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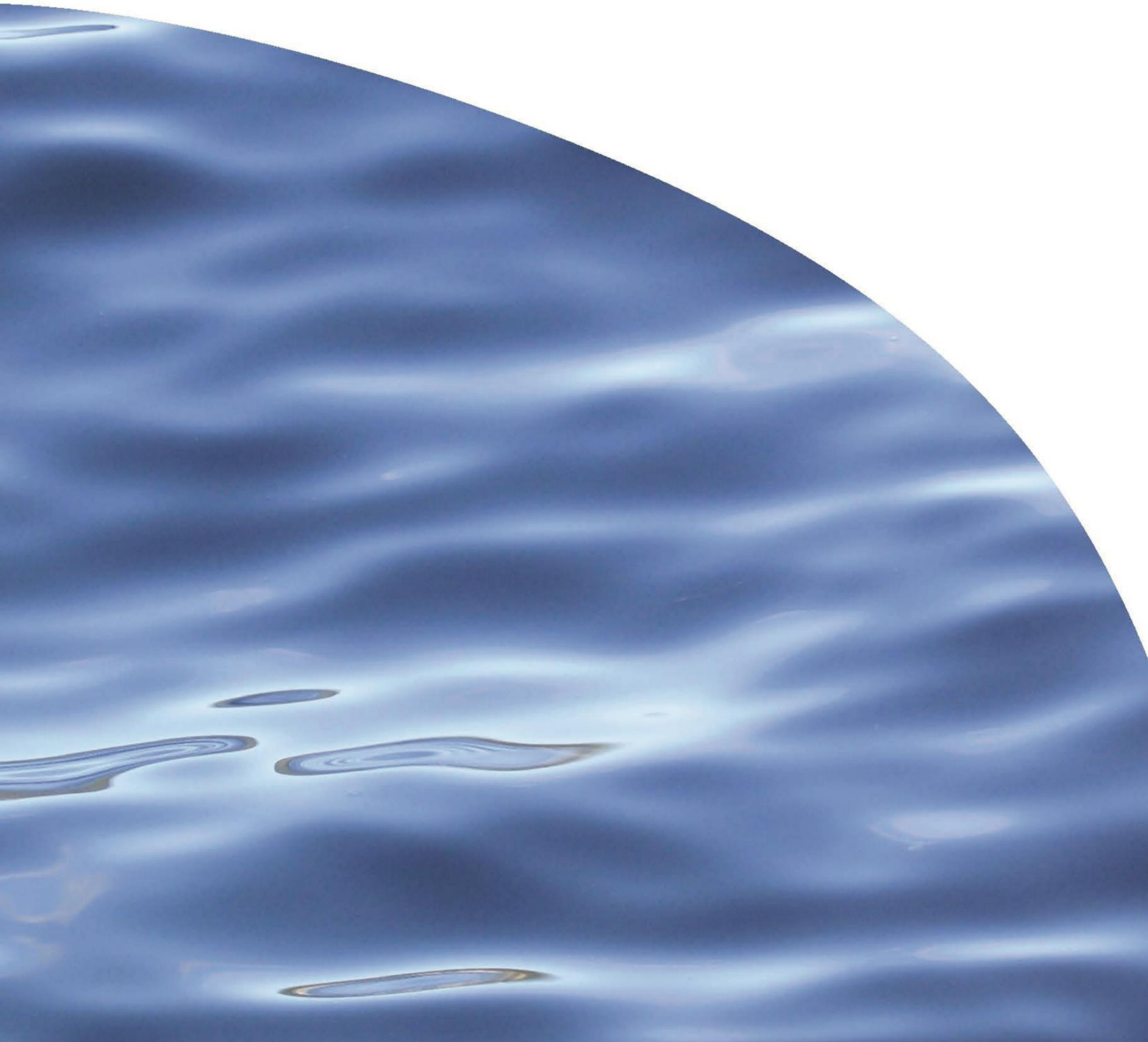
JOBS FOR NATURE BIODIVERSITY MONITORING



JOBS FOR NATURE BIODIVERSITY MONITORING

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Prepared for Department of Conservation

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EXECUTIVE SUMMARY

As part of the Government's Jobs for Nature (J4N) funding, the Department of Conservation (DOC) is administering the Ngā Awa Strategic Waterways restoration programme[1]. Working in partnership with iwi, hapū and local communities, the Strategic Waterways programme invests primarily in riparian enhancement as part of wider catchment plans to improve biodiversity.

This report outlines the development of a monitoring programme to assess the effectiveness of the Ngā Awa Strategic Waterways restoration activities. The monitoring programme is focussed on measuring biodiversity outcomes and accommodates different restoration activities, such as riparian fencing and planting, wetland restoration, sediment interception, pest control, and fish passage remediation. The programme is informed by a substantial review of existing freshwater and terrestrial monitoring approaches used to assess in-stream and riparian biodiversity in Aotearoa New Zealand. The review identified priority measures that provide national-level indicators as well as meaningful place-based assessments. Each approach was evaluated for suitability for J4N monitoring for Ngā Awa catchments according to whether it provided consistent, flexible, robust, informative, and fit-for-purpose information.

The recommended monitoring programme addresses a key challenge that many biodiversity metrics (i.e., Outcomes) will respond on a > 5-year time scale (often much longer), whereas J4N reporting on environmental outcomes will be required within 2–3 years of commencing restoration activities. The solution is to apply 'intervention logic' that explicitly links restoration actions to a reduction in anthropogenic pressures on aquatic systems, that will in turn support improved biodiversity outcomes. In other words, 'Actions' (e.g., riparian fencing), will relieve 'Proximate Pressures' (e.g., vegetation clearance by grazing stock) that will, in the long-term result in improved biodiversity 'Outcomes' (e.g., improved terrestrial plant diversity). Progress on Actions are readily documented (e.g., metres of new fence line) and improvements in Proximate Pressures are much more likely to occur on a shorter time frame than the final biodiversity Outcomes. Thus, if we can demonstrate progress on Actions and Proximate Pressures, we can logically expect progress on biodiversity Outcomes in the long-term. A well-established body of research supports the intervention logic that underlies this monitoring programme design.

A decision support tool is provided to identify relevant measures for each J4N-funded project (Figure E1, next page).

Finally, this report provides further detail of monitoring methods which informs where (the spatial location), when (timing and periodicity) and how (the methods and metrics) to assess biodiversity outcomes resulting from J4N-funded restoration activities. This information can be used to customise monitoring for each of the J4N projects.

[1] The Jobs for Nature funded Ngā Awa Strategic Waterways programme is closely aligned with, but separate to, the DOC-funded Ngā Awa programme that encompasses 14 rivers. A subset of the Ngā Awa rivers will receive Jobs for Nature funding in the Ngā Awa Strategic Waterways programme.

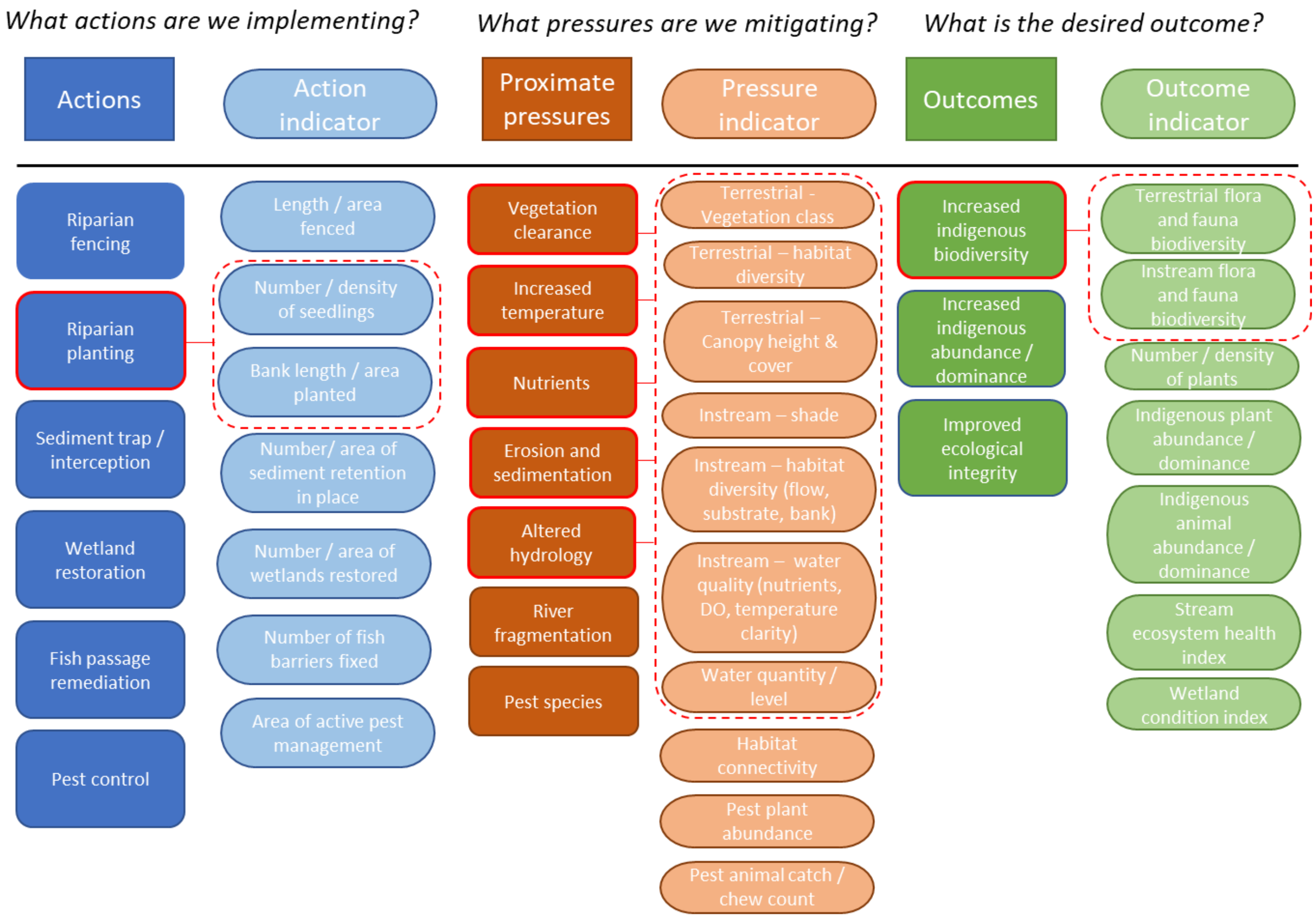

Figure E1. A decision support tool to identify measures to assess the actions, proximate pressures, and outcomes of restoration activities. The red boxes show one example of how the tool can be used.

