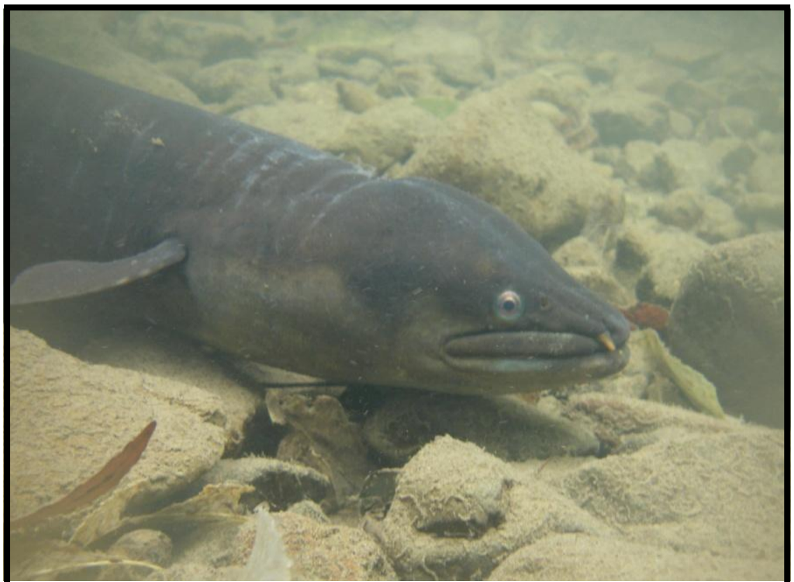
Considerations for restoration of native freshwater fish populations in the Parangarahu Lakes



Longfin eel (*Anguilla dieffenbachii*).

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Riverscapes Freshwater Ecology

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1. Executive Summary

- The coastal catchments at Parangarahu (particularly Kohangapiripiri) contain only low numbers and diversity of native fish, primarily due to issues at the outflows which are compromising the migratory pathways of these species.
- Key stakeholders and managers in this situation hold a variety of perspectives, values and desires regarding the lakes although all agree that they are special and worthy of protection and restoration.
- The past few decades have seen freshwater fish surveying undertaken by a variety of organisations, revealing that the Kohangatera Catchment contains some native fishes, including low abundance of migratory species. Although little surveying has been conducted in the Kohangapiripiri Catchment, indications are that it contains low diversity of native fish with virtually no migratory species being present. Introduced trout are present in Kohangatera but not in Kohangapiripiri. Both lakes have very low abundance of eels compared to historical times. and other comparable areas.
- Remediation of the Kohangapiripiri culvert in order to reinstate native fish passage, while also excluding the potential of invasion by sea-run salmonids is possible. In addition to culvert remediation, intervention on the beach in the form of channel-cutting will likely be necessary during key fish migration periods (late summer/autumn for adult eel emigration and spring for galaxiid and glass eel immigration) to facilitate fish passage.
- A number of future management initiatives are likely to promote protection and restoration of the native fish biodiversity of the Parangarahu Lakes, including culvert monitoring, species monitoring and biosecurity measures.

2. Background

The Parangarahu Lakes comprise two coastal lakes – Lake Kohangapiripiri and Lake Kohangatera – located on the south coast of the North Island, around ten kilometres from Wellington. Lake Kohangapiripiri is the smaller of the two, with 13 ha of open water and a catchment of 280 ha, compared with the 17 ha open water and 1700 ha catchment size of Kohangatera.

Over the past 100 years, the lakes have become progressively more cut off from the sea (Figure 1). The land barrier between the coastal road (which crosses the outflow paths of both lakes) and the sea can be predominantly attributed to natural processes such as uplift and deposition, while the build-up of material upstream of the coast road (which is also contributing to the separation of lake and sea) is likely due to the presence of the road preventing periodic scouring during high flows.

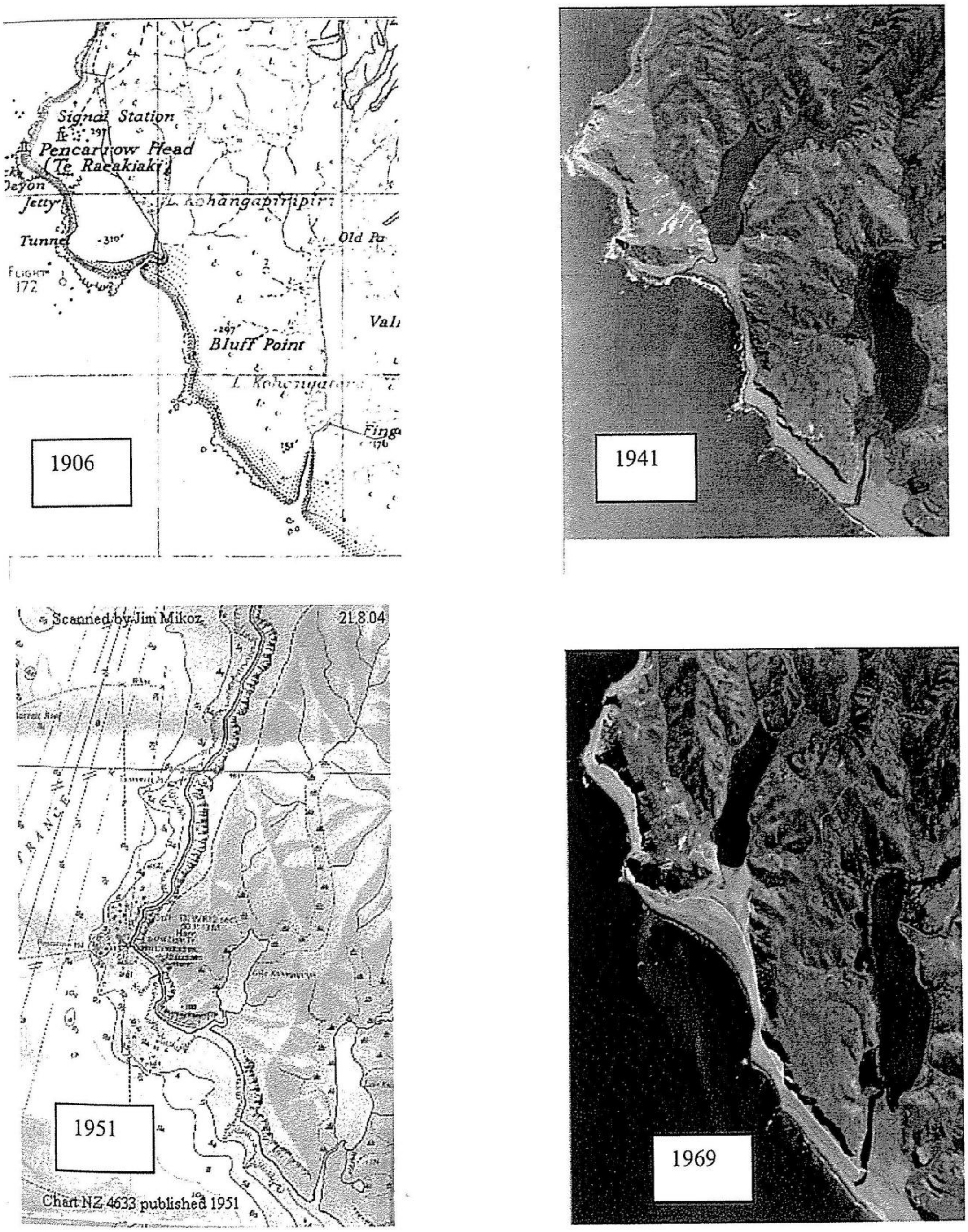

Fig 1. Historical pictures of Lake Kohangatera and Lake Kohanagapiripiri showing the outlets receding and becoming closed off to the sea. Note the road in the 1969 photo dissecting both outlets.

Partly as a result of this separation of sea and freshwater, low diversity of native freshwater fish are present in the lakes – particularly Kohangapiripiri. This is because many native species, such as eels and galaxiids, are diadromous[1] and require access between freshwater and the sea in order to complete their life cycles. Low numbers of eels (both longfin and shortfin) are likely a result of inhibited access combined with historical overfishing.

'Breaching' events (when heavy rainfall/storms cause the outlet of a lake and the sea to meet) are thought to have occurred sporadically in the recent past – more so at Kohangatera. Freshwater fish surveying conducted during recent years (see section 5) has shown that Kohangatera contains some migratory fish species, with a small range of size classes present. This indicates that there is at least sufficient interaction between the lake and the sea occurring to facilitate the persistence of potentially viable populations of migratory native fish. This is particularly so at present, due to a large storm event in June 2013 which opened up the mouth and beach.

Kohangapiripiri on the other hand, was not impacted by the storm in the same way and this lake breaches much less frequently. The freshwater fish fauna present in the lake indicates that immigration is not sufficient to maintain resident populations of migratory native fish. In particular, inanga and kōkopu species are not thought to be present in Kohangapiripiri. In addition, downstream-migrating eels are usually not able to reach the sea due to extensive gravel build-up on the beach resulting in the stream going underground. This can result in the deaths of migratory eels (Figure 2). Given these factors, the outflow area of Kohangapiripiri requires urgent management intervention if the restoration of native fish biodiversity is desired.

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[1] A diadromous fish is one that is migratory. Three broad types of diadromy are recognised: 1) Catadromy, which describes growth in freshwater and migration to the sea to spawn (e.g. eels); 2) Anadromy, which describes growth in the sea and migration into freshwater to spawn (e.g. lamprey); 3) Amphidromy, which describes growth and spawning in freshwater, followed by a brief juvenile period spent in the sea.

Figure 2. Dead migratory shortfin eels (tuna heke) that were found at the southern end of Lake Kohangapiripiri (significantly upstream of the culvert) in Autumn 2013. (Photo: Shyam Morar, Greater Wellington Regional Council).

3. Aim and scope of this report

This report consists of reporting and discussion related to the management of native fish populations in the Parangarahu Lakes. It is made up of the collection of relevant background information from key stakeholders/managers in the form of interviews, a review of all known freshwater fish surveys conducted in the lakes and recommendations for future survey/monitoring regimes, and discussion and recommendations around both the remediation of the fish passage issues at Kohangapiripiri and the future management of the fish populations of both lakes.

4. Interviews with key stakeholders

Interviews were conducted either by phone or in person and consisted of both one-on-one and group interview settings.

Note 1: To be explained at the beginning of each interview: The purpose of these interviews is to collect the views of Parangarahu Lakes stakeholders (which may have been expressed previously in other forums) and collate them into one shared location – the report associated with the above investigation. Here they will serve as necessary background information for the main purpose of the investigation which is to provide options for remediation of fish passage issues.

