ASSESSING THE HEALTH OF STEADFAST STREAM AS PART OF A RIPARIAN RESTORATION PLAN

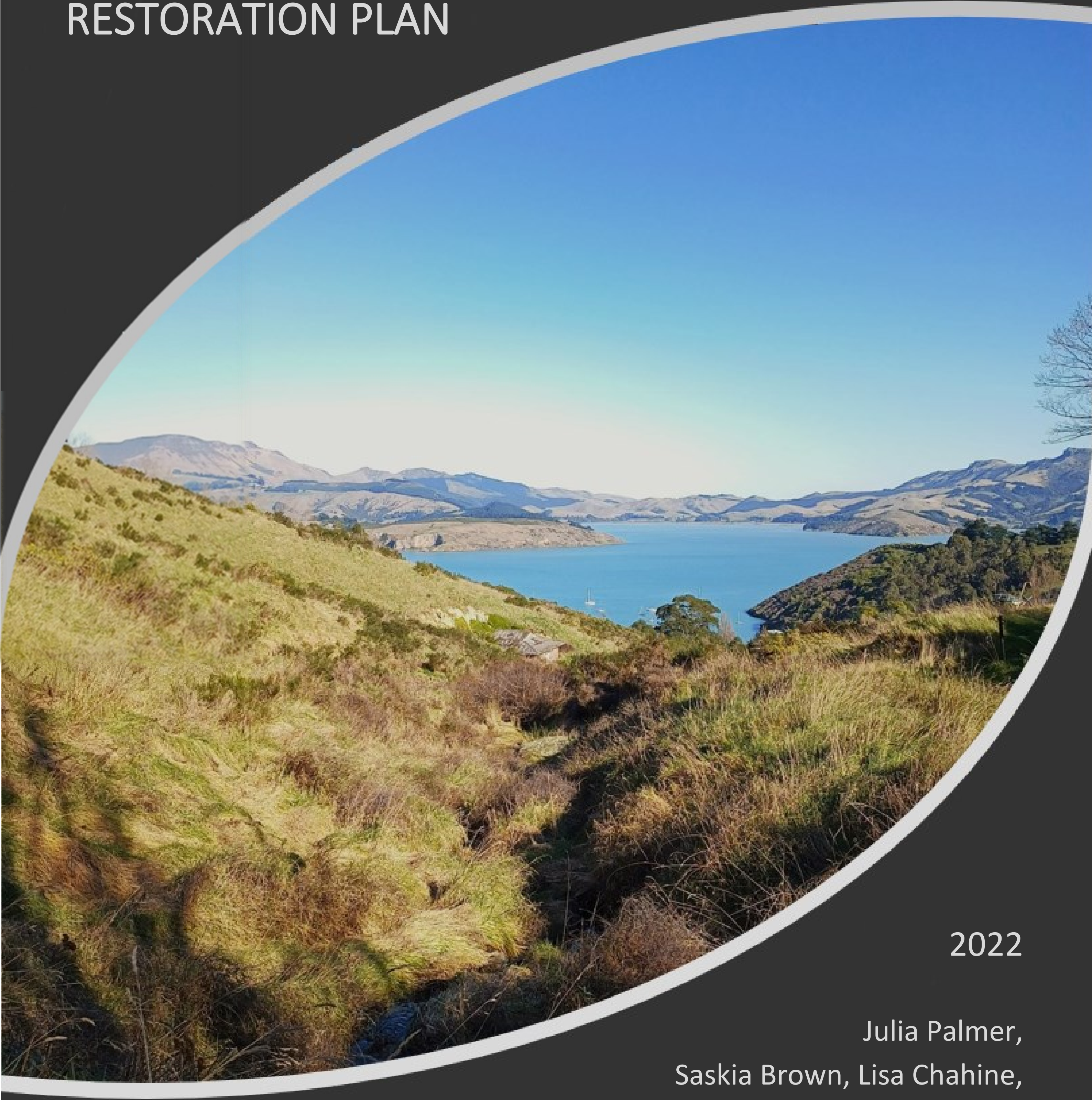

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Table of contents

1. Executive summary

Project aim
This research aimed to assess stream health and establish monitoring for Motukauatirahi Reserve to inform current and future restoration efforts. These efforts will support the long-term goals of improving water quality, native biodiversity, recreational opportunities in Motukauatirahi (Cass Bay). This project worked alongside Jenny Healey from Cass Bay Residents Association and aligns closely with the goals outlined by WhakaOra Healthy Harbour initiative.

Research question
The research question developed was "*How can we assess the health of Steadfast Stream within the Motukauatirahi Reserve to guide future restoration management and establish a long-term monitoring protocol?"* For more in-depth investigation, several subthemes were identified. They included identifying the challenges and benefits of stream restoration; utilisation of mapping in restoration; riparian planting; identifying and implementing holistic metrics of stream health; and long-term monitoring programs' importance and protocols.

Methodology
An extensive review of stream restoration literature and consultation with experts was necessary to develop freshwater sampling methodologies and a riparian planting guide. Consultation and engagement with the local community and Ngāti Wheke (local hāpu) were undertaken for all aspects of this project. Representative sampling of macroinvertebrates using habitat type was used to calculate macroinvertebrate community index. A range of water chemistry variables were measured, and habitat quality assessed. To achieve a more holistic representation we also implemented the Cultural Health Index for streams and waterways. The riparian planting plan was developed with consultation with experts, site visits, discussion with our community partner, and desktop research.

Key findings
Plant species selection will build on existing plantings as well as focuses on areas lacking current riparian vegetation. Planting close to the stream and infill planting once tree canopy establishes have been identified as priorities.

Water chemistry and turbidity within Steadfast Stream were within normal ranges. However, habitat values were low. The stream has low species richness and abundance, and the community is dominated by pollution-tolerant species. The Macroinvertebrate Community Index classified the stream as experiencing probable moderate pollution.

The Cultural Health Index identified the site as traditionally significant. Although it currently has restricted access, low mahinga kai values, and poor stream health the local rūnanga members would like to return the site to traditional use if it is restored.

Limitations
The short duration of the research project and limited resources were the main constraints. There was significant concern about sedimentation in Steadfast Stream. However, due to time constraints, quantify the sedimentation issue and instead measured turbidity (suspended sediments). More extensive data would also have allowed further GIS analysis on a catchment scale.

Recommendations and future research

The overarching recommendation is that regular and ongoing monitoring of Steadfast Stream is undertaken. Implementing the monitoring protocol established here will produce consistent and comparable results providing an indication of restoration progress through time. For future research, it is proposed that an assessment of the sedimentation issue is undertaken with a focus on finding suitable remediation options.

2. Introduction

Motukauatirahi Reserve is located above the Cass Bay residential area on the eastern slopes of the Port Hills (Figure 1). Despite being affected by past land-use including clearance of native vegetation for agriculture and development (Beaumont et al., 2014), this reserve has significant natural features including a spring feed stream, known as Steadfast Stream. Since 2020, there have been efforts to restore the stream including native plantings and control of exotic trees. Despite these restoration efforts little is known about the current conditions of the stream. Through this lack of knowledge, a project to assess stream health and guide future management was developed.

Working with our community partner, Jenny Healy, we proposed the research question: '*What is the current health of Steadfast Stream within the Motukauatirahi Reserve and how can we use this to guide future restoration management and establish a long-term monitoring protocol?'* Improving stream health through riparian planting can stabilise banks, reduces runoff, and improves cultural and recreational opportunities (Dosskey et al., 2010; Harmsworth et al., 2011). By incorporating knowledge from the community and mana whenua we can prioritise the values of the site and plan for future generations (Environmental Protection Authority, 2020). Overall, combining ecological and cultural perspectives within our research to establish a monitoring protocol to be built on in partnership to further enhance restoration.

