and dams, and need free migration routes to survive. Many organisations in New Zealand were represented at the workshop, and these organisations are currently working in an active role in the restoration and management of structures in waterways to best ensure protection of our special freshwater fish.

Taryn Wilks (taryn.wilks@pdp.co.nz) offered to be the national contact and coordinator for the day, and participants were urged to join forces and register events around New Zealand on the website (www.worldfishmigrationday.com). Suggestions for events that could be held in New Zealand included local agencies running community fun days, kid's events or competitions, fishing demonstrations, Kiwi Conservation Club fieldtrips and displays of important information at key public locations, e.g., aquariums. More than 150 events have registered worldwide, with two events being registered in New Zealand to date (February 2014):

Whakatane – An event will be held at Nukuhou Saltmarsh. Nukuhou Saltmarsh Caregroup will lead a walk around the whitebait spawning areas in Nukuhou Saltmarsh and inform participants about the life-cycle of galaxiids (whitebait) and the importance of fish passage (see www.worldfishmigrationday.com / events / 286 / whitebait-spawing)

Christchurch – Connecting fish, rivers and people in Canterbury. A fun day will be held at the Nature Play Stream site (www.greeningtherubble.org.nz / wp / ?p=1173) in Central Christchurch. Activities will include:

- Demonstrations of different barriers that can be found in our streams and how we can help fish swim through or over these barriers;
- Displays of freshwater fish and invertebrates found upstream and downstream of a barrier in the local Avon River;
- Crafts and games about fish and passage in New Zealnd streams;
- Talks by experts.

(see www.worldfishmigrationday.com / events / 284 / world-fish-migration-day-connecting-fish-rivers-and-people-in-canterbury)

For more information see:

Web: www.worldfishmigrationday.com

Facebook: www.facebook.com / WorldFishMigrationDay

Facebook: www.facebook.com / pages / World-Fish-Migration-Day-New-Zealand-2014 / 575348745881779

Twitter: twitter.com / WFMD2014

Instagram: instagram.com / fishmigrationday

4. DISCUSSION

One of the objectives of the workshop was to prompt discussion amongst participants on the key issues regarding the management and improvement of fish passage in New Zealand. Over the two days a number of discussion sessions were convened and proved very productive in terms of highlighting some of the key requirements for future promotion and enhancement of fish passage management in New Zealand. Below we attempt to summarise some of these key points and issues that were raised during the workshop discussion sessions.

4.1 National Resources

To date, there has been little national coordination with respect to characterising, understanding or improving fish passage management in New Zealand. Much of the work that has been done has been carried out at a regional or local scale, and as a consequence there has been considerable duplication of effort and a proliferation of alternate approaches to assessing fish migration barriers and implementing fish passage management. The lack of consistency within and between regions means that the scale of the fish passage problem is poorly understood and the ability to share information is hindered.

The potential benefits of developing a national fish passage assessment protocol and database were discussed by the workshop participants. It was also highlighted during the discussion sessions that many people were not aware of the existing resources available to support fish passage management in New Zealand. Many of the resources have been produced for individual organisations in different regions, but the information within them is often nationally applicable and therefore would be useful to everyone with an interest in fish passage management. There was a desire and willingness to share these resources and it was suggested that establishing a central national repository for such information, e.g., a website, was a priority. DOC have subsequently agreed to host this resource.

4.1.1 Data collection and storage

A variety of different fish passage assessment protocols are currently used by different regions and agencies across the country. This creates difficulties in developing a nationally consistent picture of the fish passage problem and acts as a barrier to effective information sharing. The idea was raised of a national fish passage assessment protocol linked to a national barriers database, to help improve the quality and accessibility of information. This idea was met with support from those at the workshop. The main potential benefits were seen as being: reduced duplication of effort, improved consistency and better availability of information. However, it was emphasised that there was a need to ensure that these resources are accessible to all parties involved in fish passage management.

Assessment protocol

There was considerable discussion amongst workshop participants about the best structure and data required for a national assessment protocol. It was recognised that there is a trade-off between the level of detail and the time required to undertake an assessment. It was suggested that a hierarchical assessment protocol incorporating both a rapid and comprehensive assessment methodology would be the best compromise to address this issue. Discussions at the workshop subsequently focussed primarily on the requirements of a rapid assessment methodology.