Note 2: Interviews will be conducted orally and the answers to most questions will include discussion; further explanations of questions will be supplied as needed on an ad-hoc basis.

Note 3: The phrase 'the lakes' noted in questions refers to the watershed including Lake Kohangapiripiri, Camerons Stream, Lake Kohangatera, Gollans Stream and Butterfly Creek.

Note 4: Word associations were used to 'warm up' interviewees, in particular the cognitive associations they have in relation to the ecology of the lakes.

4.1. Interview questions

- Word association: what are the first three words that come to mind when you hear the words "Parangarahu Lakes?"
- Word association: what is the first animal species that comes to mind when you hear the words "Parangarahu Lakes?"
- Word association: what is the first plant species that comes to mind when you hear the words "Parangarahu Lakes?"
- In what capacity do you interact with the lakes?
- How often do you visit the lakes?

- How often do the lakes show up in your day-to-day work?
- What do you value about the lakes (why are they special to you)?
- Which of the lakes' ecosystems do you identify/interact with most?
- Do you identify/interact more with plant or animal components of the lakes ecosystems?
- What do you think is the biggest risk to the lakes' ecosystems?
- If you had unlimited funds and unlimited expertise to use in the Parangarahu Lakes area, what are the first three actions you would implement immediately?
- What are your hopes and visions for the lakes in the next decade? The next 50 years? The next 100 years?
- How do you feel about recreational use of the lakes – should it be not allowed, allowed with restrictions, or freely allowed?
- How do you feel about commercial use of the lakes – should it be not allowed, allowed with restrictions or freely allowed?
- How do you feel about cultural harvest at the lakes – should it be not allowed, allowed with restrictions or freely allowed?
- Are you aware of any commercial take of eels occurring in the Parangarahu Lakes and streams prior to 2005 (when they were closed to commercial take by (then) MFish to preserve customary take)?
- What do you think about cutting the mouth to enhance fish passage?
- There are currently three options for culvert remediation at the outflow from Kohangapiripiri being considered. Which is your preference?
    1. Do nothing
    2. Replace culvert
    3. Replace culvert and realign road
- Is there anything else you would like to discuss/get on record?

4.2 Hutt City Council

Craig Cottrill from HCC was interviewed on 29 July 2013.

Word associations: **Three words:** Pencarrow Coastal Lakes

Animal: Ducks

Plants: Raupo

Craig interacts with the lakes as a land manager – dealing with the area of land associated with the coast road and some additional areas around the lake. The lakes show up in his day to day work fairly rarely, although he visits the area around 12 times per year on average. These visits involve work areas such as roading, pest control and fencing.

Craig values the lakes as ecologically and geologically special areas. They are the only coastal lakes in the region and they contain archaeologically valuable aspects such as the dendroglyphs. Craig identifies and interacts more with the terrestrial ecology of the lakes, rather than aquatic, and identifies and interacts with plant, rather than animal components of the lakes' ecosystems.

Craig feels that the biggest threat to the lakes' ecosystems is aquatic weeds. If given unlimited funds and unlimited access to expertise, the first three management actions he would implement are: producing an Action Plan for aquatic weeds, upgrading public access, and repair/improve fencing (to prevent stock access). Craig hopes that the next decade will see work begin on the actions noted above and hopes that the next 100 years will see the lakes returned to as 'ecologically natural' a state as possible.

In terms of human use of the lakes, Craig feels that recreational and customary use should be allowed with restrictions imposed and that commercial use may also be permitted, provided that heavy restrictions were imposed. Craig feels strongly that public access will drive conservation through increasing public value of the area.

In terms of specific management options, Craig would be in favour of cutting the Kohangapiripiri mouth to enhance fish passage (he rationalised that it is already a modified environment and mouth-cutting would be attempting to 'fix what we have broken' in terms of reinstating access to migratory fish) and he feels that option three (realign road and replace culvert) is the best culvert remediation option.

4.3. Fisheries Trust

Morrie Love from the Fisheries Trust was interviewed on 31 July 2013

Word associations: **Three words:** Tradition, eels, raupo

Animal: Eels – longfin and shortfin

Plants: Raupo

Morrie interacts with the lakes as part of the Tangata Whenua – the kaitiaki of the lakes. The lakes show up in his day-to-day work approximately once a week and he visits the lakes every few months.

Morrie values the lakes because they are rare and special. He feels a strong, traditional connection to not just the lakes, but the wider Fitzroy Bay area and the 'remnant' significant places valued by Tangata Whenua. Morrie described these places as "places of peace". Morrie identifies and interacts more with the aquatic ecology of the lakes, rather than terrestrial and identifies and interacts with both animal and plant components of the lakes' ecosystems.

Morrie feels that the biggest threat to the lakes' ecosystems is aquatic weeds and algae. If given unlimited funds and unlimited access to expertise, the first three management actions he would implement are: gaining control and ownership of the upper catchments (so that the entire lakes catchments are owned by the same people), ensuring that the lake outlets provide adequate migratory fish passage, and (eco-sourced) planting and enhancing the catchment to provide shade. Morrie hopes that the next decade will see the culverts and fish passage issues resolved in a sustainable manner (i.e. that roading and other works do not depreciate any remediation work carried out). He also hopes that habitat enhancement will be carried out, to assist the restoration of populations of key fish species tuna, kōkopu and piharu (lamprey). Morrie hopes that the next 100 years will see both upper catchments well on their way to reverting to original vegetation cover (as far as is possible).

In terms of human use of the lakes, Morrie feels that recreational use should be allowed with restrictions. He noted that particular care is needed as the lakes are vulnerable to weed infestation. He feels that boats should not be permitted into the lakes unless they are operating for scientific purpose and all necessary precautions have been undertaken to avoid the spread of nuisance aquatic species. Morrie also mentioned that he would like to see walking and cycling access to the lakes improved/upgraded. With regards to commercial and customary use of the lakes, Morrie feels that the former is not really appropriate/applicable (except for the possibility of guided tours) and that the latter is not currently appropriate as the lakes are in "restoration mode"

Morrie explained that commercial take of eels did occur prior to restrictions imposed in 2005 by then MFish (closure of the lakes to commercial use in favour of cultural use). He described how commercial eel fishers from the Wairarapa would travel down periodically and fish the Wainuiomata River and the inflow streams to the Parangarahu Lakes (where they would catch mostly longfins as this is the dominant species in the streams).

In terms of specific management options, Morrie would be in favour of cutting the Kohangapiripiri mouth to enhance fish passage, although he notes that such activity would need to be carefully managed through monitoring of the changing conditions at the outflows and the beaches during key migration seasons (spring and autumn). Morrie feels that option three (realign road and replace culvert) is the best culvert remediation option and his opinion is that option two (replace culvert while leaving the road in its current alignment) may be a bit of a waste of time and money as problems will likely reoccur.

When asked if there was anything else he would like to discuss, Morrie mentioned two additional areas for thought: the beach mining situation and the position of the Seaview sewage outflow pipe. With regard to beach mining, he feels that it might be useful to attempt to assess the impacts of this activity. He notes that it removes material from the beach which would otherwise contribute to raising the beach level and further inhibiting surface flow between the lakes and the sea. Because of this, he wonders if perhaps it could be helpful in terms of maintaining migratory fish passage. With regard to the sewage outflow, Morrie noted that this may be impacting on elver migration into the lakes by creating confusing migratory cues. According to Morrie, the sewage outflow enters the sea before (in terms of inshore currents) the lakes outflows and has a greater fresh water volume (and thus greater 'scent' in the water). He wonders if it could be attracting migrating elvers into the pipe instead of into the lakes' catchments and thus contributing to the low numbers of eels in the lakes.

4.4. Department of Conservation

David Moss was interviewed on 6th August 2013

Word associations: **Three words:** weeds, recreation, duck hunting

Animal: Banded kōkopu

Plants: Hornwort

David interacts with the lakes as a biosecurity manager – preventing incursions of unwanted plant and animal species. The lakes show up in his day to day work perhaps once every three months and he visits the area approximately 2 times per year on average. These visits involve liaising with duck hunters regarding biosecurity procedures as well as participating in biodiversity management and advocacy when necessary.

David values the lakes for their natural character. They are ecologically unique to the region and come with unique political and management issues. David identifies and interacts more with the aquatic ecology of the lakes, rather than terrestrial, and identifies and interacts with both plant and animal components of the lakes' ecosystems.

David feels that the biggest threat to the lakes' ecosystems is aquatic weeds – particularly new incursions. If given unlimited funds and unlimited access to expertise, the first three management actions he would implement are: facilitating migratory fish passage, implementing weed control programs, and increasing interpretation which communicates the unique natural character of the lakes. David hopes that the next decade will see fish passage issues solved and weed control undertaken. Regarding his hopes for the next 100 years, David stressed the difficulty in knowing what to hope for given the potential impacts of factors such as climate change and earthquakes. He noted that such factors could cause changes to the lakes which would strongly influence what is appropriate in terms of restoration management.

In terms of human use of the lakes, David feels that recreational and customary use should be allowed with restrictions imposed and that commercial uses such as guided tours may also be permitted. David added that commercial use such as eel fishing was not appropriate.

In terms of specific management options, David would be in favour of cutting the Kohangapiripiri mouth to enhance fish passage and he feels that option three (realign road and replace culvert) is the best culvert remediation option. When asked if he had anything further to add, David noted that culvert remediation planning will need to take the beach mining consent into account in order to avoid possible future clashes between the two activities.

4.5. Greater Wellington Regional Council

Tim Park, Owen Spearpoint and Philippa Crisp from Greater Wellington Regional Council were interviewed as a group on 17 September 2013

Word associations: **Three words:** Wetlands (x2), kuta, turf, fish (x2), natural, birds

Animal: Kōkopu, shag, lizards

Plants: Muehlenbeckia, saltmarsh ribbonwood, pimelea

Greater Wellington Regional Council staff interact with the lakes as managers and researchers – being involved with ecological management and scientific monitoring. The number of visits they make to the lakes varies depending on staff members' roles – between once per month and 5 times per year. Similarly, the frequency with which the lakes show up in staff work programs varies between 3 times per week and around 6 times per year.

Council Staff value the lakes as near-pristine, unique coastal ecosystems which are relatively accessible. They also value the opportunity that lakes' management presents to have a close working relationship with local Iwi. Staff identify and interact with both terrestrial and aquatic ecology and interact with both animal and plant components of the lakes' ecosystems.

