A long-term monitoring programme to assess the effectiveness of two stream restoration projects in the Manawatu Region

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Executive summary

Horizons Regional Council, in conjunction with stakeholders, has undertaken numerous stream restoration projects within the region over the past few years, and plans to undertake more in the future. Currently none of these projects have any long-term monitoring programmes to assess their effectiveness in achieving the outcomes that the community desires. The Council has identified two sites where it wishes to monitor the effectiveness of restoration works. The two sites, on the Turitea Stream and a tributary of the Nguturoa Stream, are both designated for riparian fencing and planting in the next few years. The effectiveness of restoration works is defined as the degree to which goals of improving aquatic biodiversity, stream habitat quality, ecosystem functioning and aesthetics are achieved.

This report recommends a list of key indicators that are suitable for measuring the achievement of the above goals, and provides a recommended schedule of monitoring. It also assesses the potential for success of each project, given constraints set by the catchment and the extent of restoration works. Recommendations are based on The Stream Restoration Indicators Toolkit (Parkyn et al. 2010), which also contains relevant information on the expected trajectory of improvement for each indicator.

The Turitea Stream will be fenced and planted along a 1.2 km reach, from which 600 m of riparian willows have recently been removed. The planted area will be under 3 m wide on each bank. The main constraints on restoration success are the narrow width and short longitudinal extent of the planted buffer. Factors promoting restoration success are the high proportion of the upstream catchment with forest cover, the lack of migration barriers for fish, and the likely existence of forest-type macroinvertebrate taxa in upstream tributaries. We recommend monitoring macroinvertebrates, fish, periphyton, ecosystem metabolism, and several physical habitat and water quality variables at a point near the downstream end of the restored reach.

Restoration on a tributary of the Nguturoa Stream involves extending the riparian cover of a small riparian bush remnant by planting 2-3 km of stream bank with native trees. The main goal is to increase the size of an existing banded kokopu population and the diversity of the native fish fauna. Associated with this, an increase in macroinvertebrate diversity is desired. With10 native species recorded within a few kilometres of the restoration site, and no physical barriers prevent movement to the site, there appears to be high potential to increase native fish abundance and richness. However, increasing the cover of riparian trees does not necessarily increase native fish richness or abundance, as some species are more abundant in open pasture conditions. An increase in macroinvertebrate diversity is limited by the lack of sources of colonists upstream of the restoration site. Some physical habitat and water quality variables may improve within the restored section, but others would require a longer stream reach to show significant change. We recommend monitoring macroinvertebrates, fish, periphyton, ecosystem metabolism, and several physical habitat and water quality variables at a point near the downstream end of the restored reach.

Monitoring is most informative when a reference site (representing the desired end-point) and a control (unrestored) site are monitored in conjunction with the restoration site. For each restoration site, a point on the same stream upstream of the restored reach would be a suitable control site, and the Kahuterawa Stream would provide a suitable reference site.

1 Introduction

Horizons Regional Council, in conjunction with stakeholders, has undertaken numerous stream restoration projects within the region over the past few years, and plans to undertake more in the future. Currently none of these projects have any long-term monitoring programmes to assess their effectiveness in achieving the outcomes that the community desires.

Monitoring of ecological changes is a component commonly omitted in stream restoration projects (Bernhardt et al. 2007), yet it is a crucial component for several reasons:

1. Maintaining the support of funders, participants, landowners and the general public relies on being able to demonstrate the success or benefits of the restoration project (Woolsey et al. 2007).

2. Failing restoration projects can be turned into successful ones by applying the knowledge gained from monitoring in an adaptive management approach (Palmer et al. 2005).

3. Designing successful restoration projects in the future depends on being able to evaluate existing projects against objectives (Bernhardt et al. 2007).

Designing an effective monitoring programme to achieve the above benefits requires a systematic approach. This report is based on the approach outlined in The Restoration Indicator Toolkit (Parkyn et al. 2010), which includes the following steps:

1. The aim of monitoring is determined. Typical aims are:

    a. to determine the effectiveness of restoration at particular sites of interest

    b. to draw conclusions about the effectiveness of a whole restoration programme, of which the monitored sites are a representative sample

    c. to determine the cumulative effect of multiple restoration projects at a catchment-level.