It was highlighted that, in most cases, the objective of undertaking an assessment is to understand whether a structure is a barrier and if so whether remediation is required. It was therefore suggested that the rapid assessment methodology should focus on collating the information most pertinent to achieving this objective. The type of information necessary to achieve this objective was debated by the workshop participants, but little agreement was achieved within the time available. It was suggested that there should be a core sub-set of mandatory fields that would be collected for all sites. This should include details such as location and type of structure, plus information used for characterising the structure such as length, perch height and slope. Ideally the mandatory data fields should be objective measurements that non-experts would be able to collect.

Photographs of all structures were identified as being vital. The issue of assessing the ‘passability’ of a structure was discussed by participants. This is an inherently subjective evaluation creating difficulties for maintaining consistency, and is reliant on the experience and expertise of the assessor. It was discussed whether a scoring system could be devised based on the mandatory data fields that could approximate the risk of the structure being a barrier to fish migration. Whilst this was a preferred approach, it was agreed that at present there is insufficient data available to develop such a system and it would be reliant on expert opinion.

It was concluded that development of a national assessment protocol was a priority for the proposed National Fish Passage Advisory Group (see below). The possibility of a mobile device application for data collection was also raised and received some support, but cost was thought likely to be a barrier for this at present.

Database

To complement the development of a national fish passage assessment protocol, it was proposed that a national database of barriers should also be established. This received widespread support from workshop participants. It is likely that NIWA will host the database, but there is an issue around who would be responsible for managing data quality. Participants identified a preference for data from the database to be available in a form that would allow direct upload into standard geographical information systems (GIS) that are widely used by councils for data management and planning purposes. However, it was also highlighted that it would be beneficial to have a simple, web-based map format that would allow community groups to look up local barrier information in their catchment.

4.1.2 Fish passage guidelines

The need for improved guidance on fish passage management was highlighted by participants throughout the workshop. In part this was a consequence of some people being unaware of existing resources, but feedback also suggested that many of the current resources did not provide the right information in the right way for practical implementation. This feedback was particularly strong from the engineers.

NIWA indicated that it was committed to providing a limited update of the current Auckland Council Fish Passage Guidelines (Stevenson & Baker 2009) by 2016. However, feedback from the workshop participants indicated demand for a wider ranging and more in-depth revision of the guidelines. The desire was to see a comprehensive set of national guidelines that would cover all main structures (i.e., culverts, weirs, tide gates, stormwater management systems, dams and diversions). In particular, participants were seeking formal best practice guidance and more specific minimum and optimum design criteria for both new structures and remediation works.

Suggestions for design criteria included, but were not limited to:

- defining the minimum time of year and / or flow range over which passage must be possible;
- describing water velocity and depth requirements of fish;
- providing minimum dimensions for structures with respect to stream size, particularly stream width;
- identifying minimum sizing and spacing requirements for baffles; and
- specifying a minimum time that tide gates should remain open.

However, it was highlighted by several participants that there are considerable knowledge gaps (see Section 4.4) with regards to the behaviour and capabilities of many of New Zealand's fish species meaning that defining such criteria would be extremely difficult. It was also emphasised that there was no 'one fix' for all situations and therefore expectation of strict criteria that would apply everywhere was not realistic. This led to a discussion around the need for improved monitoring of fish movements at and around instream structures, and the need for resources on appropriate monitoring methods for evaluating the effectiveness of different structures.

DOC have also been looking into the development of national guidance on fish passage management over the next few years. As a result, NIWA and DOC have committed to working in partnership to develop new national guidelines for fish passage management supported by the establishment of a multi-agency national fish passage advisory group. A new national fish passage management website will also be set up which will collate existing guidance, making it more accessible to end-users. It was suggested that it would be useful to include a library of case studies on the website that would highlight best practice examples, but also describe lessons learned from poorly designed structures or remediation efforts.

4.2 Strategies for Managing Fish Passage

Councils and organisations provided an overview of the strategies they have trialled and implemented to prioritise fish passage management. There were a number of lessons learnt that can be used by others considering initiating a programme to prioritise fish passage management that will save them time and money.

A critical first step was the need to collate the known information on values and barriers, so that the extent of the problem is understood, and to ensure that well informed management decisions can be made that will enhance the freshwater fish communities present. This is particularly important as some barriers can in fact be protecting remnant native fish populations from invasive species and in these limited situations barriers should be maintained. There are a number of available features and values that can be used to help prioritise fish passage in New Zealand, e.g., Freshwater Environments of New Zealand geodatabase (FENZ) & the New Zealand Freshwater Fish Database (NZFFD).