Council staff feel that the biggest threats to the lakes' ecosystems are aquatic weeds and nitrogen inputs. If given unlimited funds and unlimited access to expertise, the first three management actions they would implement are: gaining control and ownership of the upper catchments (so that the entire lakes catchments are owned by the same agency), removing the road that cuts off the lake outlets and eradicating aquatic weeds such as Egeria and Elodea[2]. They hope that the next decade will see the "explosion" of terrestrial vegetation regeneration and the minimisation of the risk of Egeria proliferation in Kohangatera. They also hope to see growing community engagement with the lakes.

[2] *Egeria densa* and *Elodea canadensis*

Staff hope that the next 100 years will see the area reverting to as natural a state as possible – examples were given such as schools of native fish, bushwalks filled with birdsong, pateke on the water and fernbirds in the vegetation. One staff member expressed a wish to "one day be able to eat an eel" (meaning eels would be present in sufficient numbers for them to feel responsible in consuming eel as it has been taken from a source where harvest can potentially be sustained). They also hoped that in the long term future, community value and level of interaction with the lakes will be high.

In terms of human use of the lakes, Council staff feel that recreational use should be allowed with restrictions. They note that recreational use is probably not appropriate in the water due to the risks and high values of the lakes' ecosystems, but terrestrial areas should be accessible for uses such as walking and biking. Staff feel that commercial and customary use of the lakes could be allowed with restrictions, although the former should be limited to the provision of a "wilderness experience" and would not, for example include commercial harvest of eels.

In terms of specific management options, Council staff would be in favour of cutting the Kohangapiripiri mouth to enhance fish passage, provided that this action does not significantly impact on beach/dune vegetation. They feel that option three (realign road and replace culvert) is the best culvert remediation option of those given, but note that variations on these options may turn out to be optimal and further consideration in this area is needed. They noted that they felt that replacing the culvert in its current location would be a better option than doing nothing.

4.6. Port Nicholson Block Settlement Trust

Liz Mellish from the Port Nicholson Block Settlement Trust was interviewed on 17 September 2013

Word associations: **Three words:** Eels, pristine, dendroglyphs

Animal: Eels

Plants: Raupo

Liz interacts with the lakes as chair of the governance group, Roopu Tiaki. The lakes show up in her day-to-day work approximately once a day and she visits the lakes three or four times per year.

Liz values the lakes as tāonga from her Tupuna, who lived around them and actively used them for survival. She identifies and interacts with both the aquatic and terrestrial ecology of the lakes, and identifies and interacts with both animal and plant components of the lakes' ecosystems. She noted however, that she viewed the lakes in a more holistic manner, rather than in the 'ecosystem components' mentioned in the interview questions.

Liz feels that the biggest threat to the lakes' ecosystems is people. If given unlimited funds and unlimited access to expertise, the first three management actions she would implement are: gaining control and ownership of the upper catchments (so that the entire lakes catchments are owned by the same people), restoration of the customary eel fishery, and implementation of a salaried operational role for a "Key Kaitiaki". Liz hopes that the next decade will see steady growth of the fisheries along with steady and regular interaction with the lakes by iwi members. She hopes that the next 100 years will see the lakes restored and existing in the best condition possible.

In terms of human use of the lakes, Liz feels that recreational, commercial and customary use should all be allowed with restrictions.

In terms of specific management options, Liz would be in favour of working with experts to determine whether cutting the Kohangapiripiri mouth to enhance fish passage is a good option. Of the culvert remediation options presented, Liz preferred option three (realign road and replace culvert).

When asked if there was anything else she would like to discuss, Liz wished to stress the importance of the restoration of native fish populations and reiterate that this is her highest priority.

5. Review of existing information regarding the health of fish populations in the lakes and recommendations for design of future survey and monitoring regimes.

For best-practice management of the freshwater fish communities of the Parangarahu Lakes, it is necessary to collate all relevant previous survey and research work and to design appropriate survey and monitoring regimes that will both provide standardised baseline data and enable lakes managers to monitor fish communities in an ongoing fashion. This section contains a **review of previous freshwater fish surveys** and **recommendations for future survey and monitoring design**.

5.1. Review of previous freshwater fish surveys

A number of freshwater fish surveys have been conducted in the Parangarahu Lakes. These surveys range in the area that they have targeted, such as stream, open water and wetland environments and were conducted by a variety of organisations. Some of these surveys have been recorded in the New Zealand Freshwater Fish Database and some have not.

5.1.1. Records from the New Zealand Freshwater Fish Database (NZFFD)

The NZFFD contains records for Butterfly Creek (in upper catchment upstream of Lake Kohangatera), Gollans Stream (immediately upstream of Lake Kohangatera), Lake Kohangatera and Lake Kohangapiripiri. Survey details are summarised below:

- In **1963** NIWA conducted electric fishing surveys in Butterfly Creek. They found banded kōkopu, giant kōkopu, lamprey, redfin bully and kōura.
- In **1966** NIWA observed giant bullies and giant kōkopu in Lake Kohangapiripiri (survey method is not recorded).
- In **1974** an unknown organisation captured giant kōkopu and banded kōkopu in Lake Kohangatera using fyke nets
- In **1987** Wellington Fish and Game conducted electric fishing surveys at 8 sites along Butterfly Creek and Gollans Stream. They found banded kōkopu, longfin eels and kōura in Butterfly Creek and found common bullies, redfin bullies, giant bullies, longfin eels, shortfin eels, banded kōkopu, giant kōkopu, inanga and brown trout in Gollans Stream.

- In **2002** the Department of Conservation observed common bullies and eels (not identified to species) using nets and traps in Lake Kohangatera.
- In **2002** the University of Massey entered records into the database that are detailed in 4.1.2. below (Joy and Hewitt (2002)).

5.1.2. Joy and Hewitt, Massey University (2002) – Both lakes, Gollans Stream and Butterfly Creek

Methods: In 2002, Joy and Hewitt were contracted by Greater Wellington Regional Council to conduct fish surveys at a number of sites in the Wellington Region which included Gollans Stream/Butterfly Creek (which were surveyed using electric fishing) and Lakes Kohangapiripiri and Kohangatera (which were surveyed using netting and trapping methods).

Results: Gollans Stream/Butterfly Creek contained high numbers of longfin and shortfin eels, giant kōkopu and kōura. Low numbers of common bully, banded kōkopu and brown trout were also found. Lake Kohangapiripiri contained common bullies, shortfin eels and longfin eels (only one longfin was captured however), while Lake Kohangatera contained high numbers of common bullies, along with low numbers of common smelt, inanga and shortfin eels. Examination of common bully morphology revealed that the fish found in Kohangatera were migratory (had been 'sea-run'), whereas the fish in Kohangapiripiri were non-migratory (had only occupied fresh water). Very low numbers of eels were found in Kohangatera (4 shortfins and 0 longfins across eight fyke nets). Higher numbers were found in Kohangapiripiri (19 shortfins and 1 longfin across eight fyke nets) but these numbers are still very low (i.e. average of approximately two eels per fyke net) for this type of lowland lake. The report's authors concluded that lack of recruitment caused by impaired migratory access in conjunction with overharvest of eels was responsible for the structure of the fish communities in the lakes.

5.1.3. Te Atiawa / Taranaki whanui eel survey (2002) – Kohangatera and Gollans Stream

Methods: In 2002 a group of Te Atiawa / Taranaki whanui representatives conducted an ad hoc eel survey in Gollans Stream and Kohangatera using six fykes set overnight in the stream and six fyke nets set overnight in the lake.

Results: A total of 53 eels were captured, 48 of which were longfins. Most eels were captured in the stream, with only two captured in the lake.

5.1.4. Nicholson (2004-2006) - Massey University – Kohangatera, Gollans Stream and Butterfly Creek

Background: Nicholson conducted netting and trapping in Lake Kohangatera and the outflow channel, and electric fishing and spotlighting in Gollans Stream and Butterfly Creek as part of her Master's Thesis across 2004–2006.

Lake

Methods: Baited, 5 mm Gee-minnow traps were set around the lake margins in 2004 and then again, along with fyke nets 2006 (at nine separate sites) in 2006. A 3.5 m (opening 1.3 x 1.02 m wide) 'southland sock' net was set in the breached channel of Lake Kohangatera on five occasions when the channel was open to the sea during a breach event in 2004.

Results: In order of abundance, common bully, inanga, smelt, longfin and shortfin eels and lamprey were captured in the lake and outflow channel. Both lake-locked and migratory smelt were captured.

Streams

Methods: One selected reach from each of Gollans Stream and Butterfly Creek were surveyed using the electric fishing method approximately every three months from June 2004 to September 2006. Spotlighting surveys were also carried out on three occasions, once each in 2004, 2005 and 2006.

Results: In order of abundance, longfin eel, giant kōkopu, banded kōkopu, kōaro, brown trout and redfin bully were captured in Gollans Stream. In order of abundance, banded kōkopu, longfin eel and giant kōkopu were captured in Butterfly Creek. Banded kōkopu and giant kōkopu were present in two distinct size classes which matched up with recent known breach events, indicating diadromous (sea-run) recruitment was occurring infrequently.

5.1.5. de Winton et al, NIWA (2011) – Both lakes

During the 2011 LakeSPI assessment (aquatic plant surveying), de Winton et al noted that kākahi are abundant in both lakes.

5.1.6. Perrie et al, GWRC (2013) – Kohangapiripiri

Methods: In 2013, Perrie et al from Greater Wellington Regional Council conducted a netting and trapping survey in Lake Kohangapiripiri. They set two 45 mm mesh trammel nets, one 35 mm mesh trammel net, sixteen fyke nets (coarse and fine mesh) and ten 3 mm gee-minnow traps in open water habitat as well as twenty 3 mm gee-minnow traps in wetland habitat. They also conducted spotlighting and night-seining (with a 10 m hand-held danish seine net) along the lake verges.

Results: In order of abundance, common bullies, common smelt, shortfin eels, longfin eels and kākahi were captured in the nets and traps, while common bullies and common smelt along with one kōura were observed during spotlighting and seining.

The authors noted that few eels were present in the lake and those that were present were large, indicating recruitment had not occurred for many years. They also found a number of dead migratory shortfin eels at the southern end of the lake, which may indicate that access out of the lake is no longer possible for downstream migrating fish – even eels which are renowned for their ability to travel overland (McDowall 1990). This may be a significant factor to take into account as these eels were not found near the road/culvert near the sea but at the edge of the main body of the lake, however it should be noted that this was following a very dry summer so water levels may have been lower than average. The authors conclude that the current population demographics and fish fauna indicates that migratory access is not occurring in Lake Kohangapiripiri and there does not appear to be any lake-recruitment of kōkopu species (given the high netting effort and zero-yield of these species in the lake). They go on to recommend that both surveying Cameron's Stream and setting bigger nets in the wetland areas would be of value in completing the 'picture' of the lake (e.g. are kōkopu species present?).