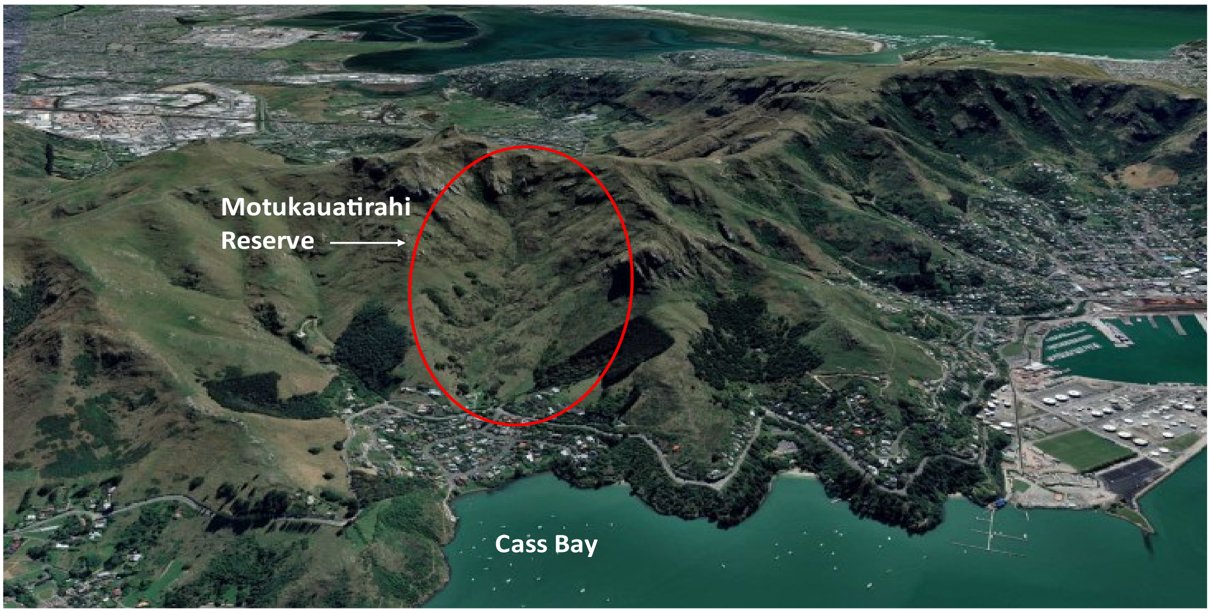


***Figure 1**. The Cass Bay area indicating the location of the Motukauaturihi Reserve (red oval) above the Cass Bay residential area. Note Lyttleton Harbour to the right and Christchurch city over the hill. Cass Bay is located on the East Coast of New Zealand's South Island.*

Aims and methods were developed based on expert consultation and review of the literature, covering topics including the use of riparian planting in stream restoration (Hogsden et al., 2021); assessing what environmental factors need to be considered when selecting plants (Feld et al., 2011); holistic metrics of stream health (Harmsworth et al., 2011); and the importance of long-term monitoring protocol (Buchanan et al., 2014). The overall aim of this project is to assess the current conditions of Steadfast stream, establish a monitoring protocol, and developed and planting plan. We achieved this through various methodological approaches including quantitative data collection and assessment of the cultural values of the site. Our results will guide future riparian planting efforts, stream monitoring, and provide recommendations for further research. Overall, this project will establish a baseline of the current condition of Steadfast Stream an effective comparison for restoration success in the future.

3. Concepts and literature review

3.1 Stream restoration

Human activities have resulted in extensive modification and degradation of freshwater environments (Parkyn et al., 2003), for example, through excess sediment inputs, altered flow regimes, and bank modification (Feld et al., 2011). Recognition of the important role waterways play in supporting biodiversity and providing ecosystem services has prompted an increased interest in restoration. Re-establishing riparian vegetation is a common method of stream restoration and is being implemented in Motukauatirahi Reserve (Hogsden et al., 2021). The riparian zone connects the terrestrial and the aquatic environments and therefore has a disproportionately large contribution to instream conditions (Collins et al., 2013). Well-established plants have a significant capacity to buffer and protect waterways (Daigneault et al., 2017; Thompson & Parkinson, 2011). Restoration efforts can have positive effects on biodiversity, for example, Jowett et al. (2009) found increases in macroinvertebrate and kōkopu abundances following stream rehabilitation. While the potential benefits of restoration are clear, there are significant challenges associated with returning an ecosystem to the desired state (Palmer et al., 1997). A key assumption of many restoration projects is that improving physiochemical attributes and habitat will result in an increase of re-establish of biodiversity; an idea known as the Field of Dreams hypothesis (i.e., “if you build it, they will come”) (Palmer et al., 1997; Parkyn & Smith, 2011). Relying on this premise is problematic as it fails to take other constraints such as dispersal or legacy effects into account and contributes to the substantial variability in the success of restoration projects (Doehring et al., 2019; Feld et al., 2011; Kail et al., 2015). It is also important to recognise the temporal component of restoration, successful projects require ongoing monitoring and investment over the long term (Lu et al., 2019).

3.2 Riparian vegetation to enhance biodiversity

Historically, Motukauatirahi Reserve would have been rich in native indigenous biodiversity (Beaumont et al., 2014). However, as reviewed previously changes in surrounding land-use through deforestation and development into agriculture have changed the landscape (Feld et al., 2011). Here we focus on the rehabilitation of the riparian zone along Steadfast Stream, which provides different environments, primarily driven by proximity to the stream and bank slope. These characteristics should be reflected in planting plans and the selection of species suited to the local environment (Feld et al., 2011; MacGibbon, 2012). This includes species that live in or near the stream enhancing instream biodiversity, as well as more distant vegetation that provides an interlink with the terrestrial environment (Feld et al., 2011). Appropriate plant selection to match the local environment is crucial for initiating the regeneration and colonisation of native biodiversity that historically inhabited the stream (Feld et al., 2011).

Retaining the aesthetic value and maximising future diversity can be enhanced by selecting species that align with historical data and sharing of indigenous knowledge (Hogsden et al., 2021). Plants selected for the site should be suited to the local environment to retain regional genetic diversity, this can be achieved by eco-sourcing seeds from Banks Peninsula (Hogsden et al., 2021). Through eco-sourcing seeds this will increase plant survival (Department of Conservation, n.d.; Parkyn et al., 2000). Steadfast stream has unique landform and substrate ranging from steep slopes, undulating banks and areas with lack of solar radiation. These areas should drive plant selection as specific plant charactersitics are needed to fit the microclimate of these areas within the reserve (Parkyn et al., 2000). The length of the riparian buffer should also be considered for the size of the stream. It is recommedened that for a small stream a riparian buffer should be greater than five meters and should be composed of a diverse selection of species with varying decomposition rates to feed instream organisms (Hogsden et al., 2021; Parkyn et al., 2000).

3.3 Metrics of stream health

Physio-chemical

Most environmental assessment and monitoring projects include water chemistry and clarity measurements. Water temperature, dissolved oxygen, conductivity, pH, and turbidity are commonly used. Water temperature is important as it influences many other variables, for example, dissolved oxygen concentrations are higher in cool water (Harding et al., 2004). In turn, water temperature is affected by other stream conditions. Elevated turbidity increases temperatures as the suspended sediment particles (e.g., clay and silt) absorb heat from the sun (Harding et al., 2004). Sedimentation is a well-recognised stressor for aquatic communities which occurs naturally but has been exacerbated by anthropogenic activities such as land clearance (Miliša et al., 2010). It degrades habitat and alters the chemical properties of the waterway (Wood & Armitage, 1997). Once in a waterway, sediment can settle or remain suspended in the water column which increases turbidity (Chapman et al., 2014). Characteristics of the stream influence sediment accumulation, Richardson and Jowett (2002) found turbidity to be higher in shallow, slow-flowing streams similar to the conditions in Steadfast Stream. Measuring turbidity (suspended particles) gives an indication of the amount of sediment which has accumulated in a waterway (Chapman et al., 2014) and can be used as a component of stream health. Additional issues arise if sediments are contaminated, for example with heavy metals. This may be reflected in the conductivity (total concentration of major ions) and influenced by water levels (Jellyman et al., 2016).

Habitat
Riparian vegetation has a strong influence over instream habitat as it regulates temperature, provides organic matter (e.g., leaf litter and branches), and increases stream heterogeneity (Doehring et al., 2019; Jowett et al., 2009). Invertebrates and fish benefit from the various habitat types in heterogeneous streams (Miller et al., 2010). For example, kōkopu and eels use undercut banks and overhanging vegetation (Jowett et al., 2009). Instream habitat is also influenced by catchment scale processes (Doehring et al., 2019), one of these large-scale impacts is sedimentation which can degrade and smother habitats (Milišа et al., 2010). There are many metrics for evaluating habitat, in New Zealand a Rapid Habitat Assessment has been developed. It visually assesses a stream based on various parameters including sediment, fish and invertebrate habitat, hydraulic heterogeneity, bank stability, and riparian characteristics.

Biological
The Macroinvertebrate Community Index (MCI) has been widely used to assess the health of New Zealand streams since the 1990s (Collins et al., 2013). Macroinvertebrates are assigned tolerance value which indicates the quality of water required for that species to survive (Parkyn & Smith, 2011). From these scores a metric of stream health can be calculated, MCI values range from 0 to 200, with greater scores indicating good water quality (Collins et al., 2013; Stark & Maxted, 2007). Biotic indexes like MCI are useful indicators as they are sensitive to long-term conditions, compared to water chemistry measurements. Invertebrate community composition is determined by physiochemical conditions, disturbance regimes, species dispersal abilities, biological interactions, and habitat availability (Wright-Stow & Winterbourn, 2003). Healthy streams with high dissolved oxygen and streambed interstices (gaps between gravels) are characterised by the presence of pollution-sensitive taxa including many Ephemeroptera, Plecoptera, Trichoptera (respectively mayflies, stoneflies, and caddisflies) (Collins et al., 2013). As stream quality decreases community composition shifts towards more tolerant species with fly larvae, worms, and snails becoming dominant (Wright-Stow & Winterbourn, 2003).