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1. INTRODUCTION

1.1. Context

As part of the Government's Jobs for Nature (J4N) funding, the Department of Conservation (DOC) is administering the Ngā Awa Strategic Waterways restoration programme. The Strategic Waterways programme is J4N funding aligned with the existing Ngā Awa river restoration programme's efforts to collaboratively improve the ecological integrity and biodiversity in 14 river catchments. Working in partnership with iwi, hapū and local communities, the Strategic Waterways programme invests primarily in riparian enhancement as part of wider catchment plans to improve biodiversity and provide employment during the COVID-19 pandemic. DOC needs to implement a new monitoring programme to assess if the J4N investment into riparian fencing and planting and other related activities is achieving biodiversity objectives as outlined in the Aotearoa New Zealand Biodiversity Strategy 2020 (referred to hereafter as the Biodiversity Strategy 2020 [DOC 2020b]) (see Appendix 1). Ideally, any monitoring programme will align to the broader J4N programme monitoring and reporting and where possible, existing DOC biodiversity monitoring. The monitoring programme design also addresses a key challenge that many biodiversity metrics will respond on a > 5-year time scale (often much longer), whereas J4N reporting on environmental outcomes will be desirable within 2–3 years of commencing restoration activities.

This report describes the design of a monitoring programme that outlines where (the spatial location), when (timing and periodicity) and how (the methods and metrics) to assess biodiversity outcomes, resulting from J4N funding into riparian fencing and planting and other J4N funded restoration activities.

1.2. Aim, scope, and outline of the report

The report aims to develop a monitoring programme to assess biodiversity outcomes resulting from J4N funding into riparian fencing and planting and other J4N-funded restoration activities. The scope includes instream and terrestrial (riparian) biodiversity benefits.

First, in Section 2 we compile and assess the suitability of existing approaches for assessing biodiversity outcomes at a national scale, focussing on high level components and measures, and identifying off-the-shelf methods for rapid implementation. We assess monitoring approaches in relation to their alignment to existing DOC biodiversity monitoring as well as cultural monitoring, and their suitability for incorporation into the J4N monitoring application. We assess a range of approaches that require expert skills through to community citizen science. We identify priority (i.e., 'must have') measures that provide national-level indicators as well as measures and methods that provide meaningful place-based assessments. In-depth reviews are provided in Section 6 Appendices while in Section 2 key assessment summaries are presented in Table 2 for aquatic indicators, Table 3 for terrestrial indicators, and a list of methods (including identification of those suitable for community groups) is provided in Table 4.

Next, in Section 3 we recommend a monitoring programme informed by the review described above. The monitoring programme is designed to provide evidence in a relatively short time frame (i.e., 2–3 years) of the effectiveness of restoration actions at achieving biodiversity outcomes using intervention logic. For example, if our outcome is improved biodiversity, then we will have evidence that we will ultimately achieve our outcome by measuring our actions (e.g., riparian planting) and the mitigation of pressures (e.g., shade, vegetation cover) as well as the biodiversity of flora and fauna. A decision support tool is provided to help identify representative measures tailored to specific J4N-funded actions and illustrated in Figure 5.

Finally, in Section 4 we provide details of methods and metrics for core biodiversity indicators recommended for the programme that can be embedded into J4N-funded projects as pragmatic measures to assess biodiversity (as well as actions and pressures). We describe the expected biodiversity outcomes of J4N investment into riparian fencing / planting and other activities anticipated in J4N-funded projects (such as wetland restoration, sediment trap / interception, pest control and fish passage remediation) including the spatial and temporal trajectories likely to be observed in recommended metrics and measures over time. We provide recommendations that are accessible to, and provide a monitoring template for, the Ngā Awa Strategic Waterways teams.

2. ASSESSING THE SUITABILITY OF EXISTING APPROACHES TO MEASURE BIODIVERSITY OUTCOMES FOR J4N PROJECTS IN NGĀ AWA CATCHMENTS

2.1. Identifying criteria to assess suitability

Ideally, a freshwater biodiversity monitoring framework meets the following criteria:

1. provide *representative* measures of biodiversity objectives within the freshwater ecosystem of interest (i.e., as defined by the wetted area, ephemeral channels, banks, and riparian zone) and / or indirect measures that signal the trajectory towards achieving biodiversity outcomes.
2. be *consistent* so that they can be applied in a standardised manner and results are comparable and can be aggregated at broader spatial scales to allow DOC to report on biodiversity outcomes
3. be *flexible* so that they can be applied in differing environmental and social settings (recognising the variability in projects and place-based values of users ensuring local ownership)
4. be *robust* and based on validated methodology
5. be *informative* for end-users and public alike; this means providing meaningful and where possible simple metrics of biodiversity
6. be *fit for purpose* so that results demonstrate the value of J4N investment to achieve biodiversity outcomes and identify ongoing investment / biodiversity management needs.

There are numerous monitoring frameworks and methods that have been developed for different purposes—whether it be State of the Environment or impact assessment. Rather than starting from scratch, it makes sense to assess existing approaches and methods to identify common high-level components and measures (i.e., prioritise measures that provide national-level indicators of in-stream and terrestrial biodiversity), and to identify off-the-shelf methods available for rapid implementation. Approaches may include for example, existing DOC biodiversity monitoring as well as cultural monitoring. Their suitability for incorporation into the J4N restoration monitoring will depend on the level of skill required (e.g., expert skills or community citizen science) and whether they provide meaningful place-based assessments.

We compiled and summarised existing literature that describe monitoring frameworks and methods and used an expert judgement-based scoring method to assess their alignment to key criteria listed above. Additional criteria assessed included:

1. alignment to existing DOC biodiversity monitoring programmes
2. skill level required to implement methods
3. resources required (labour and expenses).

The scoring method included rating each example as outlined in Table 1.

Table 1. Criteria to assess the suitability of existing monitoring frameworks and methods to measure biodiversity outcomes in J4N projects for Ngā Awa.

Criterion	Score 1	Score 2	Score 3
1. Representative	Indirect measure that assesses impact / recovery rather than biodiversity response (e.g., sediment load)	Indirect measure often used to infer biodiversity response (e.g., MCI)	Direct measure of biodiversity (e.g., taxa richness)
2. Consistent	Non-standardised method/s	Non-standardised method/s but outputs are comparable	Standardised method/s
3. Flexible	Environment or social context specific (e.g., only used by one group in one place)		Broadly applicable
4. Robust	No science validation (e.g., not peer reviewed)	Method/s may be validated by community uptake	Validated method/s via peer-review or publication
5. Informative	No clear pathway for communication; results are hard to interpret / understand		Clear and concise metrics / reporting; easily communicated and understood
6. Fit for purpose	Unlikely to provide evidence of biodiversity outcomes		Highly likely to provide evidence of biodiversity outcomes
7. Align to DOC	Contrasting methods that will be difficult to align / combine with existing DOC monitoring	Some overlap with DOC methods / metrics	Large overlap with key methods / metrics provided by DOC biodiversity monitoring
8. Skill level	Expert training required to implement monitoring; external provider required to process / interpret results	Some training required after which methods should be readily applicable; external provider likely to be required to implement some methods or process / interpret some results	Little or no training required other than provision of documents; external provider likely to be required to process / interpret some results
9. Resources required	Multiple field visits may require multiple people and / or laboratory processing costs	Single field visit may require multiple people and / or laboratory processing costs	Single field visit with single assessor with no external laboratory costs

2.2. Monitoring frameworks and methods for assessing in-stream biodiversity and overall stream health

While biodiversity outcomes are often the focus on in-stream monitoring it is not always explicitly stated. Sometimes the aim of monitoring is a broader assessment of stream health, described as either ecosystem health or ecosystem integrity, or even a more focussed assessment of water quality. Values-based monitoring is in response to policy requiring 'state of the environment' assessment or consent monitoring to assess environment effects. Beyond a government mandate, monitoring is also undertaken by industry and community groups to determine the effectiveness of restoration and / or mitigation actions to improve stream outcomes. Consequently, there are a broad range of existing frameworks and methods that provide guidance on how to measure in-stream outcomes.

Here we review frameworks and methods to identify the key elements required to assess in-stream biodiversity as aligned to the objectives of the Biodiversity Strategy 2020 (Appendix Section 6.1). Because both the Nga Awa Programme and the J4N programme aim to achieve biodiversity outcomes with an ecosystem focus through working in partnership with others, we assume specific Biodiversity Strategy 2020 objectives key to this project include:

- Mātauranga Māori is an integral part of biodiversity research and management (objective 5)
- all New Zealanders have the skills, knowledge and capability to be effective (objective 7)
- ecosystems and species are protected, restored, resilient and connected from mountain tops to ocean depths (objective 10).

The following stream monitoring methods and frameworks have been assessed for suitability to measure in-stream biodiversity outcomes of riparian restoration.

- Department of Conservation Freshwater Ecosystems of New Zealand model of ecological integrity
- Department of Conservation Tier 1 Inventory and Monitoring: rivers and streams
- National Environmental Monitoring and Reporting programme
- Ecosystem Health framework
- Stream Ecological Valuation
- Kaupapa Māori monitoring frameworks and indicators
- Restoration Indicators Toolkit
- SHMAK: Stream Health Monitoring and Assessment Kit
- Standardised monitoring methods suitable for assessing riparian restoration.

A detailed review of each method and framework is provided in Appendix Section 6.2. Here we provide a summary of assessment scores for the eight in-stream frameworks and monitoring methods reviewed (Table 2).

Table 2. Summary of assessment scores for 8 river and stream monitoring methods against the key elements of an effective monitoring programme to evaluate biodiversity outcomes of J4N projects in Ngā Awa catchments.