Once the known information is collated, the next step is to consider practical aspects including ownership, available habitat upstream, fish community value, working in with maintenance schedules, fixing all structures in one location to save costs in the long-term, and severity of restrictions. Tasman District and Greater Wellington Regional Council's experience found that it was best to focus on remediating structures that were managed and owned by themselves, prior to attempting to focus on privately owned barriers. This prioritisation makes sense as it is best to lead by example and remediate structures managed themselves so they can show others how it is best done. It also limits the time and funding needed to be spent on working with landowners that could be used to remediate more structures.

Environment Canterbury prioritised their fish management effort by focussing on road crossings where they intersected with stream reaches within key catchment zones. In-situ assessments were then undertaken, first focussing on ones closest to the coast and then prioritised for further ground truthing of upstream and downstream values where decisions will be made on remediation options. Both Auckland Council and Horizons undertook stream walks as a way of identifying, assessing and prioritising instream barriers.

Greater Wellington is taking the approach of building experience and expertise remediating their own structures, and when all council structures are remediated will use the experience gained to determine the most efficient approach and methods to remediate structures in high value catchments not under the Council's control.

Prioritisation of fish passage management should therefore include identifying all known structures and values, consider practical aspects and finally, where available, intersect barriers, values and practical aspects to determine high priority sites. Coordinating remediation efforts with existing maintenance schedules and between organisations involved in structure management (e.g., DOC, councils, transport agencies) is seen as critical to ensure the right effort is put in the right places and duplication is avoided. It was also suggested that incentivising implementation of best practice designs for new structures should be pursued. This could be achieved by allowing best practice designs to get through the consent process easily, but those of lower specification would have more rigorous conditions applied to them, including more detailed fish monitoring requirements.

4.3 Lessons Learnt

There have been a number of lessons learnt from experiences gained around the country undertaking fish passage management and progressing research in this area. However, a lot of this information has previously been in peoples heads or grey literature, so this document is a useful resource providing examples of up to date experience on good fish passage management. It is hoped that the revised national guidelines and national website will further fill this gap and ensure that ecologists, engineers and others involved in fish passage management have a central location to find the latest information and guidance.

A clear lesson from the workshop was that engineers and ecologists need to work more closely to find innovative solutions that will reconnect our waterways and allow freshwater fish to complete their lifecycles. Engineers have motivation to remedy some of the problems that create barriers to fish passage. For example, perched culverts are a problem from an engineering point of view due to wash out and erosion, as well as being a barrier to fish passage. However, engineers lack clear ideas from ecologists in the form of specific design parameters, figures, functional ranges, and the limitations of the solutions required to provide effective fish passage. It is therefore critical that research undertaken into understanding the fish and effectiveness of different structure designs is transferred into practical solutions, including sets of standard designs that will allow for effective fish passage. Common fish passage design concepts for culverts, weirs, ramps and flood / flap gates were summarised. However, currently there is very little information on the effectiveness of many of the available retrofit solutions, and this needs to be addressed before their widespread use. Designing for fish passage is complex and the need for ecologist-engineer interaction from concept to detailed design, to construction supervision, is important in achieving optimum fish passage outcomes.

Based on experiences from around the country the following key lessons should be considered when managing fish passage in New Zealand:

- When undertaking assessments of barriers it is important to gather adequate data (e.g., good photos of the structures from all angles).
- Involving engineers early in the process and providing them with appropriate information and design criteria

(e.g., flow range and target flows, burst / prolonged fish swimming speed criteria, functional range of the design, tidal access limitations, stream access upstream and downstream) is important.