Cultural
The benefits of incorporating indigenous knowledge and values such as mātauranga Māori into traditionally western scientific practices are increasingly being recognised (Ataria et al., 2018; Harmsworth et al., 2016). Projects incorporating a cultural component can influence how the science is conducted and can improve the overall outcomes (Harmsworth et al., 2016) for example, implementing the Cultural Health Index (CHI) for Streams and Waterways developed by Tipa and Teirney (2006a). This index attempts to represent both physical and intangible aspects to reflect the fundamental concepts of interconnectedness and our role as kaitiaki (guardians) of the environment which underpins the Māori worldview (Te Ara, 2007; Tipa & Teirney, 2006a). The inclusion of cultural values provides a holistic representation meaning that restoration goals are more likely to align with outcomes desired by the community and local rūnaga.

3.4 Restoration monitoring

Monitoring the effects of restoration activities is arguably as important as the restoration itself, as it guides adaptive management and provides an indication of restoration success (Harding et al., 2004;

Miller et al., 2010). Despite this, very few projects have some form of monitoring or assessment (Bernhardt et al., 2005) primarily due to limited resources and a lack of incentive for long-term monitoring (Lovett et al., 2007; Rubin et al., 2017). One of the main reasons monitoring is such a valuable tool is that while chemical and physical conditions can be improved relatively quickly, the re-establishment of biological communities is complex and takes time (Harding et al., 2004; Palmer et al., 1997). Ideally, monitoring protocols should be developed with scientific insight, but they can be successfully implemented by community groups. In addition to the benefits outlined above, this provides an opportunity for communities to engage with the environment and restoration process (Harding et al., 2004). Establishing a baseline at the start of a restoration project will provide a valuable comparison for the future.

4. Methodology

4.1 Riparian planting plan and mapping

Riparian plant selection was subject to looking at the landscape, considering underlying geology, aspect, slope, and distance from the stream. The riparian zone of the stream will be partitioned into three sections – streamside, middle, and outer. Knowledge from experts was gathered through discussing the current vegetation and benefits of enhancing certain sections of the stream and where future plantings should be focused. From this information, a planting plan has been established. Google Earth (n.d.) and ESRI (2021) were combined to create maps that show the planting zones for riparian vegetation. GPS coordinates and reference photographs were recorded using Gaia GPS at the ten sampling sites and mapped, which may assist in the future monitoring of stream health. Catchment areas were mapped which shows other activities like the old military buildings and farming activities in the past which may guide future testing of other dissolved chemicals in the stream.

4.2 Site sampling

Ten sites along Steadfast Stream were selected based on habitat type to get an accurate representation of instream conditions. We sampled riffles, small pools, pebbles/cobbles, sediment-smothered areas, grassy sections of the stream, and small cascades. Turbidity and water chemistry including temperature, specific conductivity, dissolved oxygen, and pH were measured (dissolved oxygen meter model YSI 550A, and pH meter model YSI Pro 1030). Next, a Rapid Habitat Assessment was completed, see Appendix A for criteria and scoring. Finally, a kick-net sample was taken to collect macroinvertebrates. Samples were preserved in 70% ethanol for processing and identification in the lab. This information was used to create a species list and calculate Macroinvertebrate Community Index (MCI) using taxa sensitivity scores (Stark & Maxted, 2007). MCI is calculated as follows

$$MCI = \frac{\sum a_i}{S} \times 20$$

where S is total number of taxa present in the sample, and a_i is the tolerance score for the ith taxon.

4.3 Community interaction and Cultural Health Index

Engaging with the Cass Bay community and Ngāti Wheke was a central component of this project. We discussed historical land-use, cultural significance, and future goals for the area during scheduled meetings and in more informal settings such as community planting days. This proved invaluable when implementing the Cultural Health Index for New Zealand streams and waterways to provide a holistic assessment of stream health that incorporates Māori values and worldview. As shown in Table 1 the CHI assesses a site based on three overarching components investigating traditional significance, site access, physical stream health, and comparing past and present mahinga kai resources (see Tipa and Teirney (2006a, 2006b) for further details).

Table 1: *The three main components of the Cultural Health Index for Streams and Waterways, adapted from (Tipa & Teirney, 2006b).*

Component 1: **Site status**	Component 2: **Mahinga kai measure**	Component 3: **Stream health measure**
• Tangata whenua assign the site as traditional (A) or non-traditional (B). • Tangata whenua would return to the site in the future (1), or not (0).	• Identification of mahinga kai species (birds and plants) present at the site. • Comparison between the species present today and the traditional mahinga kai sourced from the site. • Assessment of access to the site (physical and legal). • Would tangata whenua return to the site in the future as they did in the past.	• Catchment land-use • Riparian vegetation (presence of vegetation and type e.g., indigenous, or exotic). • Use of the riparian margin • Riverbed condition/ sediment (invertebrate habitat) • Channel modification (shape and human activities) • Flow and habitat variety • Water clarity (turbidity/pollution) • Water quality
There are four possible combinations. Example, a traditional site where tangata whenua would not return is reported as A-0.	The four parts are scored 1 to 5 and averaged to give overall score	Consists of assessment of eight individual stream health indicators which are scored 1 to 5 and averaged.

5. Results and Discussion

5.1 Riparian planting plan

From assessing the current conditions of Steadfast Stream, we have created a riparian planting plan. Figure 2a gives a satellite view of the stream which has been split into three sections: outer, middle, and streamside. Figure 2b shows a cross-section of the stream showing the transition between the sections recommending small species at the streamside, shrubs in the middle section, and larger tree species in the outer section. A species list with plant qualities can be found in Appendix C. This planting plan also accommodates the proposed public access route (Rodwell et al., 2021).

Incorporating mixed riparian buffers will provide organic matter for the stream community. Different plant species have different decomposition rates, for example, cabbage trees provide a have slow decomposition rates, whereas Coprosmas provide a quick release of energy to the stream (Hogsden et al. 2021). From this we can incorporate species with varying rates of leaf decomposition throughout the riparian zone of Steadfast Stream, supporting stream macroinvertebrates (Hogsden et al. 2021). Riparian species selection can also promote bird biodiversity, particularly be incorporating large canopy species that will provide cover, perching, and nesting sites will contribute to higher bird abundance (Krejcek, 2009). Choosing appropriate plants to create habitat is important for increasing biodiversity. To enhance restoration success native plants should be eco-sourced from Banks peninsula ultimately retaining genetic diversity and local adaptations (Department of Conservation, n.d.; Parkyn et al., 2000).

Through this riparian planting plan, we have aimed to maximise future diversity and rehabilitate the aesthetic value (Hogsden et al. 2021). Appropriate plant selection to match the local environment is crucial for establishing a foundation for natural regeneration and colonisation of wider biodiversity that once thrived in these stream environments (Feld et al., 2011).