Key element	DOC FENZ	DOC Tier 1 Inventory and Monitoring	NEMaR	Ecosystem Health framework	SEV	Kaupapa Māori	Restoration indicators toolkit	SHMAK
1. Representativeness	2	3	2	2/3	2/3	2/3	2/3	2/3
2. Consistency	2	3	2/3	3	2/3	1/2	2	2
3. Flexible	1	1	1	2	1	3	2/3	3
4. Robust	2	3	2/3	3	3	2	2/3	2
5. Informative	2/3	2/3	2	3	3	2	2/3	2
6. Fit-for-purpose	2	2	1/2	2	2	1	2	2
7. Align to DOC	2	3	2	2/3	2	1	2/3	2
8. Skill level	1	1	1	2/3	2	2	1/2/3	3
9. Resources required	1	1	1	1	2	3	1/2/3	2/3
Maximum Total	16	20	17	23	21	19	25	22

2.3. Monitoring methods for assessing terrestrial biodiversity outcomes of riparian restoration

Measurement of biodiversity outcomes for stream restoration projects is often focussed on in-stream aquatic biodiversity and riparian plant diversity alone. Both the Nga Awa Programme and the J4N programme aim to achieve wider biodiversity outcomes with an ecosystem focus, recognising the connectivity between terrestrial and freshwater systems. As such, the following terrestrial biodiversity outcomes have been assumed to be included in the overall biodiversity outcomes of these programmes (although not specifically stated):

- a self-sustaining riparian forest habitat
- increased diversity and abundance of indigenous bird species
- opportunities for increasing populations / distribution of indigenous bats, herpetofauna and invertebrates.

As discussed above, the terrestrial biodiversity components of most stream monitoring frameworks / methods are limited to riparian plant diversity and plant survival. To the best of our knowledge, no set methodology exists specifically designed to monitor terrestrial biodiversity in New Zealand riparian restoration. However, several terrestrial monitoring packages / toolkits have been developed for New Zealand wetland and forest habitats that could be applied or modified to assist in monitoring terrestrial biodiversity changes in riparian habitats following restoration.

The following terrestrial / wetland monitoring methods have been assessed for suitability to measure terrestrial biodiversity outcomes of riparian restoration[2]:

- FORMAK: Forest Monitoring Manual (PA Hanford & Associates 2004)
- Biodiversity Inventory and Monitoring Toolbox (Greene & McNutt 2012)
- Field protocols for Tier 1 monitoring - invasive mammal, bird, bat, RECCE surveys. Inventory and monitoring toolbox (DOC 2013)
- Field protocols for DOC Tier 1 Inventory & Monitoring and LUCAS plots (DOC 2019)
- WETMAK: A Wetland Monitoring and Assessment Kit for Community Groups (Denyer & Peters 2014)
- Wetland Restoration: A Handbook for New Zealand Freshwater Systems (Peters & Clarkson 2012)
- Guidelines for Undertaking Rapid Biodiversity Assessments in Terrestrial and Marine Environments in the Pacific (SPREP 2014)

[2] For this assessment, is has been assumed that the purpose of monitoring terrestrial biodiversity is more specifically to determine whether a restored riparian habitat has or is on a trajectory to return to a functional and self-sustaining forest ecosystem, providing habitat opportunities for a diverse assemblage of indigenous fauna. The suitability of monitoring methods for the J4N programme will vary from our assessment if the purpose of the terrestrial biodiversity monitoring differs from this.

- Cultural Health Index (Tipa & Teirney 2006).

A detailed review of each method and framework is provided in Appendix Section 6.3. Terrestrial monitoring includes a wide range of individual methods for specific biodiversity indicators. Each of the individual methods referred to throughout our assessment are described in Appendix Section 6.4. Here we provide a summary of assessment scores for the six terrestrial methods reviewed (Table 3).

Table 3. Summary of assessment scores for terrestrial monitoring methods against the key elements of an effective monitoring programme to evaluate biodiversity outcomes of J4N projects in Ngā Awa catchments.

Key element	FORMAK	DOC Tier 1 Inventory and Monitoring	Biodiversity inventory and monitoring toolbox	WETMAK	BIORAP	Cultural Health Index
1. Representativeness	2/3	2/3	3	1/2	2	1
2. Consistency	3	3	2	2	2/3	2/3
3. Flexible	2/3	1/2	3	3	3	3
4. Robust	3	3	2/3	3	2/3	2
5. Informative	2/3	3	2	2	2	2
6. Fit-for-purpose	2/3	2/3	3	2/3	3	1/2
7. Align to DOC	2	3	3	2	3	1
8. Skill level	2	2	1/2	2	1/2	2
9. Resources required	3	3	1/2/3	3	1/2/3	3

2.4. Identification of core elements and indicators

In our review of existing assessment frameworks and monitoring methods (Sections 2.2–2.3 and 6.2–6.3) we identify core biodiversity elements and indicators that can be measured using methods with various levels of skill and resource requirements (Table 4). Additionally, monitoring methods are identified for supporting core elements of ecosystem health or stream condition that provide information on the life supporting / biodiversity capacity of streams, and are furthermore likely to respond in shorter timeframes.

Table 4. Summary indicators and monitoring methods for measuring core elements of biodiversity and ecosystem health in response to riparian restoration. Monitoring methods suitable for application by community groups are marked with an asterisk. Details of terrestrial methods are described in Appendix Section 6.4.

Core element	**Indicator**	**Monitoring methods**
In-stream biodiversity	Periphyton	Visual assessment (NEMS, SHMAK)*
	Macrophytes	Visual assessment (Collier et al. 2007)*
	Benthic macroinvertebrates	Kick net (NEMS, SHMAK)*
	Fish	Spotlighting, trapping (Joy et al. 2013)*
In-stream habitat	Substrate	Visual assessment (Clapcott et al. 2011)*
	Shade	Visual assessment (Harding et al. 2009)*
	Mesohabitat types	Visual assessment (Clapcott 2015)*
	Bank erosion and condition	Visual assessment (Clapcott 2015)*
In-stream water quality	Temperature	Field meter / logger (NEMS, SHMAK)*
	Dissolved oxygen	Field meter / logger (NEMS, SHMAK)*
	Clarity	Field meter / logger / visual assessment (NEMS, SHMAK)*
Terrestrial biodiversity	Vegetation	Photo points* Rapid vegetation assessment* Permanent vegetation plots or transects*
	Invertebrates	Netting Traps
	Herpetofauna	ACOs* Pitfall traps Spot lighting* Tracking tunnels*
	Bats	Acoustic monitoring*
	Birds	Five-minute bird counts*
	Pest animals	Chew cards / Wax tags* Tracking tunnels* Trapping

3. DEVELOPMENT OF A MONITORING PROGRAMME

3.1. Introduction

Drivers of biodiversity loss include reduced habitat availability and connectivity for recruitment, climate change, non-indigenous species, resource exploitation and pollution (Millennium Ecosystem Assessment 2005; Department of Conservation 2020a). Restoration programmes cannot address all these drivers, but they do aim to mitigate some of them.

Improvements in biodiversity in response to restoration activities take time. Ecological theory might predict a variety of restoration trajectories (Lake et al. 2007), but in practice, improved biodiversity outcomes because of stream restoration are rarely observed (Palmer et al. 2014). There might be lots of confounding reasons why improved biodiversity outcomes are not seen, but it is suggested that there are two main reasons: 1) poorly designed restoration programmes—we don't restore the right things in the right place at the right time; and 2) insufficient monitoring—we don't measure the right things in the right place at the right time (Bernhardt et al. 2011).

This report does not focus on restoration programme design, but we do note that standards for ecologically successful river restoration have been proposed (Palmer et al. 2005, Parkyn et al. 2010) that include:

1. a place-specific guiding image
2. a focus on measurably improving ecological condition
3. a goal of a self-sustaining system so that only minimal follow-up maintenance is needed
4. no lasting harm is done during restoration activities
5. pre- and post-assessment must be completed.

This report focusses on the design of a monitoring framework to assess the success of J4N-funded restoration activities. *We define 'restoration success' as measurable progress toward improved biodiversity at the scale of the restoration activity*. By focusing on the project scale, we assume any factors that can limit place-based improvement have been addressed in programme design, e.g., spatial and temporal optimisation of restoration activities and addressing landscape barriers to recruitment.

In this section, we align the core biodiversity indicators identified in Section 2 to core measures of restoration activities, within a drivers-pressures-state-impact-responses framework (Section 3.2). This underlines the need to measure both restoration activities and biodiversity outcomes to assess restoration success. A simple decision support tool is then provided to identify the core indicators required for any given J4N-funded restoration project, based on the planned activities (**what and why**).

An introduction to each indicator is provided along with expected temporal trajectories in Section 4. This is important to set expectations, but also to identify the best time to measure each indicator (**when**).

Field method references are then provided and in general are drawn from existing standardised and published methods (**how and where**). This is to provide consistency with existing DOC monitoring.

3.2. Aligning restoration indicators with biodiversity outcomes indicators

Department of Conservation-funded Jobs for Nature activities are targeted at achieving long-term biodiversity outcomes. As part of an intervention logic, it is assumed that funding (inputs) will facilitate activities (restoration actions), which will have immediate outputs that over time will lead to intermediate and then finally, end outcomes (Figure 1).

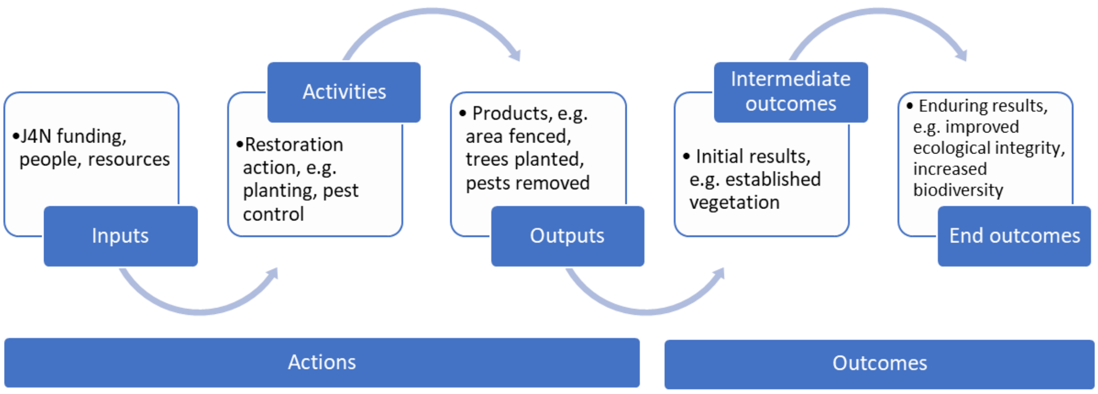

Figure 1. An intervention logic model that shows the links between restoration actions and outcomes.

An intervention logic model is an important basis to view restoration activities because biodiversity outcomes are unlikely to be achieved immediately and in fact may take many decades to be observed (Figure 2). By measuring activities as well as intermediate and end outcomes we can assess the efficiency of J4N funding in the short term and the effectiveness (of achieving biodiversity strategy) in the long term.