2. The number and location of sites for monitoring is chosen, based on the aim identified above. For example, to achieve the first aim, only the sites of interest need to be monitored (in relation to reference and control sites – see below). However, to achieve the second aim, the full number of restored sites needs to be identified, and monitoring sites need to be chosen that adequately represent the range of environmental conditions that may affect the success or failure of restoration projects. Environmental factors that may affect success include distance (and barriers) to source populations of aquatic biota, stream size, land use, geology, soil type and steepness of the catchment, the scale of restoration works, upstream riparian management and point-source discharges.

3. Objectives for each restoration project are agreed. These may be ecological, social, cultural, economic or a combination of these. The objectives of the project will determine the choice of indicators, as each indicator needs to show the degree to

which each objective is being met. For this reason, objectives must be measurable (Bernhardt et al. 2007).

4. For each monitoring site, a reference site and a control site are chosen. The reference site represents the end-point for the restoration site, i.e., the condition that the restoration site is expected to achieve. A reference site should be nearby to the restoration site (so it experiences similar climatic events) and be similar to the restoration site in terms of altitude, distance to sea, catchment size, geology, soil type, topography and the type of stream habitats it contains. If an appropriate reference site is not available, a “guiding image” may be used instead. This represents a hypothetical stream that is described in terms of a suite of relevant indicators. In contrast to the reference site, the control site represents the “start point” from which, it is hoped, the restoration site will diverge in terms of the restoration indicators. Prior to the restoration works, the control site should be as similar as possible to the restoration site. The control site provides evidence that changes in the restoration site are a result of the restoration works and not to natural changes (e.g., weather, changes in catchment land use, etc.).

5. Indicators are chosen that measure progress towards the restoration objectives. Appropriate indicators are relevant to the project objectives, can be measured using available equipment, are meaningful to stakeholders, and are likely to change with the restoration actions proposed. Indicators may be chosen either because they directly describe a particular goal or they provide context to understand why other indicators are behaving as they are.

6. Each indicator is given a target value that, it is hoped, the monitoring site will achieve. Targets may represent pristine condition (without any human impact). In this case, if a reference site is available, the target values can be taken from there. Alternatively, if a guiding image is used, target values can be developed by considering historical records of the monitoring site, using predictive models to determine the natural biota and water quality, or gathering data from a number of pristine sites that together describe a reference condition for comparable streams. If the monitoring site is affected by human impacts that cannot be fully reversed by the restoration project, then the potential of the stream to improve is constrained and pristine conditions are not appropriate targets. In that case, target values that are poorer than reference condition may be chosen instead.

7. The location and length of the survey reach are defined such that the reach is accessible and accurately represents the restoration area. For many of the physical habitat indicators, the survey reach must be a minimum of 50 m, or 20 times the channel width, and for standard fish survey methods, the survey reach must be 150 m long.

8. A monitoring schedule is decided, appropriate to the likely rate of change and the amount of natural variability in each indicator. For example, in a small stream periphyton may decrease within a few years following riparian planting, due to its sensitivity to instream light levels. In addition, periphyton varies greatly over time due to its vulnerability to high flow events and weather patterns. Therefore, to detect trends for periphyton requires more frequent data collection than for indicators that

respond more slowly and are less variable, such as the macroinvertebrate community.

NB: The monitoring schedule should include collecting baseline data before the restoration works are undertaken. Because many indicators vary naturally over time, e.g., in response to weather, the baseline dataset should include at least 1-2 years of data collected seasonally or at least 3 years of data collected annually.

Horizons Regional Council has identified two stream restoration sites that it wishes to monitor. The Council's aim in monitoring is to assess the effectiveness of these two restoration projects only, rather than the effectiveness of its entire restoration programme. If in future it wishes to achieve the latter, monitoring will be required at a larger number of sites that represents the variety of environmental settings in which restoration is being conducted.

This report makes recommendations for a monitoring programme appropriate to each of the two named sites, in relation to their physical and biological context and the restoration works planned for each.

2 Site 1: Turitea Stream

2.1 Site description

Turitea Stream originates in the Tararua Ranges and joins the Manawatu River near the Massey University Campus, opposite Palmerston North City (Fig. 1). The stream may be considered in terms of two contrasting sections. The upper section flows through steep country covered by native forest (Tararua Ranges). Near the outlet of this section are two dams that provide water supply for Palmerston North City. These dams almost certainly represent barriers to fish migration and invertebrate drift. Below the dams, the stream runs for 2-3 km through a steep-sided gorge in a pine-forest catchment to the town of Turitea. The lower section, from Turitea to the Manawatu River, flows about 10 km through much flatter country largely in pastoral farming.