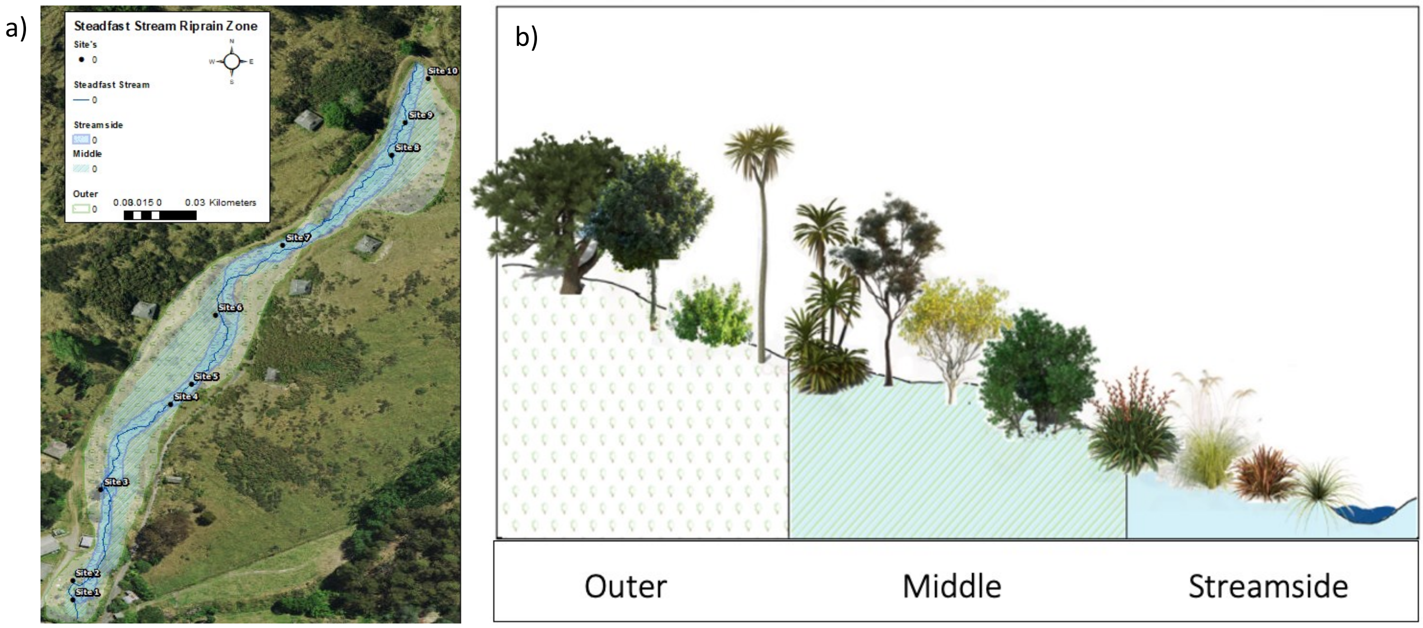


Figure 2*: a) Riparian planting zones illustrated on a map of Motukauaturihi Reserve highlighting, the streamside, middle and outer planting sections. Ten sampling sites for water chemistry and macroinvertebrate samples were taken are also incorporated on the map. To see full sizes map, refer to Appendix B. b) Illustrates the planting sections and some of the plants that can be incorporated.* selection illustrating suitable species depending on proximity to the stream.

5.2 Physiochemical

Overall, water chemistry within Steadfast Stream was within healthy parameters (Table 2 and refer to Appendix D for suitable ranges). While water temperature was not an issue as the Lyttleton side of the Harbour is relatively shady, riparian vegetation has significant ability to regulate instream temperatures (Collins et al., 2013). Once riparian vegetation has matured it will cool instream temperatures, increasing gas exchange and the amount of dissolved oxygen present in the water (Parkyn et al., 2003). These conditions will foster more suitable environments for macroinvertebrates to re-establish within Steadfast Stream. The conductivity in Steadfast Stream was not elevated, which considering the past military use and farming was surprising.

***Table 2**: Mean and standard deviation of water chemistry variables from Steadfast Stream.*

Water chemistry variable	Mean	Standard deviation
Water temperature (°C)	9.4	0.58
Dissolved oxygen %	81	0.31
Dissolved oxygen (mg/L)	11	0.63
Conductivity (µS/cm)	208	9.60
pH	6.6	0.28
Turbidity (NTU)	23.8	3.96

Suspended sediment (turbidity) was within permitted ranges (DataStream, 2021), however, streambed sedimentation was identified as a significant issue. The Lyttleton area suffers extreme sediment influxes due to the predisposition of the Port hill soils to erode (Waitaha Wai, 2020). This creates complex sediment legacies which McKergow et al. (2016) identified as a major long-term challenge in stream restoration. Suspended and settled sediment negatively affect instream habitat and aquatic biodiversity (Wood & Armitage, 1997). Figure 3 illustrates how sediment smothers benthic habitats. The sedimentation issue contributed to the poor habitat conditions identified by the Rapid Habitat Assessment (score of 51.6 – poor condition), see Appendix D for score ratings.

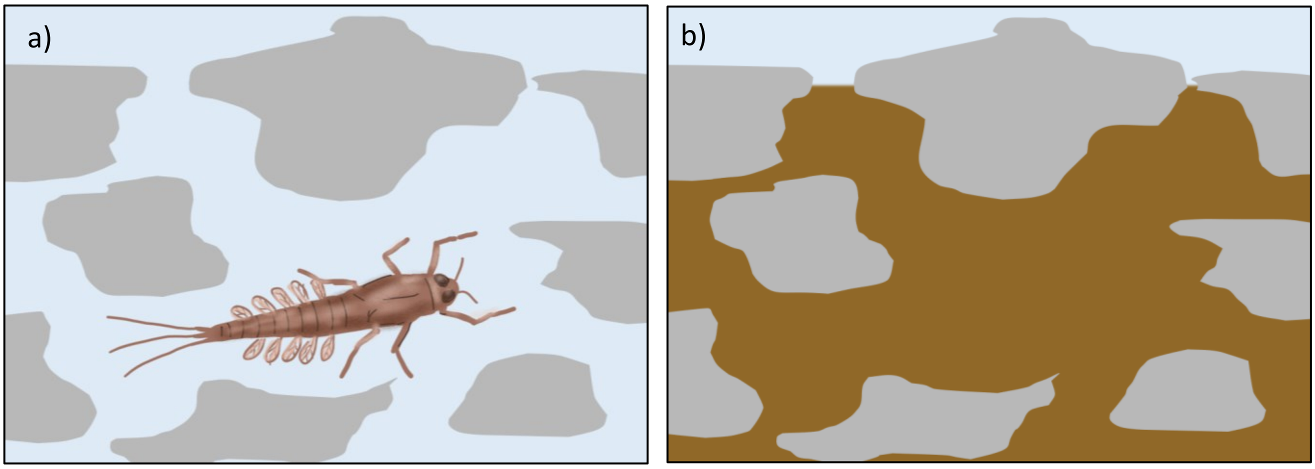


***Figure 3:** The effects of sedimentation smothering stream benthos. a) interstices between cobbles in the stream bed provide important refuges for macroinvertebrates. b) sediment infills the inter-cobble spaces.*

5.3 Biological

Steadfast Stream has a relatively low diversity and abundance of macroinvertebrates, those that are present are predominantly pollution-tolerant species. See Appendix E for the species list and tolerance scores. Using the Macroinvertebrate Community Index (MCI) outlined by Stark and Maxted (2007) the stream classifies as Fair Quality – Probable moderate pollution (MCI score of 86.7). Many ecological factors influence instream biodiversity and hinder their re-establishment following restoration. As described by Palmer et al. (2010) identifying and addressing the most limiting factor first is vital for restoration success. This study has identified poor instream habitat quality and limited dispersal to be major constraints to the re-establishment of aquatic biodiversity at the Motukauatirahi Reserve. Both constraints will require long-term efforts to overcome. As described above, sedimentation smothers the stream bed and increases turbidity in the water column. There are well-described detrimental impacts on macroinvertebrates and fish stemming from these environmental changes (Wood & Armitage, 1997). Such as damaging habitat, reducing primary productivity, impeding feeding activities, and affecting respiration (Salmaso et al., 2021; Wood & Armitage, 1997). These factors affect sensitive taxa like mayflies most strongly which is why none were present in Steadfast. The second major constraint we have identified relates to dispersal. Due to extensive land clearance, the once forested Port Hills could only support fragments of native vegetation (Wilson, 2013). This poses a challenge as species must disperse great distances to reach areas of suitable habitat. For individuals arriving at Steadfast Stream, both instream conditions and riparian vegetation are important for successful establishment, especially for those macroinvertebrates with a terrestrial adult phase (Parkyn et al., 2003). While the stream is currently surrounded primarily by long exotic grasses, once native plants become more established, conditions will be conducive to successful establishment and persistence.

5.4 Cultural Health Index

The CHI assessment found that Steadfast Stream within the Motukauatirahi Reserve is a traditional site to which rūnanga members would return. Currently, its mahinga kai values are low as there are barriers to access and most of the traditionally harvested species are absent. In the distant past, this area supplied local peoples with wood used to ignite fire using the hika ahi method. It is from this that the Māori name Motukauatirahi, meaning fire stick originates. The local rūnanga also traditionally used the area which is now Motukauatirahi Reserve to gather food and other resources like flax. Due to its location, it was an important trade and travel route over the Port Hills, joining with Rapaki track on the other side of the hill. There is interest in re-establishing this historic path over the hill in the future. In terms of stream health, Steadfast scores poorly on the Cultural Health Index. In particular, it has a degraded and sedimented streambed. As described above, siltation is one of the major factors impeding restoration efforts. Further detail on the CHI is provided in Table 3 and Appendix F.