Figure 2. Tracking riparian restoration over time demonstrates the importance of measuring initial actions, intermediate outcomes and end outcomes. Images from google.com.

3.2.1. A Drivers-Pressures-State-Impact and Responses (DPSIR) logic

It is useful to view stream restoration intervention within a Drivers-Pressures-State-Impacts and Responses (DPSIR)[3] framework to identify the relationship between restoration activities and biodiversity outcomes (Figure 3). The stream restoration activities likely to occur in J4N-funded projects aim to mitigate land-use pressures as well as directly improve ecosystem state and hence biodiversity outcomes. As such, assessing restoration success (i.e., progress toward improved biodiversity) can be achieved by measurement of the Response variables (i.e., quantification of the restoration actions), measurement of the Pressure variables (i.e., quantification of the proximate variables that drive State) and measurement of the State variables (i.e., quantification of the ecological and biological status). The State variables can be used to assess biodiversity as well as other ecosystem services and functions.

[3] The DPSIR model was developed as an integrated framework for environmental assessment and reporting (EEA 1999).

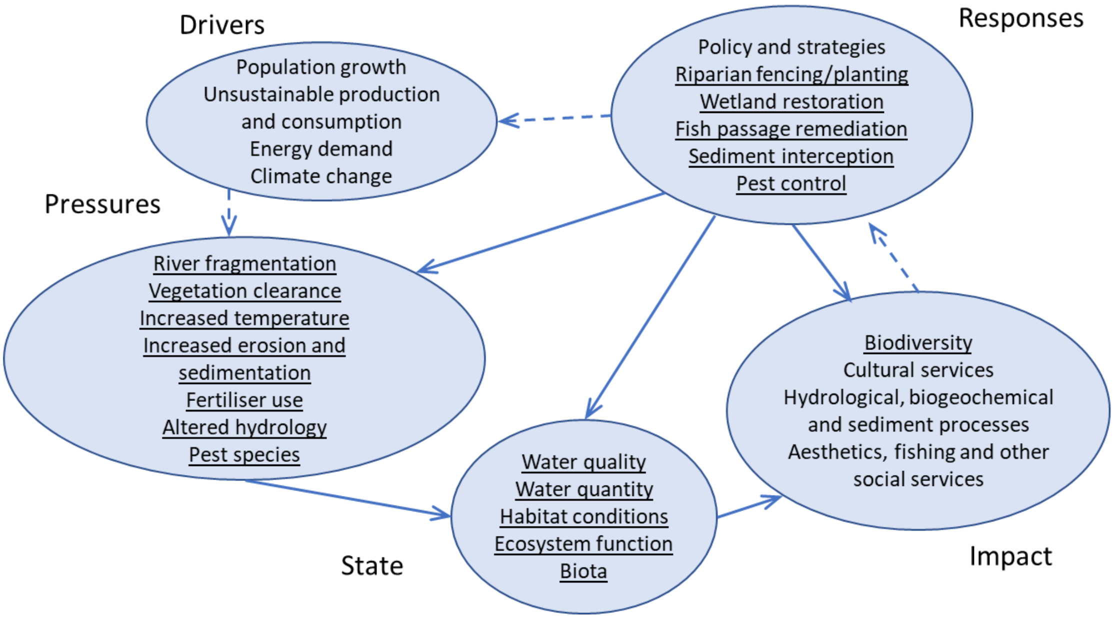

Figure 3. Viewing stream restoration activities within a DPSIR framework. Underlined text indicates pressures, state, impact and responses most relevant to stream restoration activities.

The DPSIR logic is important for assessing restoration actions because it allows for changes observed in one arena to be linked to another. For example, pest control as a Response can mitigate the Pressure of pest species and improve indigenous biological State and ultimately Impact biodiversity (Figure 3). Importantly, that means if an increase in pest control investment occurs, we can make the logical link that a positive biodiversity outcome will be observed. We can increase the evidence of a positive outcome by measuring other links in the logic chain, such as how well the pressure is mitigated (in this example via an assessment of pest density) and how well state is improved (in this example via indigenous biological diversity). Further, the time before change is observed in each area will vary. While we might be able to quantify response actions instantly, it may take many years before Impact on biodiversity outcomes are observed. For this reason, quantifying the links in the logic chain becomes important, to demonstrate progress toward the restoration outcome.

3.2.2. Operationalising the DPSIR framework

One way of viewing the relationship between Responses, Pressures, State and biodiversity Impact is through an ‘indicators’ lens (Figure 4).

Action indicators – Responses are identified as restoration actions (e.g., riparian fencing), which can be quantified with a series of action indicators (e.g., length fenced). These recommended action indicators are drawn from a review of standardised measures of land management actions focussed on freshwater ecosystems in rural areas (Doehring et al. 2020), as well as common pest monitoring indicators.

Pressure indicators – 'Proximate pressures' are those characteristics of land use that have a localised effect on stream biodiversity. One action can influence several Pressure Indicators. For example, riparian fencing as a restoration action (Action) can mitigate vegetation clearance (Proximate pressure) through the passive recovery of streamside vegetation changing the vegetation class (Pressure Indicator), it can reduce the concentration of nutrients (Pressure Indicator) entering streams via direct application and surface flow, and it can reduce bank erosion and instream sedimentation (Pressure Indicator) through the exclusion of stock (Figure 4, Figure 5). Indicators of these proximate pressures quantify the degree of reduction in pressure. For example, terrestrial plant cover is an inverse measure of vegetation clearance, and instream dissolved nutrients reflects terrestrial nutrient inputs.

Outcome indicators – Outcomes are equivalent to Impacts in the DPSIR framework and are measured using indicators which characterise state, at least for biodiversity and ecological integrity (Figure 4). For example, if the goal outcome is increased biodiversity, then outcome indicators quantify the local diversity of target flora and fauna. Recommended outcome indicators are drawn from those identified in Section 2.

An assessment of State is gained by a combination of Pressure and Outcome indicators expressed in such a way as to describe stream condition. For example, terrestrial habitat diversity indicators describe both the pressure (e.g., a lack of vegetation structure and variety capable of supporting a diversity of fauna and ecological processes) and state of habitat conditions. In turn, habitat condition is a key component indicator of indigenous biodiversity (Figure 4).

The indicator lens provides a decision support tool for the selection of appropriate indicators depending on restoration activities and goals. Figure 5 provides an example of indicator selection when the Action is riparian fencing, and the Outcome is increased indigenous biodiversity. Other examples of the decision support tool with different actions and outcomes are provided in Appendix 6.5.

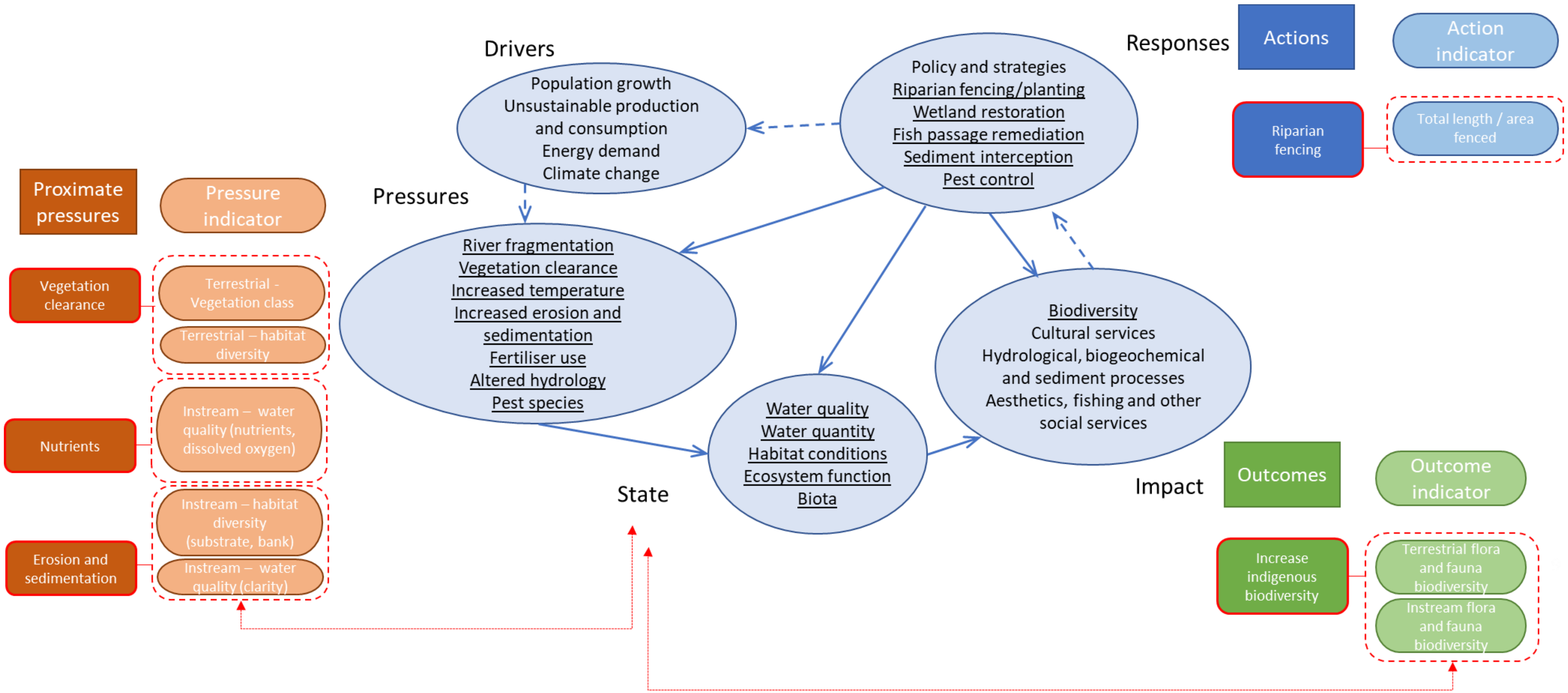

Figure 4. Aligning indicators to the DPSIR framework. Bold text indicates pressures, state, impact and responses most relevant to stream restoration activities.