- More coordinated effort is required by all agencies to work together to ensure new and existing structures comply with legislative requirements and to undertake remediation works. Both non-regulatory and regulatory mechanisms can be used to undertaken remediation.
- Mitigation and monitoring conditions should be part of any Resource Consent for a structure. There is a need for consistent national monitoring conditions and standards.
- Ensure any new structures are designed and installed correctly to allow for fish passage, preventing the need for future remediation. For example, a number of key design criteria have been suggested for installation of new culverts (e.g., using an oversize culvert relative to active stream channel width).
- Ensure rules in Council's plans adequately address fish passage requirements in the region.
- Important to identify and manage health and safety considerations.
- Some in-stream structures are no longer required for any purpose so removal should be considered, not just remediation.
- A number of remediation options have been trialled around the country, and careful consideration must be given to the environment in which options are being placed to ensure they endure and are appropriate for the fish community present (e.g., Fitting mussel spat ropes to perched culverts helps some climbing species, but does not help non-climbing species).
- Monitoring is critical, especially when novel remediation solutions are being implemented. Structures can change over time so repeated monitoring and reporting is important. Confirming persistence of upstream fish communities is important at structures with important fish communities.
- It is important to understand what proportion of fish arriving at a structure are able to effectively pass and whether that number is sufficient to maintain upstream fish communities.
- Ensure remediation work is undertaken in the most efficient way (e.g., undertaking remediation at multiple sites within a catchment on a single visit).
- In terms of retrofitting structures, clear objectives are needed to ensure we are trying to achieve the best outcome for the fish community present in the catchment.
- Invasive fish may be an important consideration when assessing structures to promote or limit fish access. Some structures can be designed and installed to prevent access for invasive species to protect threatened non-migratory native fish populations.
- Important to recognise the loss of waterways through inert structures, e.g., pipes, and the impacts of these on fish passage.
- River hazard management works should consider ecological requirements. River mouth closures are a significant barrier to achieving unrestricted fish passage.
- When designing water intakes it is important to identify the fish communities using the area, and consider all seven design criteria to best protect freshwater fish from impingement and entrainment.

4.4 Research Needs and Knowledge Gaps

Throughout the workshop there was significant discussion about current knowledge gaps relating to fish passage management in New Zealand. Three key themes emerged:

1. the need for improved understanding of the biology and ecology of New Zealand's native fish species to help define hydraulic design criteria for instream structures;
2. the need to better understand how well existing structures provide for fish passage; and
3. the need to better understand how effective remediation solutions are at providing fish passage and maintaining upstream fish communities.

It was highlighted that there has historically been little investment in the kind of research required to provide robust design criteria for providing effective fish passage at instream structures and that current recommendations are therefore limited by the biological information that is available. Consequently, it was also recognised that fish passage solutions that have been and continue to be installed in streams across the country, even where they meet best practice recommendations, may not provide optimum passage for all species at all times. It was therefore identified that there is a need for improved monitoring of these existing solutions to robustly evaluate their suitability.

4.4.1 Understanding the fish

Each of the presenters in the latest research session identified constraints to our current knowledge and understanding of fish passage requirements in New Zealand. These limitations were further emphasised by the requests for more specific design criteria for instream structures. It was raised during discussions that whilst the general life history strategies of most of the main native fish species are recognised, little is known about the specific controls on and motivation behind these different strategies and associated migrations. However, this knowledge is essential to understanding the implications of migration barriers for fish community structure and functioning.

Some of the key areas highlighted for further research included:

- What are the key motivating factors (e.g., life stage, pheromones, flow, temperature, light and habitat) for upstream and downstream movements of different fish species?
- How do fish behave in response to different hydraulic characteristics and features e.g., turbulence and water velocity?
- What are the swimming and climbing capabilities of different fish species, how do they vary between life stages, and how long / far can they be sustained?
- How do light, water quality and temperature impact on fish movements?
- What are the ecological consequences of delayed migration?
- What proportion of fish need to pass a barrier to sustain ecological integrity?
- What are the impacts on movements of other aquatic fauna, e.g., aquatic insects?

It was agreed by participants that an over-arching fish passage research strategy should be developed to identify and prioritise the most critical research needs. It was suggested that this should be a responsibility of the proposed National Fish Passage Advisory Group to be led by NIWA and DOC. An important theme that emerged during discussions over research gaps was the need to forge greater collaboration between the ecology and engineering disciplines. The availability of fluvial hydraulic facilities at both the University of Auckland and the University of Canterbury were considered to offer a great opportunity for interdisciplinary research. It was also suggested that opportunities for international collaborations could be explored with countries where fish species with similar or the same capabilities exist, e.g., Australia and Chile where *Galaxias maculatus* are also present.