Table 3: *Overall Cultural Health Index assessment score for Steadfast Stream. Scores calculated as outlined by (Tipa & Teirney, 2006b).*

Component 1: **Site status** Score: A-1	Component 2: **Mahinga kai measure** Score: 2.75	Component 3: **Stream health measure** Score: 1.59	
• This is a traditional site • Tangata whenua would return in the future	• There is an absence of mahinga kai species • Traditional mahinga kai species are no longer present • Barriers to access • Tangata whenua would return to the site	• Catchment land-use • Riparian vegetation • Use of riparian margin • Riverbed condition/sediment • Channel modification • Flow and habitat variety • Water clarity • Water quality	1.25 1.88 1.75 0.63 1.88 1.63 1.63 2.38

5.5 Monitoring protocol

A central goal of this project was to establish a monitoring protocol as it improves the chance of restoration success and allows adaptive management (Kail et al., 2015). We purposefully selected methods including Rapid Habitat Assessment, water chemistry, and kick-nets (macroinvertebrates) which are easy to implement and have been effectively applied by community groups in the past. As part of this project, we developed field data sheets (Appendix A) and a species list (Appendix E) that can be utilised during future monitoring. The project established a baseline against which future monitoring can be compared. We strongly encourage the Cass Bay Residents Association to implement the methods outlined and applied as part of this project and hope it improves restoration outcomes and provides insightful and educational experiences. See recommendations section for further details.

5.6 Limitations

The short duration of this research project was a significant limitation. We were unable to directly quantify the sedimentation issue, and instead measured turbidity (suspended sediment particles) as these measures are thought to be related (Chapman et al., 2014). Despite the streambed being visibly smothered by sediment turbidity was not elevated, this warrants further investigation to understand the extent of sedimentation. Our result may have been affected by precipitation, as our sampling was conducted in August, following the wettest July ever recorded (Fadaeff, 2022). Another constraint was limited high-resolution data for the area, with GIS-based techniques investigating how catchment scale processes affect sediment movement would have made a valuable contribution to this project.

6. Recommendations

6.1 Riparian planting

Utilizing the riparian plantation plan is a crucial suggestion; by putting the stated species in the designated places (streamside, middle, and outer), the restoration will be aided. Continued planting will also help banks become more stable, lessen sedimentation, and create habitat. Watering and weed control are crucial for successful establishment.

6.2 Stream health monitoring

We recommend regular (e.g., annual) monitoring of Steadfast Stream, ideally utilising the same sites sampled during this study so that results are directly comparable (GPS coordinates will be provided to the Cass Bay Residents Association). By implementing the sampling procedure outlined in our methods (and utilised during this project to establish a baseline of current conditions) the community will obtain reliable and comparable findings.

Monitoring entails regular sampling of the stream, including

- Taking water chemistry (e.g., temperature, conductivity, pH, and dissolved oxygen) and turbidity measures
- Doing a habitat assessment and calculating the RHA score
- Sampling macroinvertebrates using kick-nets and calculating MCI

As discussed in the restoration monitoring section above, monitoring is a vital component of stream restoration. Regular assessment of the stream will help the community make decisions around which restoration actions are most suited to the local conditions in Motukauatirahi Reserve and provide a measure of progress. It is particularly well suited to this project as the community are interested in the overall health of the stream and surrounding environments, not just the aesthetic value which is relatively easy to improve with planting.

6.3 Future recommendations and research

One of the major long-term challenges faced by this restoration project is sedimentation. Once riparian vegetation has become established it will minimise runoff (Collins et al., 2013). The sediment legacy remains (McKergow et al., 2016). There are several strategies for removing sedimentation, they include the creation of sediment traps, where a pool is dug into the stream and cleared regularly as sediment accumulates there (Hudson, 2002). We recommend further study into feasible approaches for managing the sedimentation challenge faced by Steadfast Stream.

Other recommendations include:

- Fish passage development in the lower catchment culvert to improve upstream migration. (Franklin et al., 2018) into Motukauatirahi Reserve.
- Calculating catchment capacity to determine the effects of poplar and willow removal on stream flow.

- Assessing the potential heavy metal soil contamination due to past military usage.
- Signage alongside the stream informing about riparian planting and instream biodiversity to encourage community engagement.

7. Conclusion

Through our assessment of Motukauatirahi Reserve, we found that Steadfast Stream and the surrounding area have experienced extensive modification and degradation. This is reflected in the low diversity of macroinvertebrates and sedimentation issues. By implementing the riparian planting plan outlined in this report terrestrial and instream conditions can be improved in the future. We also developed a monitoring protocol which we hope the Cass Bay Residents Association will continue to implement to assess the effects of restoration activities. While Motukauatirahi Reserve is currently closed to the public the creation of a walking track will provide recreational, cultural, and educational opportunities which will be improved as the health of Steadfast Stream improves. In conclusion, this area has great potential, and we hope this report contributes to improving restoration in Motukauatirahi Reserve and opening it to the public.

8. Acknowledgments

We are extremely grateful to our community partner Jenny Healey and Dr. Karen Banwell our academic supervisor for their insight and guidance during this project. We would like to thank Linda Morris, Dr. Helen Warburton, Dr. Collin Meurk, John Kottier, Lily Middleton, and Prof. Jon Hardin for their insight and assistance during this project.

9. References

Ataria, J., Mark-Shadbolt, M., Mead, A. T. P., Prime, K., Doherty, J., Waiwai, J., Ashby, T., Lambert, S., & Garner, G. O. (2018). Whakamanahia Te mātauranga o te Māori: empowering Māori knowledge to support Aotearoa's aquatic biological heritage. *New Zealand Journal of Marine and Freshwater Research*, *52*(4), 467-486. https://doi.org/10.1080/00288330.2018.1517097

Athens-Clarke County. (n.d.). *How healthy is your stream?* Athens-Clarke County Unified Government. https://www.accgov.com/DocumentCenter/View/31847/How-healthy-is-your-stream-#:~:text=A%20pH%20of%206.5%20to,pH%20of%205%20to%208.5.

Beaumont, L., Carter, M., & Wilson, J. (2014). *Banks Peninsula contextual historical overview and thematic framework*. Christchurch City Council. https://healthyharbour.org.nz/wp-content/uploads/2019/07/Beaumont-et-al-2014-Banks-Peninsula-Contextual-Historical-Overview-and-thematic-Framework.pdf

Bernhardt, E. S., Palmer, M. A., Allan, J. D., Alexander, G., Barnas, K., Brooks, S., Carr, J., Clayton, S., Dahm, C., Follstad-Shah, J., Galat, D., Gloss, S., Goodwin, P., Hart, D., Hassett, B., Jenkinson, R., Katz, S., Kondolf, G. M., Lake, P. S., . . . Sudduth, O. (2005). Synthesizing U.S. river restoration efforts. *Science*, *308*(5722), 636-637. https://doi.org/10.1126/science.1109769

Buchanan, B. P., Nagle, G. N., & Walter, M. T. (2014). Long-term monitoring and assessment of a stream restoration project in central New York. *River Research and Applications*, *30*(2), 245-258. https://doi.org/10.1002/rra.2639

Chapman, J. M., Proulx, C. L., Veilleux, M. A. N., Levert, C., Bliss, S., André, M. T., Lapointe, N. W. R., & Cooke, S. J. (2014). Clear as mud: A meta-analysis on the effects of sedimentation on freshwater fish and the effectiveness of sediment-control measures. *Water Research*, *56*, 190-202. https://doi.org/10.1016/j.watres.2014.02.047

Clapcott, J. (2015). *National Rapid Habitat Assessment Protocol Development for Streams and Rivers* (Report No. 2649). https://envirolink.govt.nz/assets/Envirolink/1519-NLRC174-National-Rapid-Habitat-Assessment-Protocol-for-Streams-and-Rivers.pdf

Collins, K. E., Doscher, C., Rennie, H. G., & Ross, J. G. (2013). The Effectiveness of Riparian 'Restoration' on Water Quality-A Case Study of Lowland Streams in Canterbury, New Zealand. *Restoration Ecology*, *21*(1), 40-48. https://doi.org/10.1111/j.1526-100X.2011.00859.x

Daigneault, A. J., Eppink, F. V., & Lee, W. G. (2017). A national riparian restoration programme in New Zealand: Is it value for money? *Journal of Environmental Management*, *187*, 166-177. https://doi.org/https://doi.org/10.1016/j.jenvman.2016.11.013

DataStream. (2021). *A Water Monitor's Guide to Water Quality*. https://datastream.org/en/guide/turbidity#content

Department of Conservation. (n.d.). *Collecting and propagating seeds*. New Zealand Government Retrieved from https://www.doc.govt.nz/get-involved/run-a-project/restoration-advice/native-plant-restoration/ecosource-seeds/#:~:text=By%20using%20ecosourced%20native%20plants,cuttings%20ensures%20wider%20genetic%20diversity

Department of Environment and Natural Resources. (n.d.-a). *Conductivity*. Government of the Northwest Territories Retrieved from https://www.enr.gov.nt.ca/sites/enr/files/conductivity.pdf

Department of Environment and Natural Resources. (n.d.-b). *Dissolved Oxygen (DO)*. Government of the Northwest Territories Retrieved from https://www.enr.gov.nt.ca/sites/enr/files/dissolved_oxygen.pdf

Doehring, K., Clapcott, J. E., & Young, R. G. (2019). Assessing the functional response to streamside fencing of pastoral Waikato streams, New Zealand. *Water (Switzerland)*, *11*(7), Article 1347. https://doi.org/10.3390/w11071347

Dosskey, M. G., Vidon, P., Gurwick, N. P., Allan, C. J., Duval, T. P., & Lowrance, R. (2010). The role of riparian vegetation in protecting and improving chemical water quality in streams. *Journal of the American Water Resources Association*, *46*(2), 261-277. https://doi.org/10.1111/j.1752-1688.2010.00419.x

Environmental Protection Authority. (2020). *Mātauranga Māori: Applying a Māori lens to environmental management*. New Zealand Government Retrieved from https://www.epa.govt.nz/community-involvement/science-corner/matauranga-maori/

ESRI. (2021). Environmental Systems Research Institute. ArcGIS Release 10.8.2 Redlands, CA.