The restoration site where monitoring is proposed is on the lower section of the stream, about 1.5 km upstream of Massey University campus (E 1823485, N 5525270 NZTM). It is about 7 km downstream of the lower Turitea Dam and about 5 km upstream of the Manawatu River. According to the River Environment Classification, the stream at this point is fourth-order, with a wetted width of about 5 m, a mean annual flow of 0.9 m^3s^{-1} and a catchment area of 37 km^2. The site is about 80 km from the sea, in a climate described as cool-wet. The Freshwater Environments of New Zealand database describes the upstream catchment as 54% native vegetation and 40% pasture, and predicts that at this site, the stream will have a mean nitrogen concentration of 1.03 ppm, and a gravel bed somewhat affected by fine sediment deposition. The site is surrounded by pastoral farming, with, until recently, a riparian buffer of willows (Logan Brown, pers. comm.). The land is owned by Massey University. The site is within view of the public, across a car park, but there is no public access to the site.

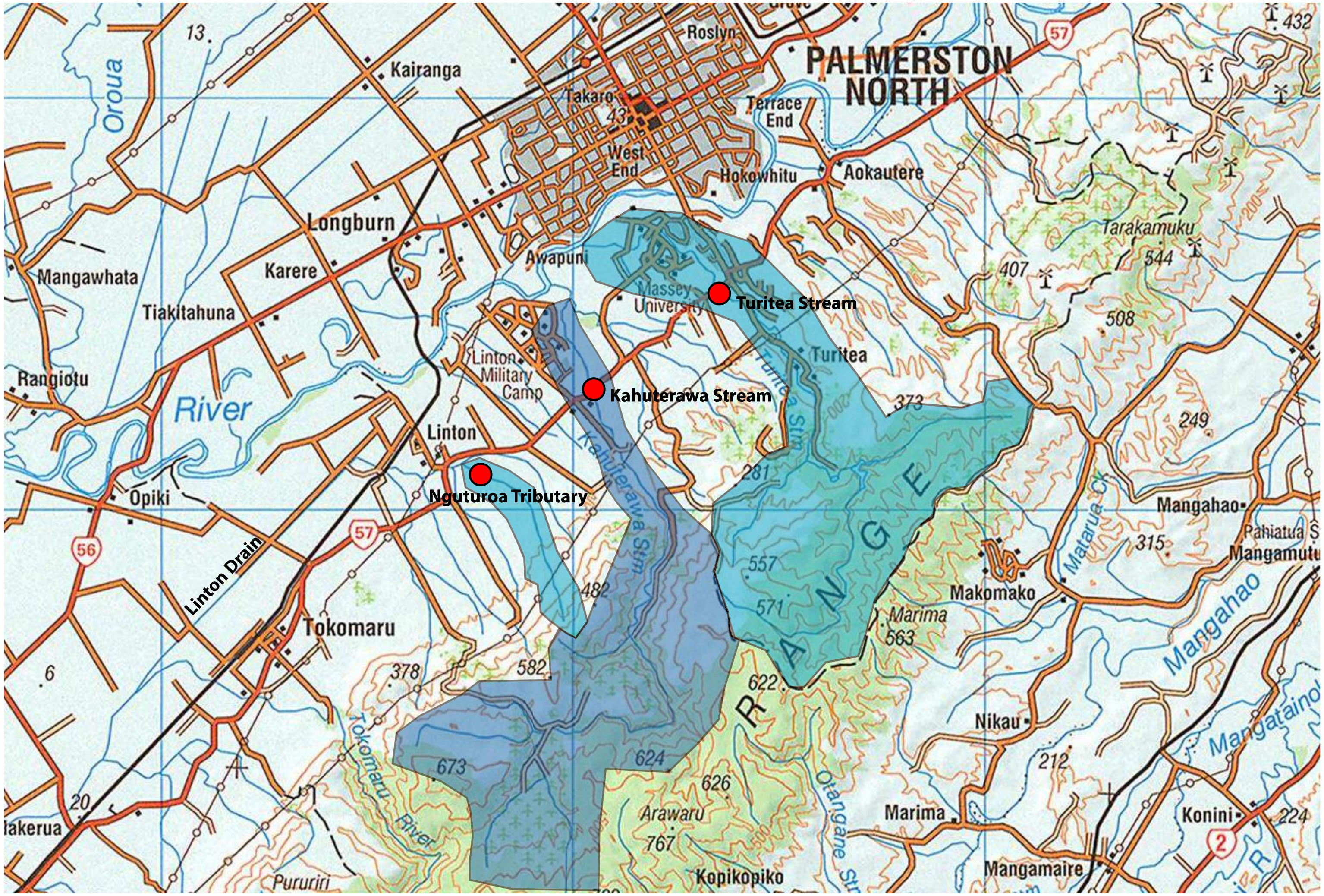

Figure 2-1: Map of the two restoration sites on Turitea Stream and Nguturoa Tributary and the recommended reference site on Kahuterawa Stream. The catchment of each stream is shown in blue shading.