4.4.2 Understanding instream structures

It was recognised by the workshop participants that existing instream structures offer an opportunity to improve understanding of how different fish species respond to and are impacted by alterations to riverine connectivity. It was suggested that learning from what is already there could assist with understanding what characteristics of different barriers (e.g., length, slope, fall height, Manning's n) are most important in determining effective passage and therefore in defining design criteria. However, this prompted discussion as to what constitutes 'effective passage'. For example, should a structure allow access to all species and all life stages all of the time, or is it sufficient to cater for only some species and life stages for specified times? Also, what proportion of fish need to be able to pass a structure to be considered sufficient for sustaining upstream fish communities? The question was also raised as to what impact does the loss of functional habitat (i.e., the replacement of streams with artificial structures such as culverts) have on aquatic ecosystems? These questions all highlighted the need for much more widespread and comprehensive standardised monitoring of fish communities at and around instream structures and for the need to share monitoring results.

A critical research need highlighted with respect to the design of instream structures, was the need for definition of key design parameters. This includes defining the functional range of the design (e.g., from a hydrological perspective a culvert must be designed to accommodate a certain size of flood), as well as providing specifications for key structural characteristics such as maximum culvert length, minimum culvert width, maximum water velocity, minimum water depths and maximum slope. These parameters should be tested both experimentally and in-situ.

4.4.3 Understanding remediation solutions

A number of workshop participants raised questions with regards to the effectiveness of retrofit solutions that are being installed to restore fish passage at barriers. There were particular concerns over some of the cheaper solutions that are being utilised, which have not been proven in the field or experimentally. There was a strong call for improved, robust and repeatable testing (Franklin & Bartels, 2012; Figure 10) of these and other solutions to ensure they are fit for purpose prior to widespread installation. It was suggested that by improving confidence in the effectiveness of different solutions, people will be more willing to invest in implementing solutions for restoring fish passage.

A need was also highlighted for improved access to key design parameters for remediation solutions. This included information such as spacing of baffles, optimum ramp length and slope, and where fish passes should be located relative to existing barriers for maximum effect.

FIGURE 10 An example of a remediation solution for a perched culvert. A rock ramp and receiving pool were installed at the end of this culvert in Hamilton to provide upstream access for smelt and inanga. Monitoring showed that while fish were now reaching the bottom of the culvert, they were not able to pass through the culvert due to its length and high water velocities. Following installation of baffles in the culvert, monitoring showed an increase in the abundance and diversity of fish upstream of the culvert (Franklin & Bartels 2012).

5.
CONCLUSION

The workshop provided a great opportunity to share experiences and update knowledge on fish passage management in New Zealand. Throughout the workshop a number of key themes emerged. One of the most important was the need for ecologists and engineers to work together to find innovative solutions to maintain and restore riverine connectivity for fish and other aquatic organisms. Another was the need for improved access to resources to support fish passage management. Also highlighted was a need for improved testing and monitoring of solutions to ensure they are fit for purpose and provide effective fish passage.

It is hoped that these proceedings will provide a valuable resource for researchers and practitioners alike. Remediation of low-head (<4 m) barriers can be a cost-effective means of achieving significant environmental and biodiversity gains. The cost of remediating fish passage at these structures is often relatively low for large environmental benefit, and is often the cheapest and single-most effective thing that can be done to improve the health of our waterways. Most Regional Councils and DOC have already started this process of remediation. However, the workshop has highlighted that there is still much work to be done in terms of ensuring that this work is effective.

A range of knowledge gaps were identified throughout the workshop. Further research into these areas is required to ensure that robust design criteria can be derived to optimise the design of both new structures and effective remediation options for providing fish passage. A number of new novel solutions were identified during the workshop. However, field testing of these tools is required to ensure their effectiveness and is a priority action.

In a few key locations, barriers can be beneficial to native biodiversity. Highly threatened resident native freshwater fish (species that live all their life in one location) can benefit from the presence of a barrier or natural waterfall as it prevents access for invasive species that can prey upon or compete with them in certain locations. This highlights the importance of identifying the native fish as a key value of an area before decisions are made on how best to manage, restore and / or protect a waterway.