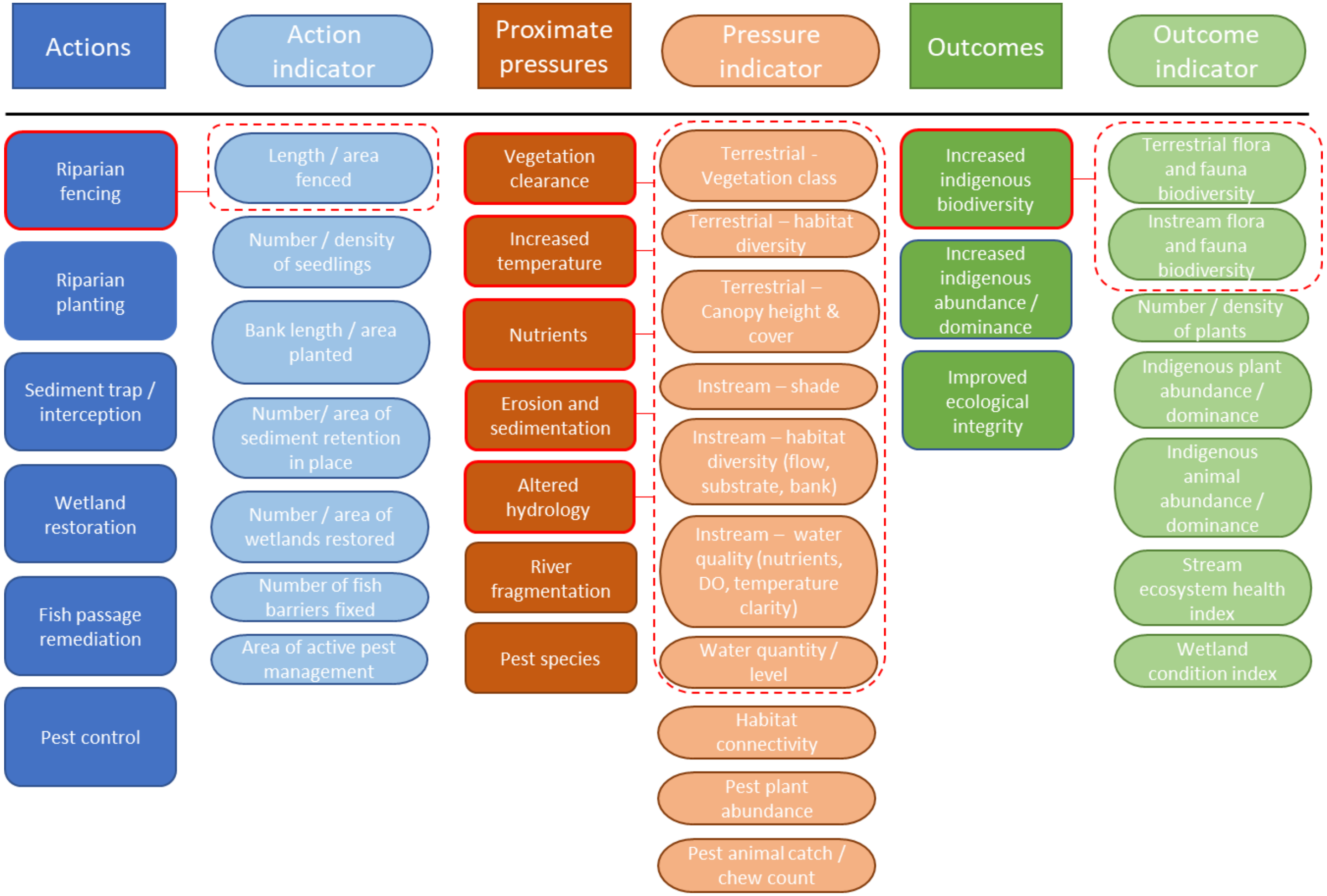

Figure 5. Decision support tool to identify relevant action, proximate pressure, and outcomes indicators for J4N-funded projects. Boxes outlined in red show an example of indicator selection when the action is riparian fencing, and the outcome is increased indigenous biodiversity. Some indicators can be used to report on multiple actions / pressures / outcomes. See Appendix 3 for examples of indicator selection for the remaining five restoration actions.

3.2.3. How variables fulfil other assessment needs

Proximate pressure variables also contribute to an assessment of ecological integrity when viewed through the lens of the freshwater biophysical ecosystem health framework (Clapcott et al. 2018) (Figure 6). Ecological integrity is the integrating biodiversity concept underpinning the New Zealand Biodiversity Assessment Framework (McGlone et al. 2020). Systems with ecological integrity (and good ecosystem health) support thriving indigenous communities (i.e., biodiversity).

Figure 6 shows how a combination of proximate pressure and outcome indicators provide an integrated assessment of ecological integrity. Proximate pressure variables provide measures of the state of physical habitat, water quantity and water quality. Additional ecological process indicators are needed, which might not otherwise be monitored to assess biodiversity outcomes, to calculate a stream ecosystem health index based on the five components of ecosystem health: physical habitat, water quantity, water quality, ecological processes, and aquatic life.

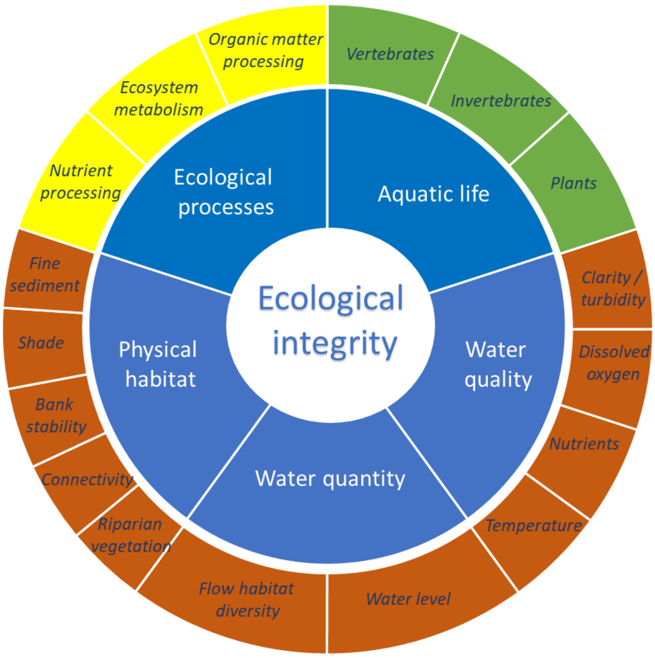

Figure 6. Alignment of pressure (brown) indicators and biodiversity outcome indicators (green) within the ecosystem health framework. To provide an assessment of ecosystem state requires additional ecological process indicators (yellow). Adapted from Clapcott et al. 2018)

The importance of the connection between environmental change (pressures and state) and biodiversity change (impacts) is also recognised in the identification of essential biodiversity variables recommended for the global standardisation of biodiversity assessment (Pereira et al. 2013). Essential biodiversity variables (EBVs) are grouped into six classes: genetic composition, species populations, species traits, community composition, ecosystem structure, and ecosystem function. Some of the Pressure and Outcome indicators identified in Figure 5 group into these classes, as shown in Table 5.

Table 5. Alignment of proximate and outcome indicators to the essential biodiversity variables (EBV) framework. '–' indicates no suitable indicator available at present.

EBV class	**EBV examples**	**Proximate pressure indicators**	**Outcome indicators**
Genetic composition	Effective population size	-	-
Species populations	Species distribution	-	Flora and fauna presence
	Species abundance	-	Flora and fauna presence
Species traits	Phenology	Terrestrial - canopy height	
Community composition	Taxonomic diversity	-	Flora and fauna biodiversity
	Community abundance	-	Flora and fauna abundance / dominance
	Trait diversity	-	Flora and fauna diversity / dominance
Ecosystem structure	Habitat structure	Terrestrial - vegetation class	# / density of plants
		Terrestrial - vegetation cover	-
		Terrestrial - habitat diversity	-
		Instream - habitat diversity	-
Ecosystem function	Nutrient retention	Instream - water quality	-
	Primary productivity	Instream - shade	-

4. BIODIVERSITY INDICATORS

The indicators presented in this section are grouped as either Action, Proximate pressure or Outcome indicators. They can be selected based on the J4N-funded project's anticipated restoration actions and project goals. For each indicator, we identify the relevant action or goal, the likely recovery time and hence the suggested timescale for monitoring. We also provide standardised methods and metrics for each indicator.

Some indicators are measured using the same field methods (Figure 7). For example, 5 m x 5 m permanent sample plots can be used to assess the number of surviving seedlings per square kilometre (Action), canopy height in metres (Pressure), and plant diversity (Outcome). Field methods should be aligned after the decision support tool has been used to identify relevant indicators.