2.2 Restoration

The primary goals of restoration works at this site are to improve stream habitat, diversity of aquatic macroinvertebrates and fish, and ecosystem functioning. The secondary goal is improving aesthetics of the stream and riparian zone.

To achieve these goals, stream banks will be fenced to prevent stock access and will be planted with native trees along 1.2 km of stream. This work will be done over 2-3 years, with 450 m planted in the first year. The total area to be planted in the first year is 2512 m^2, which equates to an average width of 5.6 m (i.e., 2.8 m on each bank), with a planting density of one tree per 1.5 m. To prepare the site, about 600 m of willows have been removed from the stream banks (leaving stumps and roots in place to protect the banks from erosion).

2.3 Potential for restoration success

Turitea Stream has relatively high potential for achieving good water and habitat quality, and a diverse macroinvertebrate community. Some of these variables may already be in reasonably good condition due to the high proportion of forest cover in the catchment. However, the restoration works planned are probably not extensive enough to produce significant changes in most stream health indicators.

The most important limitation in this project appears to be the narrow width of the planted area. At just under 3 m wide on each bank, the riparian buffer will provide only partial shading, a modest increase in organic matter input, little filtering of runoff from the adjacent farm and little change in riparian microclimate. Variables that are strongly related to stock access (e.g., *E. coli* and bank stability) are expected to show greater improvement due to the fencing. But the amount of improvement in these variables may be limited by the relatively short length of planted stream bank.

At 1.2 km long, the restoration reach is fairly short compared to the several hundred metres required for water quality, deposited sediment and biological indicators to improve in a stream flowing from pasture into native forest (Storey and Cowley 1997, Scarsbrook and Halliday 1999). However, upstream of the restoration reach there is only 3 km of stream length in pasture from where the stream exits the pine forested gorge below the Turitea Dams. Over this length, the water quality of a fourth-order stream leaving a forested catchment typically would remain relatively high, e.g., water temperature would normally increase by less than 3° C (Rutherford et al. 1999). However, due to water abstraction from the dams, discharge in this section of the river would be less than expected for a fourth-order stream, and temperatures may increase by more than expected (up to 4-5° C). In addition, nutrient and sediment inputs from the farmland could be significant, and Horizons Regional Council flood control works may occasionally release pulses of fine sediment that may accumulate in the restoration reach. In summer, dissolved oxygen and pH may be lower than in other nearby streams if the outlet from the dams is at their base (releasing hypolimnetic water). Therefore, the different water quality and habitat variables may show various degrees of human impact.

Overall, variables that are strongly influenced by the immediate surroundings, e.g., bank erosion, shade, leaf litter input, and other variables that depend on these (e.g., periphyton growth, ecosystem metabolism) are expected to change as a result of the restoration works, but less than they would with a wider riparian buffer. Variables that are influenced mainly by inflows from upstream (e.g., fine sediment deposition and most water quality variables) are unlikely to change greatly because of the relatively short length of the restored section.

Improvement in the macroinvertebrate community at a restored site depends strongly on connection to an upstream source of colonists. Although the headwaters of the Turitea Stream are in native forest, the dams prevent drift of macroinvertebrates from there to the restored reach. Downstream of the dams the macroinvertebrate community is impaired by iron floc that has accumulated at the dam outflow. However, another significant tributary (known as Greens Rd stream) joins the Turitea downstream of the dams. This tributary, which flows through pine forest, has the fish fauna expected of a forested site but a high sediment load, therefore it is not clear whether it may harbour a diverse macroinvertebrate community that could recolonize the restoration site.

The fish fauna may be expected to change at a restored site provided there are no downstream barriers to migration, a source of fish colonists exists within the dispersal range of those species, and suitable habitat and water quality have been re-established. All these conditions appear to be met at this site, therefore chances are high that a fish fauna typical of forested streams will recolonise once a suitable instream and riparian habitat have been re-established at the restoration site. However, it is important to note that the fish fauna of a forested stream does not necessarily have higher richness or abundance than that of a pasture stream. For example, while banded kokopu, giant kokopu and longfin eels are usually more abundant in forested streams, red-finned bullies and shortfin eels are usually less abundant (Rowe et al. 1999). Among 7 North Island catchments, Rowe et al. (1999) found that species richness, total fish density and biomass were significantly lower in native forest than pasture streams.