Moving forward, a key outcome of this workshop has been the establishment of a partnership between DOC and NIWA to lead the collation and development of national resources to support fish passage management in New Zealand. This will be supported by the establishment of a multi-agency National Fish Passage Advisory Group. One of the first outputs of this partnership will be the development of a new fish passage resource on the DOC website www.doc.govt.nz / fishpassage, which will provide a central repository for existing and future information on fish passage management. A focus of this resource will be to ensure that guidance given is appropriate for engineers and ecologists. Two current programmes that could result in further opportunities or changes for fish passage management in New Zealand are the Freshwater Resource Management Act reforms and the development of the National Objectives Framework:

The RMA reforms are looking at greater use of collaborative decision making processes and proposed amendments to the National Policy Statement for Freshwater Management (www.mfe.govt.nz / publications / water / proposed-amendments-nps-freshwater-management / proposed-amendments-nps-freshwater-management.pdf). This may offer the opportunity for improved fish passage provisions in Regional Council policy and plans;

Under the National Objectives Framework, www.beehive.govt.nz / release / govt-announces-next-stage-freshwater-reforms, communities / councils will be required to set management objectives for all waterways. 'Fish' has been identified as an attribute parameter under the compulsory value of ecosystem health. This means that in the next iteration of the NOF it is possible that limits for protecting fish may be included, which could include references to fish passage. This may be an opportunity to ensure a nationally consistent set of standards relating to the provision of fish passage are implemented through a national regulation.

Overall, the workshop highlighted some of the significant successes to date, but also some major challenges for the future of fish passage management in New Zealand. Effectively tackling the problem of disruptions to river connectivity is a significant challenge. However, remediation works offer the opportunity for significant biodiversity gains in our valued freshwater ecosystems.

In summary, you can help our freshwater fish by:

- Ensuring structures in waterways are designed to allow for effective fish passage;
- Removing old structures that are no longer required;
- Implementing changes at existing barriers to restore fish passage;
- Working together to fix barriers that are preventing passage of our native fish;
- Contacting DOC or your local Regional Council if you are concerned about a barrier; and
- Remembering that the perfect culvert is a bridge!

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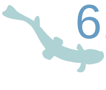
APPENDIX ONE:
Agenda for Day 1 and 2 of Workshop

DAY 1

Time	Topic	Presenter(s)
09:30–09:45	**Introduction**	Trevor James
09:45–10:00	**Why is Fish Passage Important?**	Sjaan Bowie
10:00–10:30	**Proposed National Fish Passage Assessment Protocols**	Paul Franklin
10:30–10:45	Morning tea	
10:45–11:00	**Data Collection & Storage**	
	Summary of online questionnaire	Trevor James
	Electronic data capture, storage and databases	Paul Franklin
11:00–12:00	**Strategies for Managing Fish Passage**	
	Prioritisation tools and systems for remediating, maintaining or creating fish barriers	Dave West
	Greater Wellington Regional Council – Fish passage strategy	Anna Burrows
	Tasman District Council – Practical prioritisation	Trevor James
	Environment Canterbury – Fish passage strategy	Dave Kelly
12:00–12:45	**Discussion**	All
12:45–13:30	Lunch	
13:30–14:30	**Latest Research**	
	Ramp trials	Cindy Baker
	Learning the ropes	Bruno David
	Tide gates	Paul Franklin
	New engineering ideas	Kelly Hughes
14:30–15:00	**Future Research Needs and Direction** Open discussion led by Peter West on knowledge gaps, funding, priorities	All
15:00–15:30	Afternoon tea	
15:30–16:00	**Fish Passage Guidelines** Discussion on collating and disseminating best practice	All
16:00–16:45	**Open Discussion**	All
16:45–17:00	**World Fish Migration Day**	All

DAY 2

Time	Topic	Presenter(s)
08:30–09:15	**General Discussion**	
09:15–09:30	Break	
09:30–09:45	**Introduction**	Trevor James
09:45–10:30	**Fish Passage 101**	Sjaan Bowie
10:30–10:45	Morning tea	
	Sharing Experience	
10:45–11:10	Integrating science and practical solutions for enhancing river connectivity	Paul Franklin & Cindy Baker
11:10–11:25	Lessons from remediation of fish migration barriers in the Tasman region	Trevor James
11:25–11:40	Lessons from remediation of fish migration barriers in the Horizons region	Logan Brown
11:40–11:55	Lessons from remediation of fish migration barriers in the Auckland region	Matt Bloxham
11:55–12:10	Lessons from remediation of fish migration barriers in the Waikato region	Bruno David
12:10–12:30	**Discussion** Thoughts so far…	All
12:30–13:15	Lunch	
	Sharing Experience continued…	
13:15–13:30	Getting the job done: Practical, cost effective solutions to restoring river connectivity	Kelly Hughes
13:30–13:45	Fish passage guidance for state highways – An overview	Craig Redmond
13:45–14:00	An engineering perspective	Bryn Quilter
14:00–14:15	River openings and engineered manipulations	Adrian Meredith
14:15–14:30	Fish passage at water intake infrastructure	Sjaan Bowie
14:30–14:45	Building barriers: Saving our natives	Frances Charters
14:45–15:00	**Discussion**	All
15:00–15:15	Afternoon tea	
15:15–16:15	**Discussion** Lessons learned; knowledge gaps & research needs revisited; funding needs; fish passage guidelines etc.	All
16:15–16:30	**Closing Remarks** Where to next?	Trevor James