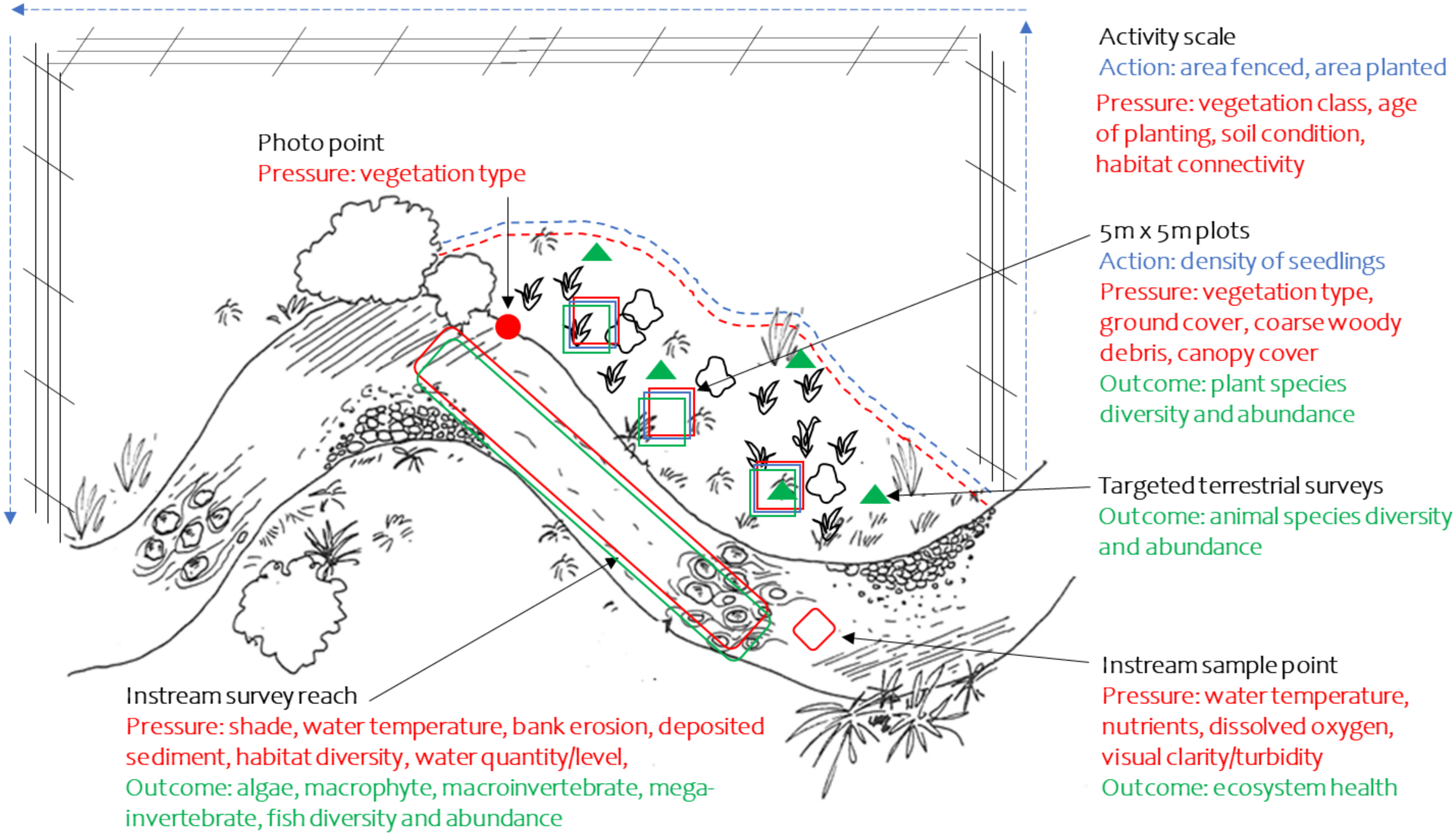

Figure 7. Site illustration showing the alignment of field methods which provide indicator data to assess restoration actions, proximate pressures and outcomes associated with riparian fencing and planting. Image adapted from Biggs et al (2002).

4.1. Action indicators

Action indicators provide a quantitative measure of the restoration activity. The J4N-funding supports nature-based restoration activities including vegetation planting for freshwater and biodiversity restoration, fencing waterways, pest and plant control, and fish passage remediation.

4.1.1. Riparian fencing

Background

Fencing using permanent or semi-permanent materials delineates a zone to be managed differently from the surrounding area. When waterways are fenced, this zone is often referred to as the 'streamside management zone' or 'riparian zone'. In the absence of human impacts, the riparian zone is characterised by unique flora and fauna; it further supports landscape biodiversity by acting as a wildlife corridor and improves instream health by regulating hydrology, light, nutrient, organic matter and sediment inputs.

Methods

Riparian fencing is assessed by spatial extent. A tape measure or hip chain can be used to measure the length (of waterway) and area fenced (Figure 8). The location of fencing should also be recorded using geographic coordinates (Easting and Northing) with GPS points. The metrics calculated and reported, from either field measures or GPS coordinates are 1) the length of waterway fenced in kilometres and 2) the area of riparian zone land fenced in square kilometres. The latter can also be expressed as percentage of the catchment.

Figure 8. The area managed as a riparian zone is delineated by fencing.

Timescale of measurement

Spatial extent of fencing should be measured at the completion of fence construction. If actions are planned to span multiple years, then an assessment should be made annually.

Link to proximate pressures

The fencing of riparian zones can mitigate pressure on stream biodiversity via several mechanisms:

1. The exclusion of stock (if present in surrounding areas) reduces soil / bank erosion, grazing of riparian vegetation and the direct input of concentrated nutrients and faecal bacteria into waterways [see Section 4.2.4. Erosion and sedimentation]
2. Passive revegetation occurs slowly over time further:
   a. stabilising surface soils and stream banks [see Section 4.2.4. Erosion and sedimentation]
   b. increasing habitat provision for terrestrial and aquatic biota [see Section 4.2.1. Vegetation clearance]
   c. slowing and filtering the surface and shallow-subsurface flow of water [see Section 4.2.5. Altered hydrology] and nutrients from the land to the waterway [see Section 4.2.3. Nutrients]
3. Fenced areas are less likely to be subject to productive land management including:
   a. the application of fertilisers and pesticides which reduces the input of nutrients and other pollutants [see Section 4.2.3. Nutrients]
   b. water abstraction for productivity [see Section 4.2.5. Altered hydrology]

Method references

- Measure with hip chain or GPS: No reference

4.1.2. Riparian planting

Background

Restoring riparian vegetation provides valuable biodiversity benefits by directly increasing indigenous plant abundance and dominance and by creating habitat conditions favourable to other indigenous species. Improved habitat conditions occur through the creation of microclimate, food and resource provisioning, and water and biogeochemical regulation.

Methods

Riparian planting is assessed by a) spatial extent and b) the density and survival of seedlings.

1. Spatial extent

A tape measure or hip chain can be used to measure the length (of waterway) and area planted (Figure 9). The planted perimeter should also be recorded using geographic coordinates (Easting and Northing) with GPS points. The metrics calculated and reported, from either field measures or GPS coordinates are 1) the length of waterway planted in kilometres and 2) the area of waterway planted in square kilometres. The latter can also be expressed as percentage of the catchment.

2. Survival of seedlings

   Permanent 5 m x 5 m sample plots are established and the number of live planted indigenous plants within the plots are recorded. Overall, a minimum of 3 plots and a maximum of 8 plots are required per restoration sites, and plots should be evenly spaced. The metric calculated is the number of alive plants per square kilometre (i.e., density of planting). This can be expressed relative to original planting density (so this needs to be recorded), to give a percentage survivorship (i.e., observed density / original planting density = % survivorship).

Figure 9. The area of riparian planting. Image source: nzffa.org.nz.

Timescale of measurement

Spatial extent of planting should be measured at the completion of initial planting activities. If actions are planned to span multiple years, then an assessment should be made annually, and each new planting area delineated. Survival of seedlings plantings should be measured annually for 5 years post planting. This will also help to determine whether supplementary planting would be necessary, if large numbers of plants have died (e.g., > 10%).

Link to proximate pressures

The planting of riparian vegetation mitigates several pressures on stream biodiversity. Active planting:

1. stabilises surface soils and stream banks, [see Section 4.2.4. Erosion and sedimentation]
2. increases habitat provision for terrestrial and aquatic biota, [see Section 4.2.1. Vegetation clearance]
3. slows and filters the surface and shallow-subsurface flow of water [see Altered hydrology] and nutrients from the land to the waterway [see Section 4.2.3. Nutrients]
4. shades waterways [see Section 4.2.2. Increased temperature]

Method references

- Measure area with hip chain or GPS: No reference
- Measure survival of seedling with permanent 5 m x 5 m plots: Department of Conservation 2019. Field protocols for DOC Tier 1 Inventory & Monitoring and LUCAS plots. Version 14.

4.1.3. Sediment trap / interception

Background

Settling ponds, basins or traps are formed by excavation or an embankment designed to intercept sediment-laden run-off from a given area and stop it from entering a stream. Commonly used as a stormwater management option in urban settings, they can also be used in rural settings targeting critical source areas. Key design features of permanent sediment traps include location, shape, depth, size, number of cells, outflow, and planting. Well-designed sediment traps can function as wetlands, which over time can provide biodiversity benefits. Sediment interception can also be achieved by the planting of wide vegetation buffers within or below critical source areas and in the riparian zone.

Methods

The effectiveness of sediment traps and / or planting to intercept sediment, can be assessed by a) the number of and spatial extent of sediment trap / planting and b) the percentage of the catchment filtered (intercepted) by the sediment trap / retention.

A tape measure or hip chain can be used to measure the area of the sediment trap or area planted to intercept sediment (Figure 10). The trap(s) / planted perimeter should also be recorded using geographic coordinates (Easting and Northing) with GPS points. The metrics calculated and reported, from either field measures or GPS coordinates are 1) the number of sediment traps, and 2) the area of sediment trap/planted in square kilometres. The latter can then be expressed as a percentage of the catchment. Generally, a sediment trap size of 1–5% of the catchment is needed to reduce sediment loads 50–90% (Environment Southland 2020)

Figure 10. The area of an established sediment trap. Image source: www.es.govt.nz.

Timescale of measurement

Spatial extent of sediment trap / interception should be measured at the completion of initial restoration activities. Sediment traps should then be monitored at least every 5 years, and preferably after heavy rainfall events, to assess whether further maintenance is required.

Link to proximate pressures

Sediment interception leads to biodiversity outcomes by mitigating several pressures:

1. Slowing and filtering the surface flow of water makes the adjacent waterway:
    a. less flashy and more likely to maintain natural flow and temperature regimes [see Section 4.2.5. Altered hydrology]
    b. less prone to bank and substrate erosion [see Section 4.2.4. Erosion and sedimentation]
2. Limiting the direct input of fine sediments improves instream habitat diversity [see Section 4.2.4. Erosion and sedimentation], and
3. Provision of off-stream habitat can improve habitat connectivity at the landscape scale. [see Section 4.2.5. Altered hydrology]

Method references

- Measure area with hip chain or GPS: No reference.

4.1.4. Wetland restoration

Background

Wetlands are literally 'wet' saturated soils and include swamps, bogs, salt marshes, lakes, and some riparian areas. They are characterised by a unique flora and fauna and provide multiple localised and landscape biodiversity benefits. It is assumed J4N-funded projects generally focus on restoring naturally occurring wetlands, rather than constructed wetlands, and follow best practice guidelines (e.g., Wetland restoration: a handbook for New Zealand freshwater systems; Peters & Clarkson 2012).

Methods

Wetland restoration action is assessed by the spatial extent of the wetland (Figure 11). A tape measure or hip chain can be used to measure the area of the wetland. The perimeter should also be recorded using geographic coordinates (Easting and Northing) with GPS points. The metric calculated and reported, from either field measures or GPS coordinates is the area of wetland in square kilometres.

Figure 11. An area of wetland restoration.

Timescale of measurement

Wetland extent should be measured at the completion of restoration activities. If actions are planned to span multiple years, then an assessment should be made annually.