2.4 Recommended location for monitoring site

Water quality, deposited sediment and biological variables change gradually over distances of several hundred metres as streams flow from pasture into native forest (Storey and Cowley 1997, Scarsbrook and Halliday 1999). Therefore, to maximise the ability to detect improvements in these variables after restoration, the monitoring site should be located near the downstream end of the restored reach.

To include the range of natural variations in physical habitat, the survey reach for measuring habitat variables and macroinvertebrates should be about 100 m long (i.e., 20 times the channel width; Harding et al. 2009). To adequately sample fish diversity, David et al. (2010) recommend 150 m. However, if there are differences in physical habitat along the 1.2 km restoration reach, three survey reaches, each 75-100 m long, may be required to record the full fish diversity. The first fish survey may reveal whether species composition does indeed change over the 1.2 km restoration reach. If not, a single 150 m-long reach may be sufficient for subsequent fish surveys.

2.5 Recommended indicators and schedule for monitoring

To track progress towards the above goals, the following indicators are recommended (Table 1).

Notes for Table 1:

1. The sampling schedule represents a compromise among the schedules recommended by Parkyn et al. (2010) for the different indicators, aiming to keep the logistics of site visits as simple as possible. Variables requiring minimal extra effort once field staff are on-site (e.g., spot temperature or DO) may be more frequent in this table than recommended by Parkyn et al. (2010). Monthly sampling requires significantly more effort than annual sampling, therefore monthly sampling has been recommended here only every second year.

2. For details of the field method and predicted recovery trajectory of each indicator, refer to the relevant section of Parkyn et al. (2010).

3. To permit statistical comparisons among years and between the monitoring, control and reference sites, macroinvertebrate sampling requires 4-5 replicates per site.

2.6 Target values, reference and control sites

A suitable reference stream is the Kahuterawa Stream, which runs roughly parallel to the Turitea Stream about 4 km to the south. Like the Turitea Stream, the Kahuterawa Stream begins in the steep forested catchments of the Tararua Range and flows through farmland in its flatter lower section. The lower section (downstream of SH57) is a fourth-order stream with a catchment area of 47 km^2 and a mean annual flow of 1.2 m^3s^{-1}. Unlike the Turitea Stream, the Kahuterawa Stream has wide riparian buffers of scrub and native trees along its lower reaches, where it achieves high QMCI scores (Logan Brown, HRC, pers. comm.). Freshwater Environments of New Zealand predicts slightly higher water quality (total nitrogen = 0.93 ppm) and less fine sediment deposition in the Kahuterawa than the Turitea Stream. An appropriate site could be located in the lower reaches several hundred metres downstream of where the riparian vegetation begins, and where high QMCI scores have been previously recorded. Since the Kahuterawa Stream is similar in most ways to the Turitea, target values for the Turitea Stream could be set at the values measured at this reference site.

A control (unrestored) site could be located on the Turitea Stream itself, a few hundred metres upstream of the restoration site. There, it could be assumed, values of most or all of the measured variables will be similar to those that occurred at the restoration site prior to restoration.

Table 1: Recommended indicators for Turitea Stream. Years -2 and -1 are 2 and 1 years, respectively, prior to restoration works.

restoration goal	indicator	indicator type	time till recovery	years -2, -1, 1	year 2	year 3	year 4	year 5	year 10	notes
all	photo from fixed photopoint	Physical habitat		1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	
all	success of riparian plantings	Biota		1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow		
aquatic biodiversity	benthic macroinvertebrates	Biota	>100 years	1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	
aquatic biodiversity	fish	Biota	10-15 years[1]	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	
aquatic biodiversity	periphyton	Biota	10 years	monthly Jan-Apr	1 in summer base flow	monthly Jan-Apr	1 in summer base flow	monthly Jan-Apr	monthly Jan-Apr	
ecosystem functioning	ecosystem metabolism	Ecosystem function	15 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	
ecosystem functioning	leaf litter retention	Ecosystem function	10-300 years[2]	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	lower priority: not likely to change much
ecosystem functioning	OM processing	Ecosystem function	20 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	lower priority: less relevant
aesthetics	access to/views of stream	Physical habitat		1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	