Table 1. Freshwater fish (and two large invertebrate) species found in the Parangarahu Lakes during surveys prior to the compiling of this document (✓* indicates that fish presence was recorded pre-1990 only)

Common name	Scientific name	Conservation status[3]	Kohangapiripiri		Kohangatera	
			Lake	Stream	Lake	Stream
Shortfin eel	*Anguilla australis*	Not threatened	✓		✓	✓
Longfin eel	*Anguilla dieffenbachii*	At risk: Declining	✓		✓	✓
Lamprey	*Geotria australis*	At risk: Declining			✓	✓*
Common bully	*Gobiomorphus cotidianus*	Not threatened	✓		✓	✓
Brown trout	*Salmo trutta*	Introduced				✓
Common smelt	*Retropinna retropinna*	Not threatened	✓		✓	
Inanga	*Galaxias maculates*	At risk: Declining			✓	✓*
Banded kōkopu	*Galaxias fasciatus*	Not Threatened			✓*	✓
Giant kōkopu	*Galaxias argenteus*	At risk: Declining	✓*		✓*	✓
Kōura	*Paranephrops planifrons*	Chronically Threatened: Gradual Decline	✓			✓
Giant bully	*Gobiomorphus gobioides*	Not threatened	✓*			✓*

[3] Conservation status is presented according to classifications at the time of writing (Hitchmough et al (2004; Allibone et al 2010)

Redfin bully	*Gobiomorphus huttoni*	At Risk: Declining				✓
Kākahi	*Echyridella menziesi*	Chronically Threatened: Gradual Decline	✓		✓	
Kōaro	*Galaxias brevipinnis*	At Risk: Declining				✓

5.2. Recommendations for future survey and monitoring design

Two options for freshwater fish survey and monitoring are presented here. These options are designed to conduct basic fish population monitoring – for discussion of monitoring associated with any structure related to fish passage remediation see section 7.1. The options outlined in this section vary according to effort expenditure and the selection of either will depend on the resources available to lakes managers at the time. The options are presented as '**basic regime**' and '**comprehensive regime**'.

5.2.1. Basic regime

A reduced regime will provide a 'snapshot' of the freshwater fish populations in the lakes at a relatively low cost. Results could be compared with subsequent snapshot surveys, although caution would need to be applied when drawing conclusions regarding differences between surveys as any differences could likely be attributable to naturally occurring variation.

Survey design

At <u>three open-water sites in each lake</u> (over one night or three closely spaced nights, with sites selected to maximise spread and coverage of both space and habitat features, while being pragmatic about access) deploy the following:

- One monofilament trammel net (30 m x 1.8 m, 45 mm mesh)
- Six fyke nets (fine mesh with exclusion chambers). If no fine mesh fyke nets are available then deploy six coarse mesh fykes and twelve gee-minnow traps (3 mm mesh).

All nets and traps should be unbaited and set in accordance with protocols described in Joy et al (2013).

Monitoring regime

Repeat surveying as described above at intervals no less than once every year if general population monitoring is the goal. Intervals may be larger depending on available resources and must be of consistent frequency and effort. Work should be conducted during the summer months to avoid both low-activity periods for fish (winter and early spring) and to avoid key eel migration times (autumn and early winter) that could confound data. The exception to this is wetland surveying, which is best carried out during winter/early spring when available habitat is maximised. However, if goals relate to the investigation of seasonal changes or factors related to reproduction then surveying can be conducted at alternative times of year.

Baseline for Cameron's Stream

Conduct at least one baseline survey of Cameron's Stream using both spotlighting and electric fishing. Two sites (with sites selected to maximise spread and coverage of both space and habitat features, while being pragmatic about access) should be surveyed according to protocols in Joy et al (2013).

5.2.2. Comprehensive regime

Open water: At three open-water sites in each lake (over one night or three closely spaced nights, with sites selected to maximise spread and coverage of both space and habitat features, while being pragmatic about access) deploy the following:

- Two monofilament trammel nets (one 30 m x 1.8 m, 45 mm mesh and one 30 m x 1.8 m, 35 mm mesh)
- Six fyke nets (fine mesh with exclusion chambers). If no fine mesh fyke nets are available then deploy six coarse mesh fykes and twelve gee-minnow traps (3 mm mesh).

All nets and traps should be unbaited and set in accordance with protocols described in Joy et al (2013).

Wetland: At three wetland sites in each lake (over one night or three closely spaced nights, with sites selected to maximise spread and coverage of both space and habitat features, while being pragmatic about access) deploy the following:

- Twelve gee-minnow traps (3 mm mesh)
- Three to six fine mesh fyke nets (with exclusion) chambers if available habitat allows

Inflow streams: In Gollans Stream and Butterfly Creek (Lake Kohangatera) and in Cameron's Stream (Lake Kohangapiripiri, depending on access), conduct the following (note that spotlighting will detect large galaxiids (adult whitebait) but may miss juvenile eels. Electric fishing on the other hand, is more likely to detect juvenile eels but may miss large galaxiids):

- **Spotlighting:** at two sites per stream (with sites selected to maximise spread and coverage of both space and habitat features, while being pragmatic about access), conduct spotlighting surveys according to Joy et al (2013).
- **Electric fishing:** at two sites per stream (the same sites as have been electric fished), conduct electric fishing surveys according to Joy et al (2013).

Kākahi surveying: Due to the importance and threatened status of kākahi, their close relationship with migratory native fish and their presence in both lakes (see section 6.3.1), it is important to include population security monitoring or at least a basic assessment of the status of current populations. At one site conduct one full kākahi survey as described in McEwan (2013).

Priorities

Where the opportunity arises to undertake some of the surveying and monitoring described here, priority should be given to baseline surveying in Cameron's Stream and kākahi population assessment. Direct monitoring of any fish remediation structure that is installed is also a priority (see section 7.1). If resources allow a more extensive monitoring effort, a more complete knowledge base would enable better informed decisions for the management of these lakes.

5.3. Equipment decontamination:

Any monitoring/sampling equipment that is used under the proposed monitoring regime should be comprehensively decontaminated prior to, and following survey, to avoid transfer of unwanted organisms (see: http://www.biosecurity.govt.nz/files/pests/didymo/didymo-whitebait-factsheet.pdf).

6. Consideration of the benefits and risks to fish populations in Lake Kohangapiripiri associated with three culvert remediation options and recommendations for culvert design that facilitates indigenous fish access while restricting exotic fish access.

Due to morphological changes to the beach caused by a significant prolonged breach event in February 2004, (as a result of a large summer storm), Lake Kohangatera now breaches more frequently. While the culvert will be creating an impediment to fish migration, the fish fauna present in the lake indicates that recruitment is occurring periodically, albeit at a reduced rate (see section 5.1). Lake Kohangapiripiri on the other hand, contains a fish fauna which indicates that migration is no longer occurring at a level to sustain indigenous fish populations in the lake (see section 5.1) and the Roopu Tiaki board members wish to address this problem (see section 4).

In 2007, Greater Wellington Regional Council commissioned a report to conduct hydrologic and hydraulic modelling in order to characterise the hydraulic conditions at each of the lakes (Templeton 2007). The report presented recommendations for the construction of enlarged culverts which would increase peak discharge rates. An increase in peak discharge rates would likely increase the frequency of breaches to the sea which would, in turn, maximise opportunities for indigenous fish to migrate into the lakes from the sea and vice versa. While all stakeholders agree that facilitating migratory access for indigenous fish is important (Greater Wellington 2012a; 2012b), interest has also been expressed by various groups in minimising opportunities for sea-run exotic fish such as salmonids (trouts and salmons) to gain access to the lakes (Greater Wellington 2012b).

This section introduces some **issues with culverts and issues with trout**, discusses three **options associated with culvert modification at the outflow of Lake Kohangapiripiri** and presents **concept design sketches for two structures** – both of which would facilitate indigenous fish passage and one which would also exclude sea-run exotic fish. **A summary of options** is also included.

6.1. Issues with culverts

Nearly half of New Zealand native freshwater fish species are diadromous (McDowall 2000) and require unimpeded passage throughout entire catchments in order to complete their life cycles. Therefore, the ability to move throughout catchments is important for native fish, and structures such as culverts often inhibit or prevent such movement. Some species, including bullies, smelt and galaxiids are able to 'land-lock' (use a lake in place of the sea for their larval phase) and both common smelt and common bullies appear to be doing this is the Parangarahu Lakes. Galaxiid species are not, however.

In terms of native fish passage, common issues with culverts include the creation of velocity barriers over laminar surfaces, predation bottlenecks whereby predatory fish inhabit the areas up and downstream of the culvert and eat the majority of fish attempting to migrate, and physical separation of the culvert mouth (perching) from the downstream bed due to erosion at the outflow point (Atkinson 2008).

Migratory juveniles are 'used' to having a wide, expansive space to move into, particularly during high flows (the condition of most river mouths in natural circumstances) – restriction of flow into a small space like a culvert can cause confusion (e.g. Figure 3).