Link to proximate pressures

Restoring wetlands mitigates:

1. Vegetation clearance by increasing habitat provision for wetland biota [see Section 4.2.1. Vegetation clearance]
2. Altered hydrology by
    a. Directly affecting water quantity and level within the wetland and helping maintain natural flow regimes in streams
    b. Increasing wetted habitat connectivity at the landscape scale, and
    c. Improving habitat diversity and condition and wetland functioning at the wetland scale [see Section 4.2.5. Altered hydrology].

Method references

- Measure area with hip chain or GPS: No reference

4.1.5. Fish passage remediation

Background

Structures that impede the movement of aquatic organisms, and in particular fish, are remediated by their removal or the placement of new features (e.g., fish ramps) that enhance fish passage. Structures can impede some species and not others and can be actively used to manage access for both native and non-native species, including pest fish species.

Methods

Fish passage remediation is assessed by counting the number of remediated fish barriers (Figure 12). It is assumed fish passage remediation has been undertaken in accordance with best practice guidelines (e.g., New Zealand Fish passage guidelines for structures up to 4 metres; Franklin et al. (2018)), in which case, the type of remediation undertaken (e.g., removal, retrofit, new structures, built barriers) will be categorised for future testing of the efficacy of the restoration action (Franklin et al. 2018). For the purposes of J4N-funded project reporting, the metric is simply the number of fish barriers fixed.

Figure 12. One type of fish passage remediation activity, with blocks creating variable flow areas, and resting spots for migrating fish. Image source: Franklin et al. (2018).

Timescale of measurement

The number of fish barriers remediated should be measured at the completion of restoration activities. If actions are planned to span multiple years, then an assessment should be made annually.

Link to proximate pressures

The remediation of fish barriers addresses habitat connectivity and generally facilitates the longitudinal movement of fishes (and other aquatic organisms) upstream and downstream. [see Section 4.2.6. River fragmentation]

Method references

- The number of fish barriers remediated: No reference. However, see Franklin et al. (2018) for further detail on classifying fish barrier remediations, if this is required – Franklin P, Gee E, Baker C, Bowie S 2018. New Zealand Fish Passage Guidelines. For structures up to 4 metres. NIWA Client Report No: 2018019HN. 160 p.

4.1.6. Pest control

Background

Weeds and predators that occur in and around waterways in numbers that affect native flora and fauna detrimentally may be considered pests. Pest plant management can involve physical control (e.g., grazing, mowing, grubbing, dredging), herbicides and / or biological control. Pest animal management can involve trapping, pesticides or extermination via shooting or kill traps. This provides direct benefits through increased abundance and diversity of indigenous species, as well as indirect benefits through increased habitat provisioning via removal of invasive species. Advice on pest control methods can be obtained from organisations like regional councils and DOC (e.g., https://www.doc.govt.nz/nature/pests-and-threats/predator-free-2050/community-trapping/trapping-and-poisoning/choose-traps-and-toxins/).

Methods

Pest control is assessed by recording effort as the total riparian area or total stream length of **active** pest control (Figure 13). A tape measure or hip chain can be used to measure the area of active pest management. The perimeter should also be recorded using geographic coordinates (Easting and Northing) with GPS points. The metric calculated and reported, from either field measures or GPS coordinates, is the area of pest control in square kilometres. This can also be expressed as percentage of the catchment. Similarly, the length of waterway treated is recorded via field measures or GPS coordinates and reported as the length of waterway in kilometres.

Details of pest control measures should also be recorded, noting that these data are likely to be more useful for local management purposes than national reporting. For example, pesticide / herbicide metrics include the type (brand and formulation), concentration and application method; and, trapping metrics include the number / density of traps, types of bait / lures used, trap maintenance (e.g., frequency checked and reset), and numbers / species of pests caught.

Figure 13. An area of active pest control. Image source: www.gw.govt.nz.

Timescale of measurement

The area / length of pest control should be measured at the completion of installation of the control regime and should include separate measurements for each target species. If pest control is ongoing, an assessment should be undertaken after each control round to inform whether changes to the regime are required. This would also help determine site-specific effectiveness of the chosen control method.

Link to proximate pressures

Controlling for pest species mitigates several pressures on terrestrial flora and fauna. Pest control:

1. Indirectly increases habitat provision for terrestrial biota via limiting browsing of indigenous flora by introduced grazers and limiting competitive exclusion of indigenous flora by introduced pest plants [see Section 4.2.1. Vegetation clearance]
2. Decreases predation pressure and competition pressure on existing indigenous species by limiting the abundance of pests and limiting abundance of introduced species that exert competitive pressure on indigenous species [see Section 4.2.7. Pest species].

Method references

- Measure area with hip chain or GPS: No reference. However, see websites of councils, DOC and other organisations involved in pest control to find fit-for-purpose guidance.

4.2. Proximate pressure indicators

4.2.1. Vegetation clearance

Actions

Riparian fencing, riparian planting

Background

Vegetation clearance directly impacts on biodiversity by removing plants and habitat for fauna, altering ecosystem health and function. Riparian fencing and native planting as restoration actions, mitigate the pressure of vegetation clearance within riparian zones by preventing grazing by stock and replacing cleared plants. This translates to increases in biodiversity and ecological integrity by the reintroduction of native plants and establishment of habitat for fauna.

Methods

Vegetation clearance mitigation is assessed using photo points, permanent 5 m x 5 m vegetation plots, and a site-wide assessment. These are detailed below:

1. Photo points.

   Permanent photo points should be established in the restoration area to provide visual evidence to communicate the change in the vegetation within the area. It is suggested that photo points are set on the corner of the permanent plots and four photos are taken at each point facing north, east, south and west.

2. Permanent 5 m x 5 m plots.

   a. Vegetation type. Qualitative visual observations are made of the vegetation within 5 m x 5 m plots and vegetation type is classified as per the DOC Tier 1 vegetation RECCE surveys, into the set categories for forests, shrublands, grassland, aquatic, alpine or other.

   b. Estimated % ground cover. This is an estimated percentage of the plot area (to the nearest 5%) that is covered by vascular vegetation, non-vascular vegetation, leaf litter, bare ground, and rock. This provides information on the quality of the site as suitable habitat for skinks, invertebrates and birds. Vegetation and leaf litter provide habitat for skinks and invertebrates which in turn provide food for foraging birds. Rock surfaces can provide basking habitat for skinks (if not permanently shaded).

   c. Estimated volume of coarse woody debris (CWD). All CWD within the plot with a diameter wider than 5 cm will be measured following a modified version of the methodology of Smale et al. (2008) and include measurements of estimated volume and decomposition state. CWD provides suitable habitat for skinks and invertebrates

   d. Estimated % canopy cover. This metric is measured as changes to an Increased temperature indicator (see next section) but also provides information on the quality of the site as suitable habitat for indigenous geckos, invertebrates and birds.

3. Site-wide assessment.

   a. Land Cover Data Base (LCDB) vegetation class. This is estimated for the restoration area from a site wide visual assessment. This metric is used to determine change in land use at a catchment scale and aligns to MfE requirements for environmental reporting.

   b. Age of planting. Based on the date of planting for the restoration area. Indigenous frogs are known to primarily inhabit areas with long undisturbed periods and are unlikely to be present in plant communities less than 30 years old. There is also a time lag for dispersal of other fauna such as skinks, geckos and some birds to immigrate into new habitats. We recommend that the age of the plant community is determined by the date of initial plantings.

   c. Vegetation height and width diversity. Tall trees (> 5 m) with a diameter at breast height > 15 cm, provide habitat and optimal foraging for bats and some birds. The range in vegetation height in the restoration area, as well as the diversity and density of roosting features (e.g., crevices, cracks, broken branches, flaking bark, epiphytes) should be recorded in a site wide survey.

Timescale of measurement and response

Habitat assessment should be undertaken at the completion of fencing / planting and then repeated every five years. It is anticipated that plantings, if successful, will be established within 5 years and a change in LCDB classification will occur. Ideally, habitat condition will continue to improve until riparian forest succession is achieved (5–50 years).

Method references

- Photo points: Hanford & Associates 2004. FORMAK: Forest Monitoring Manual.
- Permanent 5 m x 5 m sample plots for:
  - ground cover and canopy cover (Department of Conservation. 2019. Field protocols for DOC Tier 1 Inventory & Monitoring and LUCAS plots. Version 14)
  - coarse woody debris (Smale MC, Dodd MB, Burns BR, Power IL 2008. Long-term impacts of grazing on indigenous forest remnants on North Island hill country, New Zealand. New Zealand Journal of Ecology 32(1): 57- 66.
- Site wide assessment for:
  - date of initial plantings and average height of plantings (if planting was staged, each planting stage to be treated as a separate block) (No reference)
  - New Zealand Land Cover Database classes at version 5.0

4.2.2. Increased temperature

Actions

Riparian fencing, riparian planting

Background

Active riparian planting leads to a more rapid mitigation of increased temperatures than passive revegetation following riparian fencing alone. Both increase shade, which intercepts sunlight and reduces the energy that is transferred to water and soils. For small waterways, tall grass and shrubs on the stream bank can shade the water surface, and in larger waterways taller trees provide partial or full shade. Regardless of the type of vegetation, canopy density and height are the most important factors in determining how much sunlight is intercepted. Thicker and taller vegetation reduces the amount of sunlight reaching the water surface and warming the water. In addition, thicker and taller vegetation creates a microclimate that is more suited to terrestrial indigenous biodiversity.

Methods

Increased temperature mitigation is assessed using permanent 5 m x 5 m vegetation plots, an in-stream survey, and a measurement of water temperature. These are detailed below:

1. Permanent 5 m x 5 m plots.

   Within permanent plots, qualitative visual observations are made of the vegetation within the plot(s) and from the following metrics calculated:

a. Estimated canopy height in metres. This metric is used to track riparian planting survival and establishment over time and aligns to MfE requirements for environmental reporting.
b. Estimated % canopy cover. This metric is used to track riparian planting survival and establishment over time and aligns to MfE requirements for environmental reporting.

2. Instream survey.
   Within a stream survey reach (dependent on length / area of restoration activity but at a minimum 50 m long), the Rapid Habitat Assessment (RHA) protocol (Clapcott 2015) is used to estimate the percentage of shading of the streambed throughout the day due to vegetation, banks or other structure(s). The metric reported is % riparian shade. The data are directly comparable to the 'shading of water' metric assessed using the SHAP P2d method, as part of DOC Tier 1 inventory monitoring.