[1] After habitat conditions become suitable
[2] The upper bound is for the retention provided by large wood. In small streams, cobbles, small wood and overhanging vegetation would provide much of the retention. Small wood and overhanging vegetation may provide retention after as little as 10 years.

restoration goal	indicator	indicator type	time till recovery	years -2, -1, 1	year 2	year 3	year 4	year 5	year 10	notes
natural habitat	bank erosion/stability	Physical habitat	30 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	
natural habitat	mesohabitats	Physical habitat	300 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	lower priority: not likely to change much
natural habitat	OM abundance	Physical habitat	90 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	
natural habitat	residual pool depth	Physical habitat	80 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	
natural habitat	riparian microclimate	Physical habitat	20 years	log Jan-March		log Jan-March		log Jan-March	log Jan-March	lower priority: not likely to change much
natural habitat	shade at water surface	Physical habitat	10 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	To restore 60% of natural shading.
natural habitat	substrate size	Physical habitat	80 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	
natural habitat	water width/channel width	Physical habitat	30 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	
natural habitat	dissolved oxygen	Water quality	30 years	log Jan-Feb		log Jan-Feb		log Jan-Feb	log Jan-Feb	
natural habitat	water clarity	Water quality	>30 years	monthly		1 in summer base flow		1 in summer base flow	1 in summer base flow	
natural habitat	water temperature (continuous)	Water quality	>100 years	log Jan-March		log Jan-March		log Jan-March	log Jan-March	
natural habitat	water temperature (spot)	Water quality	>100 years	monthly				monthly	monthly	

3 Site 2: Tributary of Nguturoa Stream

3.1 Site description

This site is on an unnamed tributary of the Nguturoa Stream (E 1818449, N 5520747 NZTM; Fig. 1). The tributary flows through a dairy farm in a largely pastoral catchment, though it passes through a number of small native bush remnants, including one about 100 m long at the restoration site. Like the Turitea Stream, this stream originates in the Tararua Ranges, and is fairly steep in its upper reaches. But the steep headwater reaches are much less extensive than the Turitea stream, and most of this stream drains flatter land on the plains.

Although the restoration site is only 3.5 km (in a straight line) from the Manawatu River, the stream flows for 22 km before joining the river. About 4 km (by stream) downstream of the site the stream is intercepted by the Linton Drain, which carries the water south, joining with the Tokomaru River before emptying into the Manawatu River near Shannon. The Linton Drain runs through very flat land and, as part of the Manawatu flood protection scheme, is constrained by stopbanks along most of its length.

At the restoration site, the stream (NZ Reach 7041371) is third order (according to the River Environment Classification), with a wetted width of about 1 m and a catchment area of 2.8 km^2. The mean annual flow is estimated at 0.05 m^3s^{-1} and the mean annual 7-day low flow at 5 Ls^{-1}, but in some summers (e.g., summer 2012-13) flow stops altogether. In contrast to the Turitea, the headwaters of this stream arise in pasture and gorse, and there is no significant native vegetation cover at the stream source. According to Freshwater Environments of New Zealand, 99% of the catchment upstream is pasture and 0% is native vegetation, thus the predicted mean nitrogen concentration is higher than the Turitea Stream, at 2.7 ppm, and the gravel stream bed shows greater fine sediment deposition. The site is about 51 km from sea.

Despite the significant pressures on this stream, the reach within the small bush remnant harbours a population of banded kokopu. Trout are also present in the stream.

3.2 Restoration

Restoring and enhancing aquatic biodiversity is the main goal of the restoration works at this site. In particular, the population of banded kokopu is regarded as a key natural value to be enhanced, but it is hoped that other species of native fish and invertebrates, and also trout, will also recolonise. Secondary goals include improving ecological functioning, terrestrial biodiversity and stream habitat. Improvements to downstream water quality are considered unlikely given the small scale of the restoration works. Because there is no public access to the site, aesthetics is not a focus.

To achieve these goals, stream banks will be fenced to exclude stock and planted with native trees at an estimated density of one tree per 2 m. The fencing and planting will extend both upstream and downstream of the native bush remnant, over a total distance of 2-3 km.

3.3 Potential for restoration success

Some characteristics of this site suggest potential for achieving the primary goal, while others will seriously limit progress.