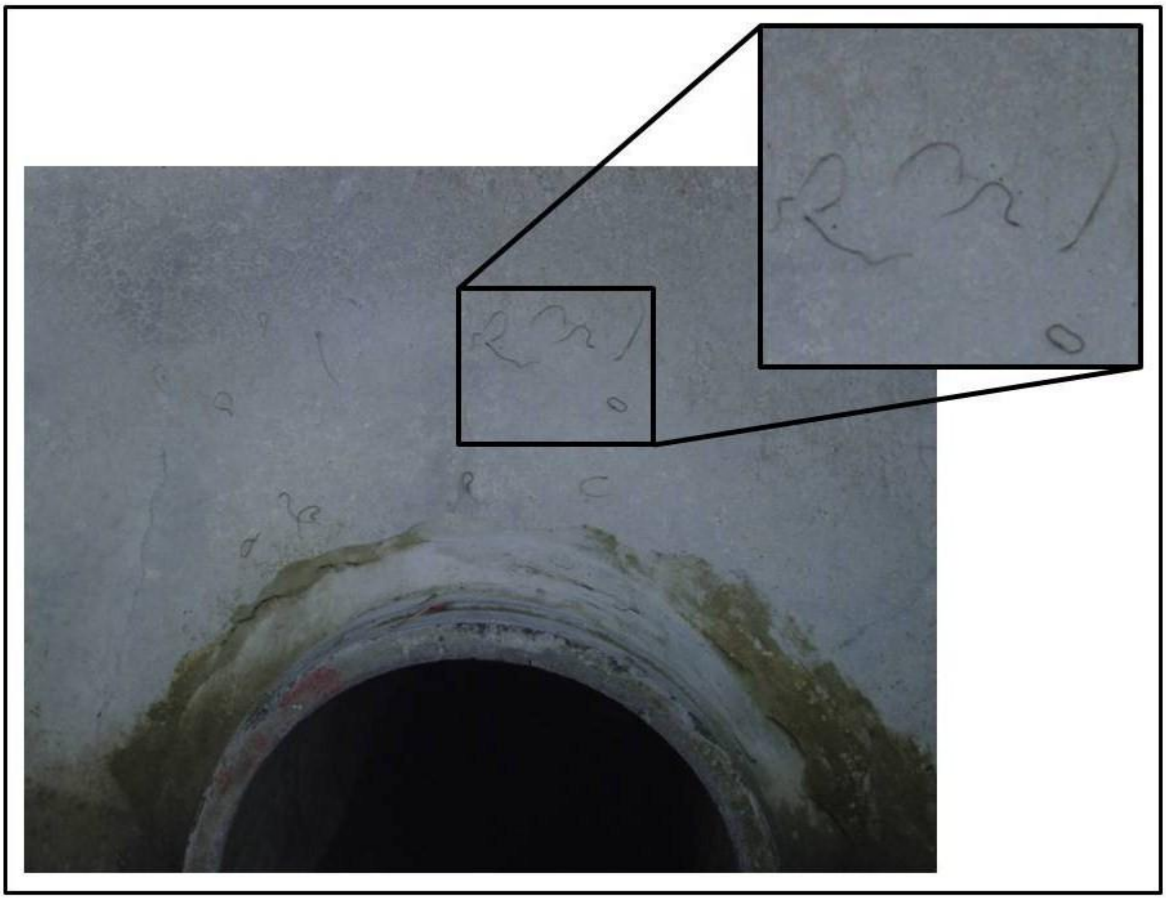

Figure 3. A pipe culvert directing the outflow of a dune wetland underneath a road into an estuary. Heavy rain occurred the night prior to this photo being taken, during which large numbers of juvenile eels apparently attempted to migrate upstream. They have been confused by the water running off the road and down the face of the culvert. When the rain stopped and the sun came out, they were trapped and desiccated (Photo: Amber McEwan).

6.2. Issues with trout

The negative impacts of salmonids on New Zealand native fish is now well documented (McDowall 1990; Glova et al 1992; McIntosh et al 1992; Townsend 1996; McDowall 2003; McDowall 2006; McIntosh et al 2010). Salmonids, primarily brown trout (*Salmo trutta*) in this case, (although salmon have been recently captured sea-running into lake Ōnoke off the Wairarapa Coast (Pers comm Liz Mellish 17 Sept 2013)) enter rivers from the sea predominantly during spring to predate on upstream-migrating whitebait and late summer to migrate upstream for spawning (Griffiths 2010). Both of these occasions coincide with native fish migration times (spring for upstream-migrating galaxiids and glass eels and late summer/autumn for downstream-migrating eels), therefore without suitable precautions being taken, the facilitation of native fish migration between the sea and Lake Kohangapiripiri will also make possible the ingress of any sea-run salmonids which may be in the area.

Brown trout are present in Kohangatera although it is uncertain whether the population originated from anadromous (sea-run) individuals or was deliberately introduced for sport fishing purposes. They can be assumed to be having negative impacts on the native fish present, given that they both predate on and compete with a range of native fish species. However, they are present only in very small numbers (see section 5.2), and there is a relatively greater amount of suitable inflow stream habitat available in the Kohangatera catchment, compared to the Kohangapiripiri catchment. From this, we could reasonably assume that if sea-run trout did gain ingress to Kohangapiripiri, then they would likely occur in low numbers only.

6.3. Options for culvert modification at Lake Kohangapiripiri

Three general options are currently under consideration for culvert remediation at the Kohangapiripiri outflow: 1) do nothing, 2) replace the existing culvert and 3) replace the existing culvert and realign the coast road. Removal of the road was not presented as an option.

6.3.1. Option one: do nothing

Currently common bullies, smelt, longfin eels, shortfin eels, kōura and kākahi are known to be present in Lake Kohangapiripiri (see section 5.1). In the absence of a large-scale natural event physically reinstating fish passage between Kohangapiripiri and the sea, both longfin and shortfin eel numbers (and any other remnant migratory species such as kōkopu) will continue to decline until they are locally extinct.

Common bullies and smelt will remain as they are able to recruit within the lake – common bullies are known to be doing this (Joy and Hewitt 2002) and smelt are assumed to be the same (given their short life spans combined with the absence of breaching events). Kōura will also be present as they are an exclusively freshwater species with no need to migrate.

The absence of migratory fish poses a unique problem for kākahi. Kākahi themselves are non-migratory however they depend heavily on migratory fish, primarily kōaro as hosts which enable them to complete their life cycle (Percival 1931)[4]. They have also been known to use common bullies as hosts (Phillips 2006) and these are plentiful in the lake, however if they are not able to use them in Lake Kohangapiripiri then kākahi may in fact be functionally extinct. Kākahi are very long-lived (up to 40 years (Grimmond 1968)), therefore an absence of recruitment will not be apparent for many years after initial recruitment failure. Recent surveying in Wairarapa Moana (McEwan 2012) has shown that, despite the presence of high numbers of common bullies in the lakes, kākahi recruitment appears to be occurring either at low levels or not at all and the authors conclude that this is mostly likely due to the absence of migratory galaxiid species such as kōaro (also due to migratory barriers). The author of this report noted that, without sufficient recruitment, kākahi will be locally extinct in Lake Wairarapa within a few decades.

In the absence of natural immigration it may be possible to artificially introduce juvenile eels into the lakes in an attempt to maintain an eel population. Without the addition of assisted emigration however (such as a trap-and-transfer type program), the lake would function simply as a population 'sink'[5] for eels and would still remain inaccessible to

[4] The kākahi lifecycle is complex and currently not well understood. While most mussels expel eggs and sperm for external fertilisation in the water, a mother kākahi keeps her eggs inside her shell to develop. She takes in sperm through her inhalant siphon and her eggs, (thus fertilised) are then held internally, in brood chambers until they develop into larvae called glochidia. These glochidia (about the size of a grain of sand) are then 'sneezed' out of their mother's exhalent siphon, whereupon they latch onto the pectoral fins, head or mouth of a passing native fish (preferably kōaro, although they have also been found on eels, giant bullies, common bullies and trout). The larvae live on the fish for a few weeks, after which they drop off. A developmental strategy like this provides a useful means of dispersal for kākahi—allowing population growth, while avoiding overcrowding.

[5] From source-sink ecological theory (Pulliam 1988), which explains the phenomenon whereby some areas can function as a 'source' of a widely distributed species (e.g. a completely protected waterway in which eels have full access to the sea along with abundant food resources on which to grow particularly large and fecund). An example of a 'sink' population would be a waterway which facilitated animal ingress but not egress (e.g. a dam with an upstream elver transfer program or a small waterway in which all/nearly all the downstream migrating eels were captured by humans).

other native species such as galaxiids. In addition, obtaining the necessary permits associated with such an activity may be problematic.

6.3.2. Option two: replace existing perched culvert with new culvert

The existing single culvert is a very small pipe which is perched on both sides. The SKM report recommends a paired box culvert structure (Templeton 2007). In terms of maximising fish passage, arch or circular culverts are preferred over box culverts as they are less likely to cause flow 'spread' which results in a wide, very shallow wetted area which fish find difficult to navigate (see NZTA 2013). In the Kohangapiripiri situation, this is particularly important due to the low flow levels usually present.

In many situations, allowing fish passage *through* a structure is the primary consideration in situations involving a culvert. In the Kohangapiripiri situation however, planning for passage *through* the culvert is less of an issue than the build-up of material at the lake outflow inhibiting access *to and from* the culvert. Nearby Kohangatera provides a useful contrast: although the culvert is larger, it is still allowing native fish migration (due to higher flows from the larger catchment that 'blow out' the beach gravels during storms). The smaller catchment of Kohangapiripiri is much less likely to produce such high flows, therefore the reinstatement of autonomous fish passage between Kohangapiripiri and the sea may not simply be achieved by replacing the culvert and will likely also require ongoing contouring of the downstream area (e.g. channel cutting).

The installation of a structure which facilitates native fish passage but excludes trout may be difficult in this particular situation, as such a structure relies on the presence of a reasonable amount of head height (or fall). The slope across the Kohangapiripiri downstream area is shallow (approximately 1.5 m (Pers comm Owen Spearpoint)). See section 6.4. for further discussion regarding this type of culvert structure.

6.3.3. Option three: realign existing road and install new culvert

An option to realign the coast road has been put forward. This would involve shifting the culvert location a small way back towards the lake and opening up some more of the beach area to wave action. This would also allow the outflow to follow a more natural path and thus potentially encourage more frequent breaching (Figure 4).

Figure 4. Proposal for road realignment at the mouth of Lake Kohangapiripiri to restore natural breaching of the lake and assist fish passage. The existing perched culvert can be seen adjacent to the existing road. Red line is road to be removed, blue line is new road, green line is existing road to be upgraded. Black rectangle is proposed new box culvert. Image courtesy of Tim Park.

Given that one of the main issues with fish passage through the culvert is lack of access to the culvert from the sea due to material build-up on the beach, it is uncertain whether moving the culvert slightly further inland will make a significant difference to this problem.

Alternative options have been put forward which will need further discussion, including the relocation of the culvert to other possible locations on the existing road.

6.4. Concept designs for culvert structure

Structure which does not exclude trout:

Given the wider issues around fish passage associated with the Kohangapiripiri outflow (see section 6.3 above), the characteristics of a 'fish-friendly' structure which does not differentiate between native and exotic fish can be simply drawn from NZTA (2013). A double arch culvert would be ideal as this type of structure allows natural substrate to remain at either end as well as inside the culvert. If this option is impractical for other reasons then a double circular culvert would also be suitable, provided that it is not perched at either end (and which will not become perched as a result of erosion). This could be avoided by the addition of small amounts of rock armouring at the outflow (Figure 5), however care would be needed that the water at low flows did not become sub-surface at the outflow as this would also prevent fish passage. The invert level of the culvert should be below the natural bed level[6]. The addition of baffles or synthetic substrate is not needed in this situation due to the short length and shallow incline of the culvert combined with the low flow levels present.