Fadaeff, N. (2022). *Climate Summary for July 2022*. Retrieved October 3, 2022 from https://niwa.co.nz/climate/monthly/climate-summary-for-july-2022

Feld, C. K., Birk, S., Bradley, D. C., Hering, D., Kail, J., Marzin, A., Melcher, A., Nemitz, D., Pedersen, M. L., Pletterbauer, F., Pont, D., Verdonschot, P. F. M., & Friberg, N. (2011). From Natural to Degraded Rivers and Back Again. A Test of Restoration Ecology Theory and Practice. In *Advances in Ecological Research* (Vol. 44, pp. 119-209).

Franklin, P., Gee, E., Baker, C., & Bowie, S. (2018). *New Zealand Fish Passage Guidlines* (Report No. 2018019HN). NIWA and Taihoro Nukurangi. https://niwa.co.nz/static/web/freshwater-and-estuaries/NZ-FishPassageGuidelines-upto4m-NIWA-DOC-NZFPAG.pdf

Google Earth. (n.d.). [Google Earth Cass Bay location]. Retrieved October 4, 2022 from https://earth.google.com/web/@-43.60331716,172.69464293,61.51683306a,1781.0718684d,35y,-0h,0t,0r

Harding, J. S., Mosley, P., Pearson, C., & Sorrell, B. (Eds.). (2004). *Freshwaters of New Zealand*. New Zealand Limnological and Hydrological Societies, Christchurch.

Harmsworth, G., Awatere, S., & Robb, M. (2016). Indigenous Māori values and perspectives to inform freshwater management in aotearoa-New Zealand. *Ecology and Society*, *21*(4), Article 9. https://doi.org/10.5751/ES-08804-210409

Harmsworth, G. R., Young, R. G., Walker, D., Clapcott, J. E., & James, T. (2011). Linkages between cultural and scientific indicators of river and stream health. *New Zealand Journal of Marine and Freshwater Research*, *45*(3), 423-436. https://doi.org/10.1080/00288330.2011.570767

Hogsden, K., O'Brien, S., Bartlett, S., Warburton, H., Devlin, H., Collins, K., Febria, C., Goeller, B., McIntosh, A., & Harding, J. (2021). Riparian plant species offer a range of organic resources to stream invertebrate communities through varied leaf breakdown rates. *New Zealand Journal of Marine and Freshwater Research*. https://doi.org/10.1080/00288330.2021.2005637

Hudson, H. R. (2002). *Development of an in-channel coarse sediment trap best management practice*. Report FRM500. Environmental Management Associates Limited, Prepared for the Ministry of Agriculture and Forestry, Christchurch.

Jellyman, P. G., Davie, T., Pearson, C. P., & Harding, J. S. (2016). *Advances in New Zealand freshwater science*. New Zealand Hydrological Society. https://go.exlibris.link/LgwMWLfs

Jowett, I. G., Richardson, J., & Boubée, J. A. T. (2009). Effects of riparian manipulation on stream communities in small streams: Two case studies. *New Zealand Journal of Marine and Freshwater Research*, *43*(3), 763-774. https://doi.org/10.1080/00288330909510040

Kail, J., Brabec, K., Poppe, M., & Januschke, K. (2015). The effect of river restoration on fish, macroinvertebrates and aquatic macrophytes: A meta-analysis. *Ecological Indicators*, *58*, 311-321. https://doi.org/10.1016/j.ecolind.2015.06.011

Krejcek, S. (2009). Riparian Management in Taranaki - A success for native biodiversity? *Carl von Ossietzky University Oldenburg, Department of Biology and Environmental Sciences.* https://uol.de/f/5/inst/biologie/ag/landeco/download/Staff_Stahl/Arbeiten-Zweitgutachter/DIPLOMA_THESIS_Susanne_Krejcek.pdf

Lovett, G. M., Burns, D. A., Driscoll, C. T., Jenkins, J. C., Mitchell, M. J., Rustad, L., Shanley, J. B., Likens, G. E., & Haeuber, R. (2007). Who needs environmental monitoring? *Frontiers in Ecology and the Environment*, *5*(5), 253-260. https://doi.org/10.1890/1540-9295(2007)5[253:WNEM]2.0.CO;2

Lu, W., Arias Font, R., Cheng, S., Wang, J., & Kollmann, J. (2019). Assessing the context and ecological effects of river restoration – A meta-analysis. *Ecological Engineering*, *136*, 30-37. https://doi.org/10.1016/j.ecoleng.2019.06.004

MacGibbon, R. (2012). *Riparian Planting for Aquatic and Terreterial Biodiversity.* Tane's Tree Trust. Technical Article No. 9.3. https://www.tanestrees.org.nz/site/assets/files/1069/9_3_for_aquatic_and_terrestrial_biodiversity-1.pdf

McKergow, L. A., Matheson, F. E., & Quinn, J. M. (2016). Riparian management: A restoration tool for New Zealand streams. *Ecological Management and Restoration*, *17*(3), 218-227. https://doi.org/10.1111/emr.12232

Miliša, M., Živković, V., Kepčija, R. M., & Habdija, I. (2010). Siltation disturbance in a mountain stream: Aspect of functional composition of the benthic community. *Periodicum Biologorum*, *112*(2), 173-178. https://www.scopus.com/inward/record.uri?eid=2-s2.0-77958529508&partnerID=40&md5=5cc7c5608d63af7141b04add9d78df71

Miller, S. W., Budy, P., & Schmidt, J. C. (2010). Quantifying macroinvertebrate responses to in-stream habitat restoration: Applications of meta-analysis to river restoration. *Restoration Ecology*, *18*(1), 8-19. https://doi.org/10.1111/j.1526-100X.2009.00605.x

Palmer, M. A., Ambrose, R. F., & Poff, N. L. (1997). Ecological theory and community restoration ecology. *Restoration Ecology*, *5*(4), 291-300. https://doi.org/10.1046/j.1526-100X.1997.00543.x

Palmer, M. A., Menninger, H. L., & Bernhardt, E. (2010). River restoration, habitat heterogeneity and biodiversity: A failure of theory or practice? *Freshwater Biology*, *55*(SUPPL. 1), 205-222. https://doi.org/10.1111/j.1365-2427.2009.02372.x

Parkyn, S., Shaw, W., & Eades, P. (2000). Review of information on riparian buffer widths necessary to support sustainable vegetation and meet aquatic functions. *Auckland Regional Council.* http://www.aucklandcity.govt.nz/council/documents/districtplanmanukau/changes/29NIWA.pdf

Parkyn, S. M., Davies-Colley, R. J., Halliday, N. J., Costley, K. J., & Croker, G. F. (2003). Planted riparian buffer zones in New Zealand: Do they live up to expectations? *Restoration Ecology*, *11*(4), 436-447. https://doi.org/10.1046/j.1526-100X.2003.rec0260.x

Parkyn, S. M., & Smith, B. J. (2011). Dispersal constraints for stream invertebrates: Setting realistic timescales for biodiversity restoration. *Environmental Management*, *48*(3), 602-614. https://doi.org/10.1007/s00267-011-9694-4

Richardson, J., & Jowett, I. G. (2002). Effects of sediment on fish communities in East Cape streams, North Island, New Zealand [Article]. *New Zealand Journal of Marine and Freshwater Research*, *36*(2), 431-442. https://doi.org/10.1080/00288330.2002.9517098

Rubin, Z., Kondolf, G. M., & Rios-Touma, B. (2017). Evaluating stream restoration projects: What do we learn from monitoring? *Water (Switzerland)*, *9*(3), Article 174. https://doi.org/10.3390/w9030174

Salmaso, F., Espa, P., Crosa, G., & Quadroni, S. (2021). Impacts of fine sediment input on river macroinvertebrates: the role of the abiotic characteristics at mesohabitat scale. *Hydrobiologia*, *848*(18), 4189-4209. https://doi.org/10.1007/s10750-021-04632-8