The major factor limiting an increase in aquatic biodiversity is probably the geographic isolation of the restoration site, which is effectively an island of suitable habitat within a sea of poor quality habitat. For macroinvertebrates, the lack of forested habitat upstream of the site means that taxa characteristic of forested streams are unlikely to arrive by drift. The nearest source of such taxa, the Kahuterawa Stream, is more than 2.5 km overland, and recruitment from there would require aerial transport, by flight or passive transport on birds' legs. The relatively flat terrain between the two streams presents no significant barrier to insect flight, but the distance is likely to prevent all but a few strong fliers (mainly caddisfly species) from reaching the restoration site.

Fish recolonisation at this site depends mainly on access from downstream reaches. Physical migration barriers are unlikely to prevent fish from reaching the restoration site. No culverts are known to impede fish passage between the restoration site and Linton Drain, and the flood protection scheme on the Linton Drain is designed to remove any impedance to flow.

The following fish species have been recorded in the Linton Drain and adjacent Tokomaru River (NZ Freshwater Fish Database), and presumably are able to reach the restoration site:

- *Anguilla australis* (Shortfin eel)
- *Anguilla dieffenbachii* (Longfin eel)
- *Cheimarrichthys fosteri* (Torrentfish)
- *Galaxias maculatus* (Inanga)
- *Geotria australis* (Lamprey)
- *Gobiomorphus breviceps* (Upland bully)
- *Gobiomorphus cotidianus* (Common bully)
- *Gobiomorphus huttoni* (Redfin bully)
- *Neochanna apoda* (Brown mudfish)
- *Carassius auratus* (Goldfish)
- *Salmo trutta* (Brown trout)

In addition, *Retropinna* (smelt) are predicted with 83% certainty to be present in Linton Drain (Leathwick et al. 2008). Species other than these have not been recorded and have less than 10% chance of occurring in waterways near the restoration site, therefore are unlikely to reach the restoration site after the restoration project is complete.

The other factors limiting the potential for achieving restoration goals are the relatively low density and the short longitudinal extent of planting. With 2 m spacing between trees we may expect limited improvement in variables such as shading, organic matter input and riparian microclimate until the trees are quite mature (>10 years). At 2-3 km, the restored reach is small relative to the 7.5 km length of stream channel upstream of the site. Some water quality, habitat and biological indicators can improve within several hundred metres after a stream flows from pasture to native forest. Scarsbrook and Halliday (1999) found that shade, channel width and periphyton biomass all improved within 300 m, and Storey and Cowley (1997) found that dissolved oxygen increased to near-saturation over 300 m. However, other variables such as dissolved nutrients, water temperature and suspended solids and deposited fine sediment take much longer to return to forest stream levels (e.g., models indicate that maximum daily water temperature in a third-order stream would require 10 km to drop from 25 °C to 19 °C after flowing from open pasture into native forest; Rutherford et al. 1999).

Overall, the primary goal of enhancing the population of banded kokopu is likely to be achieved, and other fish species typical of native forest are likely to recolonize, given the lack of physical barriers. However, this may not result in an overall increase in native fish richness or abundance (Rowe et al. 1999, and see comments in Section 2.3). The macroinvertebrate community is less likely to change significantly due to the geographic isolation of the restoration site.

3.4 Recommended location for monitoring site

As in the Turitea Stream, the monitoring site should be located near the downstream end of the restored reach in order to maximise the ability to detect improvements in water quality, habitat quality and biological indicators after restoration.

To include the range of natural variations in physical habitat, the survey reach for measuring habitat variables and macroinvertebrates should be at least 50 m long (the minimum specified in Harding et al. (2009) for a narrow stream). To adequately sample fish diversity, 150 m is required (David et al. 2010).

3.5 Recommended indicators and schedule for monitoring

To track progress towards the above goals, the following indicators are recommended (Table 2).

Table 2: Recommended indicators for Nguturoa tributary. Years -2 and -1 are 2 and 1 years, respectively, prior to restoration works.

restoration goal	indicator	indicator type	time till recovery	years -2, -1, 1	year 2	year 3	year 4	year 5	year 10	notes
all	photo from fixed photopoint	Physical habitat		1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	
all	success of riparian plantings	Biota		1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow		
aquatic biodiversity	benthic macroinvertebrates	Biota	>100 years	1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	
aquatic biodiversity	fish	Biota	10-15 years[3]	1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	1 in summer base flow	
aquatic biodiversity	periphyton	Biota	10 years[4]	monthly Jan-Apr	1 in summer base flow	monthly Jan-Apr	1 in summer base flow	monthly Jan-Apr	monthly Jan-Apr	
ecosystem functioning	ecosystem metabolism	Ecosystem function	15 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	
ecosystem functioning	leaf litter retention	Ecosystem function	300 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	lower priority: not likely to change much
ecosystem functioning	OM processing	Ecosystem function	20 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	lower priority: less relevant
natural habitat	bank erosion/stability	Physical habitat	30 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	
natural habitat	mesohabitats	Physical habitat	300 years	1 in summer		1 in summer		1 in summer	1 in summer	lower priority: not likely to