APPENDIX TWO:
Attendance List

Name	Organisation	Email	Area of knowledge/expertise	Day 1	Day 2
Adrian Meredith	Environment Canterbury	adrian.meredith@ecan.govt.nz	Water Quality Scientist	✓	✓
Alex James	EOS ecology	alex@eosecology.co.nz	Freshwater Ecologist	✓	
Alton Perrie	Greater Wellington Regional Council	alton.perrie@gw.govt.nz	Environmental Scientist	✓	
Andrew Balme	Damwatch Engineering	andrew.balme@damwatch.co.nz	Civil Engineer		✓
Andrew Gray	Porirua City Council	agray@pcc.govt.nz			✓
Anna Burrows	Greater Wellington Regional Council	anna.burrows@gw.govt.nz	Biodiversity Restoration Advisor	✓	✓
Bart Jansma	Taranaki Regional Council	bart.jansma@trc.govt.nz	Freshwater Biologist	✓	
Belinda Whyte	Christchurch City Council	belinda.white@ccc.govt.nz	Fw Ecologist/Planner	✓	
Bill Veale	Damwatch Engineering	bill.veale@damwatch.co.nz	Civil Engineer		✓
Brent Gilmour	Viking Conveyer	brent.gilmour@vikingconveyor.co.nz			✓
Brent Merritt	Hynds	brent.merritt@hynds.co.nz	Tech Sales		✓
Brett Ogilvie	Tonkin & Taylor	boglivie@tonkin.co.nz	Freshwater Ecology/ Water Quality		✓
Bruno David	Waikato Regional Council	bruno.david@waikatoregion.govt.nz	Fish Ecologist	✓	✓
Bryn Quilter	Tonkin & Taylor	bquiter@tonkin.co.nz	Engineer	✓	✓
Caleb Royal	Te Wananga –O-Ruakawa	caleb@hapaiwhenua.co.nz	Ecologist	✓	✗
Carol Nicholson	Northland Regional Council	caroln@nrc.govt.nz	Freshwater Ecologist	✓	✓
Cindy Baker	NIWA	cindybaker@niwa.co.nz	Aquatic Ecologist	✓	✓
Clare Ridler	Horizons	clare.ridler@horizons.govt.nz	Freshwater Co-Ordinator	✓	✓
Craig Redmond	New Zealand Transport Agency	craig.redmond@nzta.govt.nz	Environmental Specialist	✓	✓
Dave Kelly	Environment Canterbury	dave.kelly@ecan.govt.nz	Water Quality Scientist	✓	✓
Dave West	Department of Conservation	dwest@doc.govt.nz	Freshwater Scientist	✓	✓
David Aires	Marlborough District Council	david.aires@malborough.govt.nz	River Engineering	✓	✓
David Boothway	Bay of Plenty Regional Council	david.boothway@boprc.govt.nz	Engineering Manager	✓	✓
David Cooper	Mahurangi Technical Institute	david@mti.net.nz	Fish Breeding	✓	✓
Dean Olsen	Otago Regional Council	dean.olsen@orc.govt.nz	Environmental Scientists	✓	✓