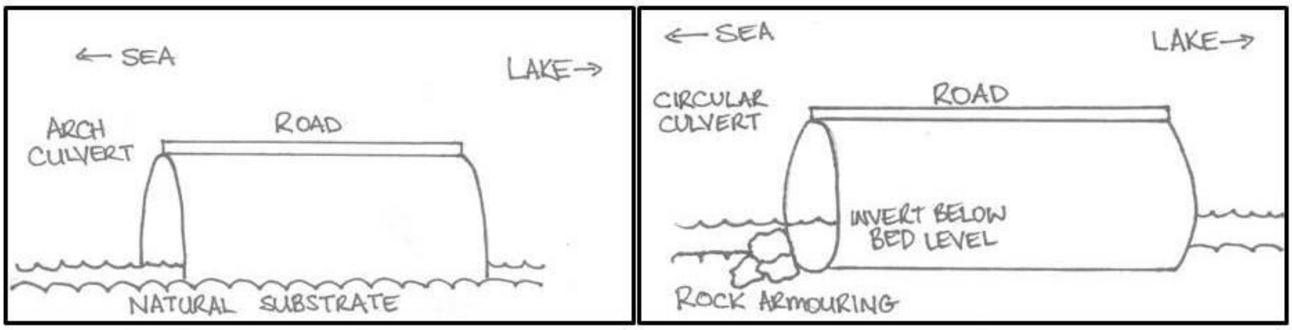

Figure 5. Concept design sketch for a culvert which will facilitate upstream and downstream movement of native fish passage...

[6] The distance between the invert of the culvert pipe and the waterway bed level should be approximately 20% of the culvert diameter (WRC 2006).

Structures which exclude trout:

In order to create a structure which facilitates the passage of one species/group and prohibits the passage of another, differences in species/group mobility are necessary. Fortunately, in New Zealand, there are large differences in climbing ability between native and exotic fish, which can be capitalised upon in situations such as the Kohangapiripiri outflow. Longfin eels and many of the galaxiid species are superb climbers (e.g. longfin eels have been observed scaling vertical surfaces 40 m high (McDowall 2012)), while introduced species, including salmonids are 'jumpers' and are completely unable to traverse vertical surfaces.

The construction of salmonid barriers to protect native fish has been attempted previously in New Zealand, mostly to isolate threatened non-migratory galaxiid populations from brown trout in the South Island (e.g. Allibone 2000; Ravenscroft et al In Press; Charters In Press and references therein). These situations are relatively simple, as the blocking off of all fish passage is the only requirement of the structure (because the species above the structure are non-migratory). There are a number of other situations in New Zealand, similar to the Kohangapiripiri situation, in that the passage of migratory native fish is still desired by freshwater managers. For example, a situation is currently being investigated in the Rotopiko/Serpentine Lakes in the Waikato. These lakes are considered to have high ecological significance and managers are attempting to create an intentional barrier which excludes exotic fish (in this case, rudd, goldfish and catfish, which are to be eradicated from the Serpentine Lakes but are also present in downstream connected lakes) but which still allows indigenous fish passage. A report was developed which discusses the functionality, pros and cons associated with several structure types (Rowe and Dean-Speirs 2009). There are two examples thus far in New Zealand in which such a structure has been specifically built: Orokonui Creek and Hamurana Spring. Managers of Orokonui Creek in Otago attempted to use gabion baskets to facilitate native fish passage and exclude exotic fish. Monitoring showed that it was not successful (Campbell in Press) and the report author recommended that the structure be removed based on observed significant declines in native fish populations above the gabion basket. Hamurana Spring is a waterbody in the Te Arawa Lakes which was recommended for the installation of a structure which block brown trout passage but facilitate that of migratory kōaro (Rowe et al 2008). The structure, utilising a weir and anti-jump grille (Figure 6), has been in place for 18 months (at the time of writing) and monitoring thus far indicates that it is functioning successfully. (see Thompson 2013).

Figure 6. The weir at Hamurana Spring (in the Te Arawa Lakes), utilising an anti-jump grille to exclude trout while allowing passage of native kōaro (Photo: Kristina Thompson).

Some successes have been made in this area using mussel spat ropes. Within culverts, fast, laminar flows can inhibit fish passage as there are no zones of negative hydraulic pressure (low-velocity zones) available where upstream-migrating fish can rest such as would exist on a natural, heterogeneous surface (Larinier 2002; Macdonald and Davies 2007). Mussel spat ropes (structurally complex bundles of UV-stabilised polypropylene yarn; Figure 7) serve to break up laminar flows and create low-velocity zones (David and Hamer 2012), thus alleviating migratory difficulty not only at the culvert-outflow interface, but also within the culvert itself.

Figure 7. Mussel spat ropes installed in a perched culvert to facilitate upstream-migrating indigenous fish passage both into and through the culvert (in Lake Harihari) Photo: Bruno David).

Mussel spat ropes have been shown to facilitate passage of indigenous fish such as banded kōkopu, eels, inanga and redfin bullies through perched culverts (David et al 2009; David and Hamer 2012) and through culverts with velocity barriers (Tonkin et al 2012)[7]. The former authors specifically recommend the use of spat ropes in situations where migratory access is inhibited to an area of high ecological value in which native fish need to be assisted but exotic fish are needed to be excluded.

[7] Video footage of fish and shrimp use of mussel spat rope in experimental culverts. Jonathan D Tonkin, Bruno O. David. View at (copy and paste into browser): figshare<http://figshare.com/>.http://dx.doi.org/10.6084/m9.figshare.695084

Option 1:

Note: This is only potentially possible as an additional structure further upstream (between the main body of the lake and road) due to insufficient fall available in the road area.

In order to avoid jumping by salmonids, it is advised to maintain a shallow area (~10 cm deep; Kondratieff and Myrick 2006) at the base of the culvert. Such an area could be formed by a concrete apron, however, with a perched structure (which is necessary to exploit the differences in climbing ability between trout and native fish), this may present a hazard to downstream migrating eels, which could land heavily and be injured. Therefore, one way to ensure a salmonid barrier is created is by the installation of a high vertical wall (≥ 2 m; Rowe and Dean-Speirs 2009) underneath the culvert outflow (Figure 8). Native fish upstream passage (for eels, along with some bully and galaxiid species) could be facilitated by spat ropes installed in the culvert (a circular culvert is needed because a box culvert is likely to spread flow too much and lessen the effectiveness of the ropes). A disadvantage of this structure is that poor climbers such as inanga would not be able to access the culvert. In addition, it seems unlikely that such a structure is able to be installed at the Kohangapiripiri outflow, due to the low level of drop available. It may be possible to install an additional weir with these characteristics upstream of the culvert where the available head height may be greater (although potentially still not great enough to facilitate the two metre drop required).

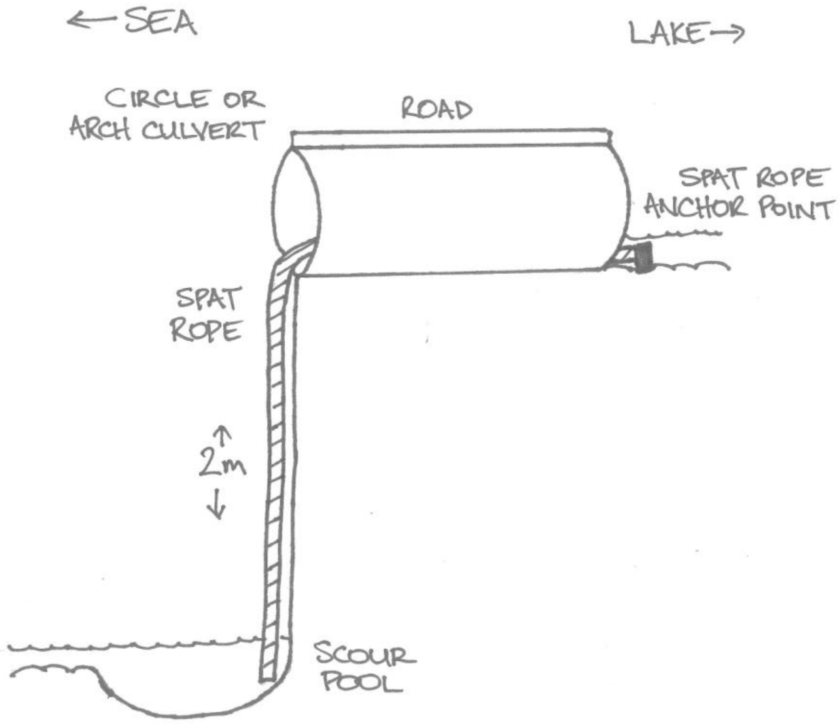

Figure 8. Concept design sketch for a culvert which will facilitate upstream and downstream movement of native fish passage while excluding upstream movement salmonids (option 1: high structure).

Option 2:

An alternative structure which would also exclude trout could use an artificially maintained shallow area (by the use of a sloped concrete ramp) at the base of the culvert combined with spat ropes to assist native passage and an overhead grille installed at the culvert mouth to prevent trout jumping (Figure 9). The grille structure inhibits jumping by acting as a ceiling (e.g. see Thompson 2013).

Using a concrete apron means that the water level can be controlled to remain shallow for a sufficient distance to prevent large jumps by trout potentially reaching the mouth of the culvert. Using a sloped apron as opposed to a vertical or horizontal surface means that less competent climbing native species, such as inanga will be able to access the culvert (a horizontal apron would necessitate a vertical lip at the culvert mouth (in order to exploit the differences in climbing ability between trout and native fish), which inanga would not be able to negotiate, even with spat ropes). In addition, a sloped apron would mean that mature eels are provided with safe passage downstream. A long, sloped apron also eliminates the possibility of a deep scour pool developing at the base of the culvert (such as with a vertical 'apron') which would allow trout to make leaps large enough to potentially land on top of the grille and then flop into the culvert.

Juvenile inanga are capable of climbing a five degree slope over a three metre distance (Doehring et al 2012), although if spat ropes are added, this slope can be increased to ten degrees and the fish are able to navigate a longer distance (David et al In Press). Use of a greater slope (around ten degrees) in the Kohangapiripiri situation will likely make it more difficult for trout to swim up the ramp (depending on the depth of the water over the ramp). Maintaining a distance of at least two metres from the downstream edge of the grille and the termination of the sloped apron will mean that any large leaps attempted from a scour pool (which will likely develop) will fall short of the grille. A slope of ten degrees will mean that the entire structure requires a fall of approximately 0.5 m, which is available at the current culvert location (Tim Park, Pers comm 1 November 2013).