[3] After habitat conditions become suitable
[4] Values are different from Turitea Stream site due to different stream width

restoration goal	indicator	indicator type	time till recovery	years -2, -1, 1	year 2	year 3	year 4	year 5	year 10	notes
				base flow		base flow		base flow	base flow	change much
natural habitat	OM abundance	Physical habitat	90 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	
natural habitat	residual pool depth	Physical habitat	80 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	
natural habitat	riparian microclimate	Physical habitat	20 years	log Jan-March		log Jan-March		log Jan-March	log Jan-March	lower priority: not likely to change much
natural habitat	shade at water surface	Physical habitat	10 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	
natural habitat	substrate size	Physical habitat	80 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	
natural habitat	water width/channel width	Physical habitat	30 years	1 in summer base flow		1 in summer base flow		1 in summer base flow	1 in summer base flow	
natural habitat	dissolved oxygen	Water quality	30 years	log Jan-Feb		log Jan-Feb		log Jan-Feb	log Jan-Feb	
natural habitat	water clarity	Water quality	>30 years	monthly		1 in summer base flow		1 in summer base flow	1 in summer base flow	
natural habitat	water temperature (continuous)	Water quality	>50 years[4]	log Jan-March		log Jan-March		log Jan-March	log Jan-March	
natural habitat	water temperature (spot)	Water quality	>50 years[4]	monthly				monthly	monthly	

Notes for Table 2:

1. The recommended schedule is very similar to that for Turitea Stream, except:

    1.1 Fish monitoring is more frequent, since fish diversity is the primary goal.

    1.2 Rubbish and access to stream are removed, since aesthetics is not a goal.

2. Macroinvertebrates are unlikely to return quickly, so macroinvertebrate sampling could be reduced to every second year. But I recommend sampling every year, if possible, since aquatic biodiversity is the primary goal.

3. The electrofishing survey method described in Parkyn et al. (2010) is designed to assess fish diversity and relative abundance. If absolute abundances of key species are required, then a two- or three-pass method is recommended instead of the single-pass method in Parkyn et al. (2010). To determine whether recruitment is occurring, it is important to measure fish size as well as numbers. This can be done rapidly by eye if size categories are used in place of actual measurements. Since the focus of this project is on restoring fish diversity rather than on the return of key indicator species, we recommend the electrofishing method over other methods, such as spotlighting, that are more selective).

4. For details of methods and recovery trajectories, refer to the relevant section of Parkyn et al. (2010).

3.6 Target values, reference and control sites

Located roughly midway between Nguturoa and Turitea Streams, the Kahuterawa Stream is suitably located to act as a reference site for this as well as the Turitea restoration project. Its gradient and physical environment are comparable to the Nguturoa tributary, however it is significantly larger (catchment area 47 km^2 cf. 2.8 km^2; mean annual flow 1.2 m^3s^{-1} cf. 0.05 m^3s^{-1}). A reference site of comparable size would be preferable if one can be found that is similar to the Nguturoa tributary in attributes such as gradient, stream bed substrate composition, flow regime and distance to sea. However, in the absence of such a site, the Kahuterawa Stream will suffice, given that New Zealand macroinvertebrate and fish communities and physicochemical variables show little progressive change with increasing stream size (Winterbourn et al. 1981).

A control (unrestored) site could be located a few hundred metres upstream of the restoration site on the same stream, assuming that there, values of most or all of the measured variables will be similar to those that occurred at the restoration site prior to restoration. Alternatively, the next tributary to the south appears suitable, as it has similar land use and is of similar size to the restoration reach.

4 Other considerations for monitoring

For stream restoration projects involving landowner or community participation, or those undertaken on public land, monitoring indicators of social change should also be considered. Experience in other restoration projects indicates that changes in awareness and attitudes, or increases in social cohesion, may occur among people participating in restoration activities, or perceptions and use of the stream by the public may improve following stream enhancement. Documenting these changes may maintain or increase support for future restoration projects.

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