Stark, J. D., & Maxted, J. R. (2007). *A user guide for the Macroinvertebrate Community Index* (Report No. 1166). https://environment.govt.nz/assets/Publications/Files/mci-user-guide-may07.pdf

Sullivan, S. M. P., Watzin, M. C., & Hession, W. C. (2004). Understanding stream geomorphic state in relation to ecological integrity: Evidence using habitat assessments and macroinvertebrates. *Environmental Management*, *34*(5), 669-683. https://doi.org/10.1007/s00267-004-4032-8

Te Ara. (2007). *Te Ao Mārama - the natural world*. Te Ara - the Encyclopedia of New Zealand. Retrieved September 29, 2022 from https://teara.govt.nz/en/te-ao-marama-the-natural-world/page-2

Thompson, R., & Parkinson, S. (2011). Assessing the local effects of riparian restoration on urban streams. *New Zealand Journal of Marine and Freshwater Research*, *45*(4), 625-636. https://doi.org/10.1080/00288330.2011.569988

Thriving Southland. (n.d.). DIY Stream Health Monitoring https://www.thrivingsouthland.co.nz/diy-stream-health-monitoring/

Tipa, G., & Teirney, L. (2006a). *A Cultural Health Index for Streams and Waterways: A tool for nationwide use* (Prepared for the Ministry for the Environment). https://environment.govt.nz/assets/Publications/Files/cultural-health-index-for-streams-and-waterways-tech-report-apr06.pdf

Tipa, G., & Teirney, L. (2006b). *Using the Cultural Health Index: How to assess the health of streams and waterways*. https://environment.govt.nz/assets/Publications/Files/chi-for-streams-and-waterways-feb06-full-colour.pdf

Waitaha Wai. (2020). Section 4: Discovering your local waterway - Banks Peninsula/Horomaka. https://www.ecan.govt.nz/education

West, A. C. (2019). *Stream invertebrates of Banks Peninsula, New Zealand* [Master's thesis, University of Canterbuy]. http://dx.doi.org/10.26021/7034

Wilson, H. D. (2013). *Plant Life on Banks Peninsula*. Manuka Press.

Wood, P. J., & Armitage, P. D. (1997). Biological effects of fine sediment in the lotic environment. *Environmental Management*, *21*(2), 203-217. https://doi.org/10.1007/s002679900019

Wright-Stow, A. E., & Winterbourn, M. J. (2003). How well do New Zealand's stream-monitoring indicators, the macroinvertebrate community index and its quantitative variant, correspond? *New Zealand Journal of Marine and Freshwater Research*, *37*(2), 461-470. https://doi.org/10.1080/00288330.2003.9517180

10. Appendices

Appendix A

Data sheet developed for sampling Steadfast Stream. Rapid habitat assessment adapted from Clapcott (2015).

Date: ____/ ____/____

Steadfast Stream Monitoring

Site #: _______ **GPS Coordinates:** ________________________________ **Team:** ______________________________

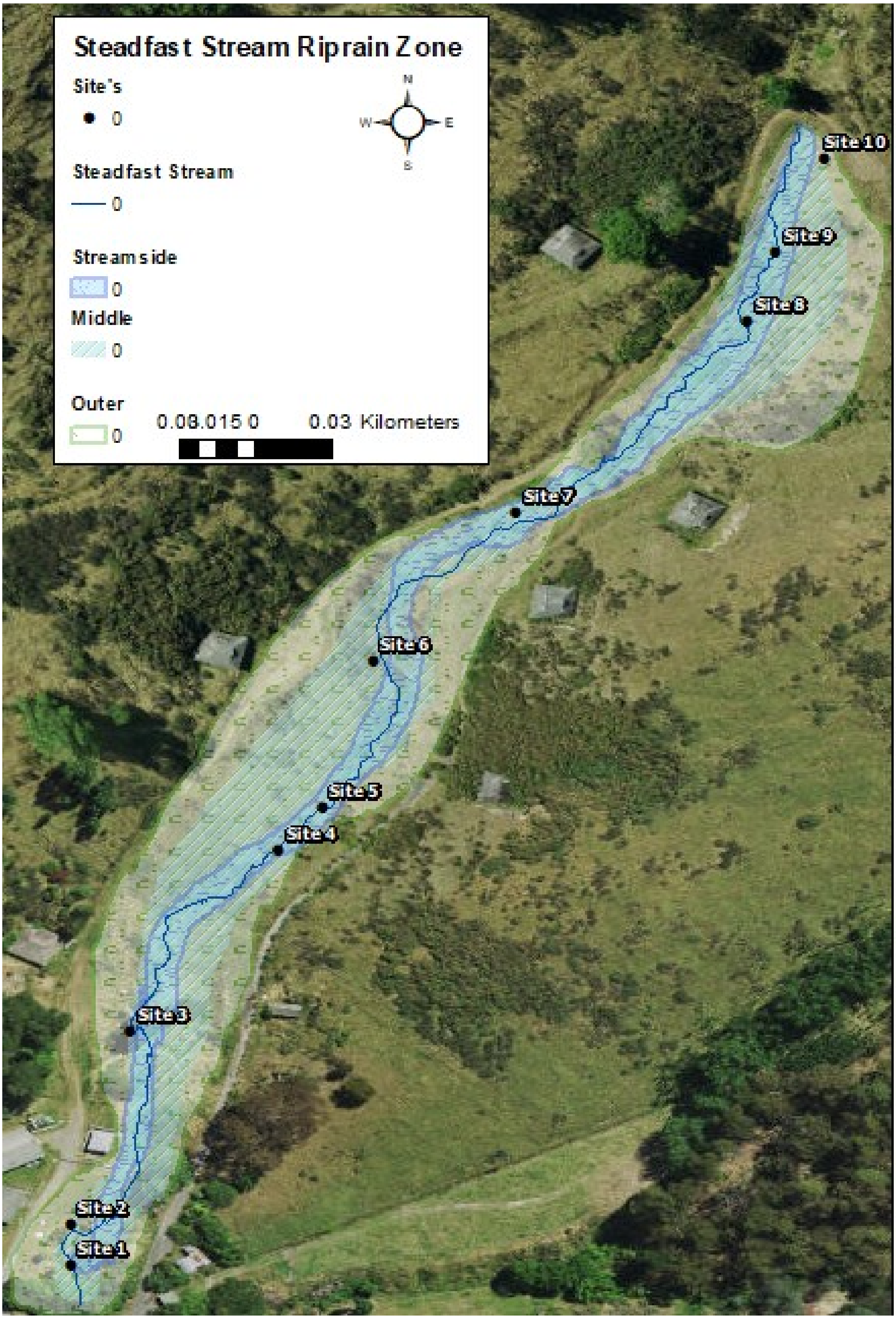
WATER CHEMISTRY	
Temperature	
Dissolved O2 (mg/L) & % saturation	
Specific conductivity	
pH	
Turbidity (NTU)	

NOTES (e.g., weather conditions, rainfall over last few days, anything else notable):
____
____
____
____

RAPID HABITAT ASSESSMENT											
Habitat parameter	Condition category										SCORE
Deposited sediment	*The percentage of the stream bed covered by fine sediment*										
	0	5	10	15	20	30	40	50	60	≥ 75	
SCORE	10	9	8	7	6	5	4	3	2	1	
Invertebrate habitat diversity	*The number of different substrate types such as boulders, cobbles, gravel, sand, wood, leaves, root mats, macrophytes, periphyton. Presence of interstitial space score hight.*										
	0	5	10	15	20	30	40	50	60	≥ 75	
SCORE	10	9	8	7	6	5	4	3	2	1	
Invertebrate habitat abundnace	*The percentage of substrate favourable for EPT colonisation, for example water flowing over gravel-cobbles clear of filamentous algae/macrophytes*										
	0	5	10	15	20	30	40	50	60	≥ 75	
SCORE	10	9	8	7	6	5	4	3	2	1	
Fish cover diversity	*The number of different substrate types such as woody debris, root mats, undercut banks, overhanging vegetation, macrophytes, boulders, cobbles. Presence of substrates proving spatial complexity score higher.*										
	0	5	10	15	20	30	40	50	60	≥ 75	
SCORE	10	9	8	7	6	5	4	3	2	1	
Fish cover abundance	*The percentage of fish cover available.*										
	0	5	10	15	20	30	40	50	60	≥ 75	
SCORE	10	9	8	7	6	5	4	3	2	1	
Hydraulic heterogeneity	*The number of hydraulic components such as pool, riffle, fast run, slow run, rapid, cascade/waterfall, turbulence. Presence of deep pools score higher.*										
	0	5	10	15	20	30	40	50	60	≥ 75	
SCORE	10	9	8	7	6	5	4	3	2	1	
Bank erosion	*The percentage of the stream bank recently/actively eroding due to scouring at the water line, slumping of the bank or stock plugging.*										
	0	5	10	15	20	30	40	50	60	≥ 75	
SCORE	10	9	8	7	6	5	4	3	2	1	
Bank vegetation	*The maturity, diversity, and naturalness of bank vegetation.*										
	0	5	10	15	20	30	40	50	60	≥ 75	
SCORE	10	9	8	7	6	5	4	3	2	1	
Riparian width	*The width (m) of the riparian buffer constrained by vegetation, fence or other structure (s).*										
	0	5	10	15	20	30	40	50	60	≥ 75	
SCORE	10	9	8	7	6	5	4	3	2	1	
Riparian shade	*The percentage of shading of the stream bed throughout the day due to vegetation, banks or other structure(s).*										
	0	5	10	15	20	30	40	50	60	≥ 75	
SCORE	10	9	8	7	6	5	4	3	2	1	
TOTAL	Sum of habitat parameters										

Appendix B

Riparian planting zones alongside Steadfast Stream, used in the riparian planting plan. Streamside (blue), Middle (darker green), and Outer (light green).