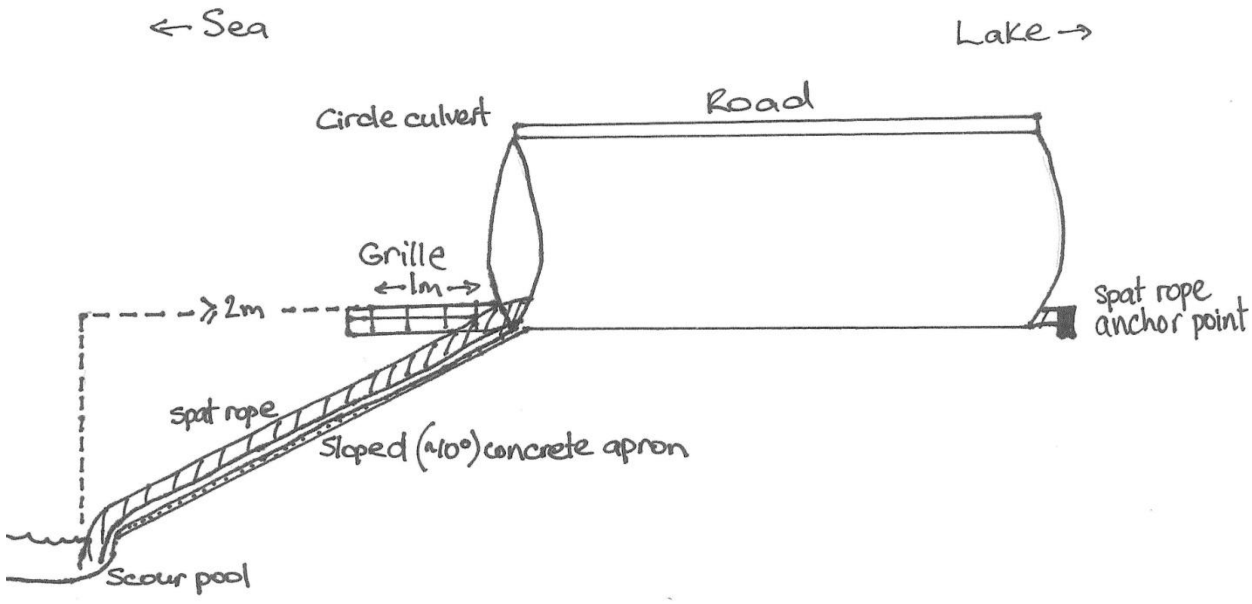

Figure 9. Concept design sketch for a culvert which will facilitate upstream and downstream movement of native fish passage while excluding upstream movement salmonids (option 2: low structure).

6.5. Summary of options

Given that the one of the main issues regarding fish passage is the build-up of material on the beach, simply replacing the culvert will not be sufficient to reinstate autonomous fish passage - ongoing engineering of the lower beach will likely be required. Realigning the road is unlikely to solve the beach build-up problem. However, increased flow velocity through a larger culvert will likely remove more material than is currently being flushed out to sea during the rare occasions that the lake does breach.

Trout are not currently present in Kohangapiripiri and it would be preferable for the status quo to remain, given the negative impacts they have on indigenous fish. The fact that the trout population in the Kohangatera catchment is small combined with the scarcity of suitable stream habitat (for residency and spawning) in the Kohangapiripiri catchment means that if trout did enter Kohangapiripiri at any time, the impact they would have may not be severe.

The structure which allows native fish passage and also excludes trout, while only requiring a minimal amount of fall (the third structure detailed above) is the preferred option (Table 2). The other structure which also excludes trout is unlikely to be able to be installed in the Kohangapiripiri situation, given the large fall that it requires. If neither of these options are selected, then a structure which allows access of native fish along with possible sea-run trout (the first structure detailed above) would be preferable to maintaining the status quo of no fish access i.e. trout will cause less 'harm' to the indigenous biodiversity of Lake Kohangapiripiri than that which is currently being caused by the lack of migratory access.

Table 2. Options for restoration of migratory native fish passage at the Lake Kohangapiripiri freshwater/sea interface

Options	**Pros**	**Cons**	**Costs**	**Other**
Do nothing	Costs nothing in time and resources Will avoid the possibility of sea-run trout invasion	Will result in no migratory native fish present in lake	nil	
Leave culvert as is and translocate desired fish species	Will avoid the possibility of sea-run trout invasion	Will result in more of a 'farming' situation than a functioning indigenous ecosystem Eels will need to be wild-caught as juveniles (can't be captive-bred) Unlikely to be able to successfully maintain migratory galaxiid populations due to difficulty of getting larvae to the sea Likely to be difficult to obtain appropriate permits	Medium/high and ongoing	

Install spat ropes in existing culvert	Cheap and easy - such culvert retrofitting has been done successfully before. **Will allow passage of some migratory native species** (longfin eels, kōaro , banded kōkopu) when surface flow connection between lake and sea is present	Unlikely to be functional very often as existing culvert is set relatively high and water does not flow through it often	Low	Will require beach cutting during key migration periods in order to allow access to culvert from the sea
Replace existing culvert with structure which allows passage of both trout and native fish	**Will allow passage of all migratory native species** (inanga, shortfin eels and giant kōkopu in addition to the better climbers) when surface flow connection between lake and sea is present Simpler than attempting to also exclude trout – structure would require less maintenance than more complex ones.	Will allow access of possible sea-run trout during high flows	Medium	Given the lack of suitable trout habitat available in the Kohangapiripiri Catchment, any trout that did manage to sea-run in would likely have a less than major impact. Very low numbers of trout are present in Kohangatera Will require beach cutting during key migration periods in order to allow access to culvert from the sea

Replace existing culvert with structure which allows native fish passage and excludes trout (option 1: high structure)	**Will allow passage of some migratory native species** (longfin eels, kōaro , banded kōkopu) when surface flow connection between lake and sea is present Will exclude sea-run trout		Medium	Will require beach cutting during key migration periods in order to allow access to culvert from the sea
Replace existing culvert with structure which allows native fish passage and excludes trout (option 2: low structure)	Will allow passage of all migratory native species (inanga, shortfin eels and giant kōkopu in addition to the better climbers) when surface flow connection between lake and sea is present Will exclude sea-run trout		Medium	Will require beach cutting during key migration periods in order to allow access to culvert from the sea
Road realignment in combination with culvert remediation options above	Will allow passage of migratory native species depending on culvert option selected May result in more frequent breaches	May allow access of sea-run trout during high flows depending on which culvert option selected May cost a lot of money and effort for little to no impact on breaching rates	High	Will likely require beach cutting during key migration periods in order to allow access to culvert from the sea

7. Recommendations for future management of native fish populations in the lakes

7.1. Monitoring of structure

Ongoing monitoring of the culvert is required to ensure that it is functioning as intended – blockages, breakdown, wear and tear or vandalism all have the potential to compromise the structure's integrity. Four main types of monitoring should be conducted at appropriate times: 1) Maintenance monitoring (e.g. to clear screens/ropes/blockages and check on functioning: 4-6 times annually); 2) Incident monitoring (e.g. following floods: as required); 3) Long-term monitoring (e.g. to assess function – the possibility of erosion, subsidence etc: 1-2 times annually); and 4) Outcome monitoring (e.g. are native fish getting through the culvert?). Outcome monitoring should be both local (involving surveying directly upstream and downstream of the culvert during key migration times) and overall (involving ongoing surveying of one or more designated sites within the Kohangapiripiri catchment to detect whether populations of native fish species are establishing and persisting).

7.2. Strategic intervention on the lower beach

In addition to uplift caused by earthquakes, large amounts of gravel are being transported down the up current river catchments (Wainuiomata and Orongorongo) and deposited on the beaches in the Parangarahu area (Pers comm Tim Park). This is contributing to the build-up of the beaches and the resultant lack of surface connectivity of the outflow streams (particularly at Lake Kohangapiripiri). This effect will be being exacerbated to by the 'dampening' of outflow strength at medium to high flows caused by the presence of the coast road (as outflows are dammed behind the road and then focussed in a narrow path through the culvert).

The beach build-up is an important factor in managing fish passage at Kohangapiripiri and in order to create/maintain surface flow connectivity between any new culvert and the sea, it will probably be necessary to mechanically cut some or all of the required channel at appropriate times. The channel will need to be inspected and re-contoured as necessary during key fish migration periods (late summer/autumn for adult eel emigration and spring for galaxiid and glass eel immigration).

It would be useful to also monitor the culvert-sea interface at Kohangatera and intervene with works if necessary.

7.3. Lakes biosecurity

The isolation of the Parangarahu Lakes has undoubtedly played a significant role in protecting them from human-mediated biosecurity incursions and future management planning should take this into account.

Aquatic plant and fish species are commonly transported in equipment associated with recreational activities such as boating, fishing and duck-shooting. Such activities are likely to be the origin of the incursions of *Egeria densa* and *Elodea canadensis* which are currently being managed in Kohangatera.

Exotic fish could also be introduced purposefully (albeit illegally) for the purposes of recreational fishing. Of particular concern in this situation is the illegal introduction of 'coarse' fish species such as perch, tench and rudd which have the potential to successfully colonise the lakes in large numbers and would likely have significant adverse effects on aquatic ecosystems. The odds of detecting such an incursion before a reasonable population has established is very low – even with intensive monitoring effort. In addition, with currently available technologies, once these species are present in a waterbody like the Parangarahu Lakes, they are virtually impossible to eradicate. The lakes are currently unusual in the North Island for being large waterbodies that do not contain any of these species. See section 6.2 for discussion on sea-run trout.

7.4. Kākahi population security

Kākahi rely on the presence of healthy native fish populations in order to reproduce (see Section 6.3.1.). Due to the long life spans of kākahi, recruitment (entrance of juveniles into a population) reduction or failure is not always obvious as a large number of adults will still be present for many years after recruitment has ceased. A number of recent studies have found such populations in various areas of New Zealand (James 1985; Rainforth 2008; McEwan 2012). A survey of the kākahi populations in the Parangarahu Lakes is needed to ascertain whether different size classes are present (recruitment is occurring) or whether individuals are all of a similar size (recruitment has ceased and population is ageing).

7.5. Active transfer of desired species

An alternative to the reinstatement of autonomous native fish passage is the active transfer of desired species (e.g. eels, galaxiids) over the culvert barrier. Gaining the relevant permits for such an activity may be complicated, although logistically it would be fairly straightforward. It is possible to obtain some galaxiid species which have been captive-bred in New Zealand, although individuals which have been reared in captivity are generally less hardy than wild-bred individuals (Theriault et al 2011; Christie et al 2012). Any eels would need to be wild-caught as juveniles as technology to successfully breed eels in captivity is not currently available.