Name	Organisation	Email	Area of knowledge/expertise	Day 1	Day 2
Deb Campbell	New Plymouth District Council	campbell@nppc.co.nz			✓
Deborah Hewett	KiwiRail	deborah.hewett@kiwirail.co.nz	Senior Advisor		✓
Des Scrimgeour	Capacity	dscrimgeour@capacity.net.nz	Engineer		✓
Elaine Heneghan	MWH	elaine.c.heneghan@mwhglobal.com	Engineer		
Frances Charters	University of Canterbury	frances.charters@pg.canterbury.ac.nz	Engineering	✓	✓
Frances Forsyth	Wildlands	frances.forsyth@wildlands.co.nz	General Ecologist	✓	
Francis Leniston	Capacity	francis.leniston@capacity.net.nz	Engineer		✓
Ian McSherry	Capacity	ian.mcsherry@capacity.net.nz	Engineer		✓
James Dare	Environment Southland	james.dare@es.govt.nz	Environmental Scientist	✓	
Jenna Voigt	Tasman District Council	jenna.voigt@tasman.govt.nz	Transport Network Engineer		
Jennifer Critchley	KiwiRail	jennifer.critchley@kiwirail.co.nz	Engineer		✓
Jeroen Lurling	Tasman District Council	jlurling@yahoo.com.au	Barrier Remediation Student	✓	✓
Joe Hay	Cawthron	joe.hay@cawthron.org.nz	Ecologist	✓	✓
John McCartin	Palmerston North City Council	john.mccartin@pncc.co.nz	Stormwater Engineer		✓
Jubran Naddaf	Humes	jubran.naddaf@humes.co.nz	Engineer		✓
Karen Stokes	Cardno	karen.stokes@cardno.co.nz	Engineer		✓
Kati Doehring	Cawthron Institute	kati.doehring@cawthron.org.nz	Freshwater Ecologist	✓	✓
Katrina Smith	Cardno	katrina.smith@cardno.co.nz	Ecologist	✓	✓
Kelly Hughes	ATS Environmental	kellyh@ats.environmental.com	Consultant	✓	✓
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Kevin McFall	Marlborough District Council	kevin.mcfall@malborough.govt.nz	River Engineering	✓	✓
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Kristy Hall	MWH	kristy.hall@mwhglobal.com	Ecologist		✓
Kurt Mullis	Wellington City Council	kurtos9@hotmail.com	Environment Management	✓	
Kurt Mullis	ATS Environmental	kurtos99@hotmail.com			✓
Leila Saidi	Hawke's Bay Regional Council	leila@hbrc.govt.nz	Civil Engineer		✓
Liza Inglis	Tonkin & Taylor	linglis@tonkin.co.nz	Ecologist	✓	✓
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Luke Edwards	PDP	luke.edwards@pdp.co.nz	River Engineer		✓
Marion Thiele	Streamlife	marionjade@web.de	Freshwater Ecologist		✓
Mark Hooker	Greater Wellington Regional Council	mark.hooker@gw.govt.nz	Engineer		✓
Marnie Fornusek	Bay of Plenty Regional Council	marnie.fornusek@boprc.govt.nz	Engineer	✓	✓
Mat Daling	NZ Enviro Tech	mat@nzet.net.nz	Scientist		✓

Name	Organisation	Email	Area of knowledge/expertise	Day 1	Day 2
Matt Bloxham	Auckland Council	matthew.bloxham@aucklandcouncil.govt.nz	Freshwater Scientist		✓
Merilyn Merrett	Open Polytechnic	mfmerritt@gmail.com	Ecology		✓
Michael Hewison	Eastern Consulting Ltd	mikeh@eastern.co.nz	Civil Engineer		✓
Michael Mador	Kapiti Coast District Council	mikem@kapticoast.govt.nz	Stormwater	✓	
Mike Joy	Massey University	m.k.joy@massey.ac.nz	Lecturer	✓	✗
Mike Patterson	Horizon Regional Council	michael.patterson@horizons.govt.nz	Research Associate	✓	
Myfanwy Emeny	Wellington City Council	myfanwy.emeny@wcc.govt.nz	Ecologist	✓	
Paul Fisher	Nelson City Council	paul.fisher@ncc.govt.nz	Ecologist	✓	✓
Paul Franklin	NIWA	paul.franklin@niwa.co.nz	Freshwater Ecologist	✓	✓
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Peter Hamill	Marlborough District Council	hamill@malborough.govt.nz	Environmental Scientist	✓	✓
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Phil Jellyman	NIWA	phillip.jellyman@niwa.co.nz	Ecologist	✓	✓
Rhonda Hill	Opus	rhonda.hill@opus.co.nz	Engineer		✓
Richard Coles	Auckland Council	richardcoles@aucklandcouncil.govt.nz	Engineering, Stormwater, Hydraulics	✓	✓
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Tom Jolly	Capacity	tom.jolly@capacity.net.nz	Engineer		✓
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Trevor James	Tasman District Council	trevor.james@tasman.govt.nz	Freshwater Ecologist	✓	✓

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