Appendix C

Planting species list developed for riparian planting plan. Abbreviations Streamside (S), Middle (M) and Outer (O) indicate proximity to the Steadfast Stream.

Table 4: Tree species

TREE SPECIES	COMMON NAME	ZONE PLACEMENT	USES
Kunzea robusta	Kanuka	M/O	Early successional species.
Dodanaea viscosa	Ake Ake	M	Shrub and lowland forest.
Griselinia littoralis	Broadleaf/kapuka	M/O	Lowland forest to subalpine scrub.
Hoheria angustifolia	Narrow-leaved lacebark	M	High banks and dry areas of riparian edges.
Myoporim laetum	Ngaio	M/O	Open areas in grasslands, scrub, riparian habitat
Pittosporum eugenoides	Lemonwood	M/O	Riparian margins, undulating margins.
Podocarpus totara	Totara	O	Shaded in juvenile phase.
Prumnopitys taxifolia	Matai	O	Drier climates and flooded water soils with dry summer.
Pseudopanax crassifolius	Lancewood	M/O	Low land, scrub land, dry ridges, poor soil.
Sophora microphylla	Kowhai	M/O	Nitrogen fixer, suitable for planting near limestone outcrops.
Cordyline australis	Cabbage Tree/ Ti Koura	S/M	Riparian terraces, forest margins, riverbanks, open areas.
Carpodetus serratus	Marble Leaf/Putaputaweta	M	Secondary forest species, stream sides and forest margins.
Pittosporum tenuifolium	Black mapou/Kohuhu	M	Early successional species, in shrublands and forested habitat.
Myrsine australis	Red matipo	M	Regenerates in mature forest.
Pseudopanax arboreus	Five Finger	M	Secondary forest species.

Dacrycarpus dacrydiodes	Kahikatea	O	Frequently flood and poorly drained soils.
Melicytus ramiflorus	Mahoe	M	Forests, forest margins and stream sides.
Aristotelia serrata	Wine Berry	M	Lowland forest, less common in drier areas.
Leptospermum scoparium	Manuka	M/O	Low nutrient soils.
Plagianthus regius	Lowland ribbonwood	M	Low land forest, tolerates dry exposed sites, riparian edge.

Table 5: Shrub species

SHRUB SPECIES	COMMON NAME	ZONE PLACEMENT	USES
Coprosma propinqua	Mingimingi	M	Swampy forest, scrub and stream banks, stony areas.
Coprosma robusta	Karamu	M	Shrublands and open forest areas.
Coprosma rotundafolia	Round Leaf Coprosma	M	Riparian and shrubland areas.
Macropiper exelsum	Kawakawa	M	Damp shady, well drained forest.
Myrsine australis	Red matipo	M	Regenerates in mature forest
Veronica salicifolia	Koromiko	M	Open sites/forest with moist soils
Schefflera digitata	Seven Finger	M	Damp forest areas and stream banks
Pennantia corymbosa	Kaikomako	M	Scrub and forest edges
Olearia paniculata	Akiraho	M	Dry woodland
Plagianthus divaricatus	Swamp ribbonwood	S/M	Swamp areas or damp gravelly places
Coprosma pedicellata	-	M/S	Tolerant to water logging and can be found growing in water, moist forest
Coprosma dumosa		M	Damp, semi-shaded areas
Myrsine divaricata	Weeping matipo	M	Semi-shade or full sun

Table 6: Grasses and flax species

GRASSES AND FLAXES	COMMON NAME	ZONE PLACEMENT	USES
Phormium tenax	Flax/Harakeke	S	Stream edge, damp locations.
Austroderia richardii	Toe Toe	S	Stream banks, riverbeds.
Carex forsteri	Frosters sedge	S/M	Under canopy (forest) or area will low aspect.
Carex solandri	Forest sedge	S/M	Canopy required.
Carex geminata	Cutty grass/Rautahi	S	Stream banks, damp ground.
Carex secta	Makura	S	Streamside, moist soils in sun or semi-shade.
Astelia fragrans	Bush Lily	M	Forest floor, among native bushes.
Cortaderia richardii	Toe Toe	S	Stream banks/edges, moist soil.
Phormium cookianum	Mountain flax	S	Stream edge, damp locations.
Cyperus ustulatus	Giant umbrella-sedge	S	Low areas near water.
Carex coriacea	Cutty Grass	S	Damp areas and river flats.

Table 7: Fern species

FERNS	COMMON NAME	ZONE PLACEMENT	USES
Histiopteris incisa	Water fern/mata	M	Open sites, primary coloniser.
Polystichum vestitum	Shield Fern/puniu	M	Forest margins, gulley floors, tussock grasslands.
Polystichum richardii	Pikopiko	M	Forested hillsides, banks in well-lit conditions, under scrub.
Leptinella dioica	Shore cotula	S	Creeping perennial herb, grows in wet habitats.

Appendix D

Rapid Habitat Assessment (RHA) and water chemistry ranges, including Steadfast Stream values for easy comparison and general comments.

Stream Metrix	Range(s)	Steadfast Stream measurement	Reference
Dissolved oxygen (% and mg/L)	80 - 120 % or 6.5 - 8 mg/L for healthy stream	81% and 11mg/L	(Department of Environment and Natural Resources, n.d.-b).
Conductivity (µS/cm)	Pristine streams: 0 to 200 Mid-range: 200 to 1000 Saline: 1000 to 10,000	208 (µS/cm)	(Department of Environment and Natural Resources, n.d.-a).
pH	Healthy streams: 5 - 8.5 Optimal conditions for plants and macroinvertebrates are between 6.5 - 8	6.6	(Athens-Clarke County, n.d.).
Turbidity (NTU)	Low: 10. Moderate: 50-100	23.8 NTUs	(DataStream, 2021).
RHA	Poor condition: 0-68 Marginal condition: 69-168 Suboptimal condition: 70-168 Optimal condition: 169-200	51.6. lack of habitat diversity and low habitat quality (e.g., sediment) contributed to low score.	(Sullivan et al., 2004; Thriving Southland, n.d.).

Appendix E

Table 8: Macroinvertebrates present in Steadfast Stream. MCI scores from (Stark & Maxted, 2007). These species are similar to those found by West (2019) in her assessment of the Steadfast steam.

Taxon		**MCI score**
ACARI		5
ANNELIDA	Oligochaeta	1
COLEOPTERA	Dytiscidae	5
COLLEMBOLA		6
CRUSTACEA	Amphipoda	5
	Isopoda	5
	Ostracoda	3
DIPTERA	Chironomidae	2
	Culicidae	3
	Hexatomini	5
	Limonia	6
	Nothodixa spp.	4
	Zelandotipula	6
MOLLUSCA	*Potamopyrgus*	4
TRICOPTERA	*Hydrobiosis*	5

Appendix F

Cultural health index assessment: Steadfast Stream (A-1/2.75/1.59)

This assessment has confirmed that:

- This is a traditional site
- Rūnanga members would return to the site
- Its mahinga kai values are low.
    - It receives a low score for access (currently closed to the public).
    - The site is heavily modified, there was an absence of mahinga kai species aside from kereru
    - It receives a low score because most of the traditional mahinga kai species are no longer present.
    - It scores high because rūnanga members would return to the site.
- It scores poor for stream health
    - Catchment land-use 1.25
    - Riparian vegetation 1.88
    - Use of the riparian margin 1.75
    - Riverbed condition/sediment 0.63
    - Channel modification 1.88
    - Flow and habitat variety 1.63
    - Water clarity 1.63
    - Water quality 2.38