Assisting transferred species on the journey back to the sea however, would be much more difficult, particularly with galaxiids which make this trip as larvae (McDowall 1990). Migrating eels could be captured periodically during the downstream migration season and assisted over the road and down to the sea.

7.6. Eel harvest in the future

In the future, if restoration efforts are successful, there may come a time when eel populations are at such a level that managers feel it may be appropriate to conduct recreational or cultural eel harvesting. One way of working towards the sustainable take of eels is to focus on the shortfin species (*Anguilla australis*), as they are typically much faster-growing than the longfin species (*Anguilla dieffenbachii*). Brochures which describe how to tell the difference between these species (McEwan and Joy 2013) are available from the Department of Conservation, Massey University or Riverscapes Freshwater Ecology. Any future harvest of eels in the Parangarahu Lakes should be strictly controlled and monitored to ensure that numbers remain stable. Commercial eeling will likely never be perceived as appropriate or sustainable in these waterbodies, as they are relatively small and commercial extraction at a typical scale can remove extremely high numbers of eels from small waterbodies (Jellyman and Graynoth 2005).

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9. References

Allibone RM (2000). Fish population and fish passage monitoring for Orokonui Creek, Otago. Conservation Science Notes No. 304. Department of Conservation, Wellington, New Zealand

Allibone R, David B, Hitchmough R, Jellyman D, Ling N, Ravenscroft P, Waters J (2010) Conservation status of New Zealand freshwater fish, 2009. New Zealand Journal of Marine and Freshwater Research 44: 271–287

Atkinson NK (2008). 'Rites of Passage': biotic and abiotic influences on freshwater fish migration. MSc Thesis, Massey University, Palmerston North, New Zealand

Bloxam M (2010). Rotorua Lakes kōaro restoration project. Department of Conservation internal document, indexed by Lander R, document ref: docdm-904891

Campbell C (In Press). Monitoring the effectiveness of the gabion basket in Orokonui Creek. Department of Conservation internal report, Coastal Otago Area Office, Dunedin, New Zealand

Charters, F (In Press). Waterway barrier design for protection of native aquatic values. Report prepared for the Department of Conservation. University of Canterbury, Christchurch, New Zealand

Christie MR, Marine ML, French RA, Waples RS, Blouin MS (2012). Effective size of a wild salmonid population is greatly reduced by hatchery supplementation. Herdity 109: 254–260

David, BO, Hamer MP, Collier KJ (2009). Mussel spat ropes provide passage for banded kōkopu (*Galaxias fasciatus*) in laboratory trials. New Zealand Journal of Marine and Freshwater Research 43: 883–888

David BO, Hamer MP (2012). Remediation of a perched stream culvert with ropes improves fish passage. Marine and Freshwater Research 63: 440–449

David, BO, Tonkin JD, Taipeti K, Hokianga H (In Press). Learning the ropes: Mussel spat ropes improve fish and shrimp passage. Journal of Applied Ecology

de Winton, M.; Champion, P.; Wells, R. 2011. LakeSPI assessment of the Parangarahu Lakes and Lake Pounui: with reference to management of ecological values. Prepared for Greater Wellington Regional Council. NIWA Client Report No. HAM2011-038.

Doehring K, Young R, McIntosh A2 (2012). Facilitation of upstream passage for juveniles of a weakly swimming migratory galaxiid. New Zealand Journal of Marine and Freshwater Research 46: 303–313

Gibbs, G.W. 2002. Pencarrow Lakes: Conservation values and management. Department of Conservation, Wellington Conservancy, Wellington, New Zealand

Glova GJ, Sagar PM, Naslund I (1992). Interactions for food and space between populations of Galaxias vulgaris Stokell and Salmo trutta L. In a New Zealand stream. Journal of Fish Biology 41: 909–925

Greater Wellington (2012a). Notes from Taranaki Whanui workshop, 19 September 2012. Source: Parks Planner, Corporate Planning, Greater Wellington Regional Council, Wellington, New Zealand

Greater Wellington (2012b). Notes from Parangarahu Lakes stakeholders workshop, 25 September 2012. Source: Parks Planner, Corporate Planning, Greater Wellington Regional Council, Wellington, New Zealand

Griffiths M (2010). Biology and distribution of trout in New Zealand. Wildflies article, available:http://www.wildflies.co.nz/articles/Biology%20and%20Distribution%20of%20Trout%20-%20Marc%20Griffiths.pdf

Grimmond NM (1968). Observations on growth and age in *Hyridella menziesi* (Mollusca: Bivalvia) in a freshwater tidal lake. MSc Thesis. Otago University, Dunedin, New Zealand.

Hitchmough R, Bull L, Cromarty P (2005). New Zealand Threat Classification System lists. Department of Conservation, Wellington New Zealand

James MR (1985). Distribution, biomass and production of the fresh-water mussel, *Hyridella-menzisi* (Gray), in Lake Taupo, New-Zealand. Freshwater Biology 15: 307–314

Jellyman DJ, Graynoth E (2005). The use of fyke nets as a quantitative capture technique for freshwater eels (*Anguilla* spp.) in rivers. Fisheries Management and Ecology 12: 237–247

Joy MK, Hewitt A (2002). Freshwater fish survey of selected sites for Wellington Regional Council. Report prepared for Wellington Regional Council (Document number 68190), Wellington, New Zealand

Joy MK, David BO, Lake M (2013). New Zealand freshwater fish sampling protocols. Part one: wadeable streams and rivers. Massey University, Palmerston North, New Zealand.
Available:http://www.envirolink.govt.nz/PageFiles/31/New%20Zealand%20Freshwater%20Fish%20Sampling%20Protocols.pdf

Kondratieff MC, Myrick CA (2006). How high can brook trout jump? A laboratory evaluation of brook trout jumping performance. Transactions of the American Fisheries Society 135: 361–370

Larinier M (2002). Fish passage through culverts, rock weirs and estuarine obstructions. Bulletin Francais de la Peche et de la Pisciculture 364: 119–134

MacDonald JI, Davies PE (2007). Improving the upstream passage of two galaxiid fish species through a pipe culvert. Fisheries Management and Ecology 14: 221–230

McDowall RM (1990). New Zealand Freshwater Fishes: A Natural History and Guide. Auckland, Heinemann Reed. 553 p.

McDowall RM (2000). The Reed Field Guide to New Zealand Freshwater Fishes. Auckland, Reed Books. 224 p.

McDowall (2003). Impacts of introduced salmonids on native galaxiids in New Zealand upland streams: a new look at an old problem. Transactions of the American Fisheries Society 132: 229–238

McDowall RM (2006). Crying wolf, crying foul or crying shame: alien salmonids and a biodiversity crisis in the southern cool-temperate galaxioid fishes? Reviews in Fish Biology and Fisheries 16: 233–422

McEwan AJ (2012). Wairarapa Moana kākahi survey 2012. Report for Wairarapa Moana Wetlands Group, Wellington, New Zealand.

McEwan AJ (2013). Kākahi reference and monitoring guide. Greater Wellington Regional Council, Wellington, New Zealand.

McEwan AJ, Joy MK (2013). Freshwater eels in New Zealand. Brochure printed by Massey University Press, Palmerston North, New Zealand.

McIntosh AR, Townsend CR, Crowl T (1992). Competition for space between introduced brown trout (*Salmo trutta* L.) and common river galaxias (*Galaxias vulgaris* Stokell) in a New Zealand stream. Journal of Fish Biology 41: 63–81

McIntosh AR, McHugh PA, Dunn NR (2010). The impact of trout on galaxiid fishes in New Zealand. New Zealand Journal of Ecology 34: 195–206

New Zealand Transport Authority (2013). Fish passage guidance for state highways. Public Report, ISBN 978-0-478-40716-7

Nicholson, C.A. 2008. Diversity, distribution patterns and recruitment of fish in the Lake Kohangatera catchment and the implications of breaching to the sea. Unpublished MSc thesis, Massey University, Palmerston North, New Zealand

Percival E (1931). A note on the life history of Diplodon lutulentus Gould. Transactions of the New Zealand Institute 62: 86–91. (Echyridella menziesi).

Personal Communication. Owen Spearpoint, 17 September 2013, Parangarahu, New Zealand

Personal Communication. Tim Park, 17 September 2013, Parangarahu, New Zealand

Phillips N (2006). Review of the potential for biomanipulation of phytoplankton abundance by freshwater mussels (kākahi) in the Rotorua lakes. National Institute of Water & Atmospheric Research Ltd, Hamilton, New Zealand.

Pulliam HR (1988). Sources, sinks and population regulation. American Naturalist 132: 652–661

Rainforth HJ (2008). Tiakina kia ora – protecting our freshwater mussels. MSc Thesis. Victoria University, Wellington, New Zealand.

Ravenscroft P, Bowie S, Jack D, Nelson D (In Press). Fraser Spring galaxiid restoration – review of success of trout removal and barrier installation. Department of Conservation internal publication, Wellington, New Zealand

Rowe DK, Dean-Speirs T (2009). Design of a fish barrier to prevent exotic fish entry to the Rotopiko/Serpentine Lakes: issues options and optimal designs. Report prepared for the Department of Conservation. NIWA Client Report HAM2009-079

Rowe DK, Smith JP, Grayling S (2008). Status of kōaro (*Galaxias brevipinnis*) populations in the Te Arawa lakes and options for their restoration. Report prepared for the Te Arawa Lakes Trust. NIWA Client Report HAM2008-100

Templeton J - Sinclair Knight Merz (SKM) (2007). Pencarrow lakes fish passage investigation. Report prepared for Greater Wellington Regional Council, Wellington, New Zealand

Theriault V, Moyer GR, Jackson LS, Blouin MS, Banks MS (2011). Reduced reproductive success of hatchery coho salmon in the wild: insights into likely mechanisms. Molecular Biology 20: 1860–1869

Thompson K (2013). Kōaro Monitoring July 2013. Internal Memo, Department of Conservation. File Ref NHS-08-08-03-02

Tonkin, JD, Wright LA, David BO (2012). Mussel spat ropes assist redfin bully Gobiomorphus huttoni passage through experimental culverts with velocity barriers. Water 4: 683–689

Townsend CR (1996). Invasion biology and ecological impacts of brown trout *Salmo trutta* in New Zealand. Biological Conservation 78: 13–22

Townsend CR, Crowl TA (1991). Fragmented population structure in a native New Zealand fish: an effect of introduced brown trout? Oikos 61: 347–354