3. Water temperature.
   In the stream, continuous water temperature is recorded using a temperature logger deployed at least during summer months. The data are used to calculate maximum daily and mean daily (°C) temperature, from which the Cox-Rutherford Index can be calculated, which is useful for interpreting critical thermal stress for stream fauna. Alternatively, if a temperature logger is not used, a spot measure of water temperature should be made at mid-afternoon mid-summer and used to estimate the Cox Rutherford Index. Spot temperature measures are undertaken in DOC Tier 1 inventory monitoring.

Timescale of measurement and response

Canopy height and estimated % canopy cover, % shade of the streambed and water temperature should be measured annually for five years post planting and then every subsequent five years. Canopy height and cover is dependent on planting regime; restoration of flax / shrub vegetation may be achieved within 10 years while restoration of a riparian forest may take up to 50 years. Similarly, depending on stream size (especially width), partial or full shade may be achieved within 10 years. A direct correlation between shade and water temperature is dependent on the extent and location of fencing and planting activities within the catchment. For example, water temperature is most likely to change in response to riparian shading when a long stretch (> 100 m) of a headwater stream (< 5 m wide) is subject to riparian planting.

Method references

- Canopy cover – Department of Conservation 2019. Field protocols for DOC Tier 1 Inventory & Monitoring and LUCAS plots. Version 14.
- Shade – Clapcott J 2015. National rapid habitat assessment protocol development for streams and rivers. Prepared for Northland Regional Council/Envirolink. Cawthron Report no. 2649. 29 p

- Water temperature:
  - spot measurements – DOC National Freshwater Field Team Manual 2021, – in situ measurements
  - continuous measurement – Parkyn S, Collier K, Clapcott J, David B, Davies-Colley R, Matheson F, Quinn J, Shaw W, Storey R 2010. The restoration indicators toolkit: Indicators for monitoring the ecological success of stream restoration. National Institute of Water and Atmospheric Research, New Zealand. 134 p.

4.2.3. Nutrients

Actions

Riparian fencing, riparian planting, wetland restoration

Background

Riparian fencing and planting mitigate nutrient pressures by excluding productive farming practices from adjacent waterways. They provide a 'buffer' to filter the flow of surface and shallow sub-surface flow of nutrients from productive farming systems. Wetlands mitigate nutrients by physical nutrient removal (e.g., settling / sedimentation) and biochemical processing (e.g., denitrification and plant growth). Excess nutrients (eutrophication) and unlimited light in waterways contribute to the proliferation of undesirable plant and algal growth which affects water quality, habitat availability and food resources for stream fauna. High nitrate concentrations can also be directly toxic to stream fauna. Primary effects on water quality due to eutrophication are changes in dissolved oxygen (DO) and pH. Low DO concentrations can be lethal to stream fauna and pH mediates biogeochemical cycling (i.e., availability of toxicants). As outlined in the Restoration Indicators Toolkit, while pH is not expected to be affected by most stream restoration scenarios, DO on the other hand, can provide a good measure of restoration success when the aim is to improve the life supporting capacity of streams.

Methods

1. Nutrients.

   Nutrient concentrations are assessed by taking a water sample and sending it to a laboratory for ammonia, nitrate, nitrite, phosphate and total nitrogen and total phosphorous analysis. All metrics are reported in mg/L. Alternatively, nitrate and phosphate, can be estimated using the SHMAK method (NIWA 2019).

2. Dissolved oxygen.

   Dissolved oxygen varies throughout the day and is ideally assessed by the placement of a datasonde for a minimum 24-hr period in summer (the time of maximum primary productivity). Alternatively, a hand-held DO logger can be used to record minimum DO immediately before dawn. The metric reported is minimum DO (mg/L). If water temperature is recorded at the same time, temperature can be used to calculate minimum DO (% saturation).

Timescale of measurement and response

Nutrients (nitrate and phosphate) should be assessed annually for five years and then subsequently every five years. A reduction in nutrients is likely to be detected if restoration activities are targeted to critical source areas of nutrients within a catchment. With this strategic approach a reduction in nutrients might be achieved within 10–20 years, with the establishment of vegetation and associated nutrient processing. While little improvement might be expected in the first five years, the annual measurements provide a baseline for assessing future change. Dissolved oxygen should be assessed annually and at a minimum every five years. It provides a good indication of life supporting capacity and can change relatively rapidly in response to light limiting primary productivity (< 10 years).

Method references

- DOC National Freshwater Field Team Manual 2021 – Water sample collection.
- NIWA 2019. SHMAK Stream Health Monitoring and Assessment Kit User Manual. NIWA Christchurch. 84 p.

4.2.4. Erosion and sedimentation

Actions

Riparian fencing, Riparian planting, Sediment trap / interception

Background

The condition of riparian surface soils, stream banks and instream substrate can change considerably following restoration, due to the direct and indirect effects of riparian fencing, planting and other sediment control practices such as sediment traps and basins. The effect on biodiversity and ecological integrity is via the availability of habitat; whether it be groundcover for terrestrial invertebrates, stream bank vegetation for fish cover / egg laying habitat, diversity of bed substrate sizes for instream flora and fauna, or water quality. Each of the following mechanisms and factors (riparian soil condition, bank erosion, instream sedimentation, clarity) are measured with different methods but are equally important for quantifying the reduction in erosion and sedimentation pressures on stream biodiversity.

Methods

1. Riparian soil condition.

   A qualitative visual assessment of ‘soil drainage’ and ‘rills / channels’ is undertaken in permanent vegetation plots using the Stream Habitat Assessment Protocols (SHAP) P2d method (Harding et al. 2009). The metrics are recorded as a score from 1 to 5. The SHAP P2d methods are used in DOC Tier 1 inventory monitoring.

2. Bank erosion.

   A qualitative visual assessment of bank erosion is obtained using the Rapid Habitat Assessment (RHA) protocol (Clapcott 2015). The percentage of the stream bank recently / actively eroding due to scouring at the water line, slumping of the bank, or stock pugging is recorded for each of the left and right stream banks and averaged. The metric is % stream bank erosion. The data are directly comparable to an assessment of 'stream stability' undertaken using the SHAP P2d method in Tier 1 DOC inventory monitoring.

3. Substrate / deposited sediment.
    a. If it is safe to enter the stream, a semi-quantitative assessment of particle size distribution, including fine sediment, on the streambed is made using the SAM3 – Wolman pebble count (Clapcott et al. 2011). The metric is the % of deposited sediment (combined silt-clay and sand). In addition to this metric, the diversity of substrate sizes can be calculated to provide a measure of instream habitat diversity. These methods and metrics are the same as those used in DOC Tier 1 inventory monitoring.
    b. If it is not safe to enter the stream, a qualitative visual assessment of deposited sediment is obtained using the Rapid Habitat Assessment (RHA) protocol (Clapcott 2015). The percentage of the streambed covered by fine sediment (clay-silt or sand) is estimated from the stream bank. The metric is the % deposited sediment. The data are comparable to an assessment of deposited sediment undertaken using the SAM2 method in DOC Tier 1 inventory monitoring.
4. Visual clarity.
    a. A quantitative assessment of visual clarity is made using a clarity tube or black disc, which both measure the distance through water that a human eye can see a black object, following the SHMAK method (NIWA 2019). The metric is visual clarity (m).
    b. Turbidity (NTU) is correlated to visual clarity and easily recorded using a calibrated water quality meter (e.g., YSI Pro DSS) as in done in DOC Tier 1 inventory monitoring. If turbidity is recorded it will need to be converted to visual clarity using a site regression; the metric reported for biodiversity monitoring is visual clarity (m).

Timescales of measurement and response

The assessment should be made annually for five years and then repeated every five years. As noted in the Restoration Indicators Toolkit, riparian soils are likely to stabilise first (< 5 years); bank erosion may undergo several cycles of stabilisation and erosion as bank vegetation changes over time before relatively stable stream banks are established (1–20 years); and, instream sediment will respond rapidly (< 5 years) to sediment retention (if the retention area is of sufficient size) or respond over time to catchment and bank erosion processes (1–20 years).

Method references

- riparian soil condition – Harding JS, Clapcott JE, Quinn JM, Hayes JW, Joy MK, Storey RG, Greig HS, Hay J, James T, Beech MA, Ozane R, Meredith AS, Boothroyd IKD 2009. Stream habitat assessment protocols for wadeable rivers and streams of New Zealand. University of Canterbury Press, Christchurch.

- bank erosion – Clapcott J 2015. National rapid habitat assessment protocol development for streams and rivers. Prepared for Northland Regional Council/Envirolink. Cawthron Report No. 2649. 29 p
- deposited sediment
    - instream – Clapcott JE, Young RG, Harding JS, Matthaei CD, Quinn JM, Death RG 2011. Sediment Assessment Methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values. Nelson, New Zealand, Cawthron Institute.
    - bankside – Clapcott J 2015. National rapid habitat assessment protocol development for streams and rivers. Prepared for Northland Regional Council/Envirolink. Cawthron Report No. 2649. 29 p.
- clarity / turbidity
    - DOC National Freshwater Field Team Manual 2021 – In situ measurements.
    - NIWA 2019. SHMAK Stream Health Monitoring and Assessment Kit User Manual. NIWA Christchurch. 84 p.

4.2.5. Altered hydrology

Actions

Riparian fencing, Riparian planting, Sediment trap / interception, Wetland restoration

Background

The flow regime (including floods and droughts) supports a diverse range of flora and fauna throughout their full life cycles. Land use, water extraction and climate change alter the natural flow regime affecting stream flows, water level, and connectivity with surrounding terrestrial habitat and other fresh waters (e.g., rivers and their floodplains, and wetlands). Restoration activities seek to mitigate the effects of land use and climate change on stream flows by increasing the residence time of water on the land (i.e., less and slower runoff). This would ideally reduce the duration of low flows and possibly higher flows for some events, while maintaining a diversity of hydraulic habitat instream as well as upstream-downstream connectivity. Further, wetland restoration can increase the connectivity between in- and out-of-channel aquatic habitats. Hydrological indicators include a measure of spatial extent, (e.g., water quantity / level, spatial coverage), connectivity (e.g., flows that connect instream water with out-of-channel water and groundwater) and variability (e.g., high and low flows, hydraulic habitat diversity).

Methods

1. Instream habitat diversity (flow).

    A qualitative visual assessment of hydraulic habitat diversity is obtained using the Rapid Habitat Assessment (RHA) protocol (Clapcott 2015). The number of hydraulic components such as pool, riffle, fast run, slow run, rapid, cascade /

waterfall, turbulence, backwater is recorded. The metric is number of hydraulic habitats.

2. Water quantity / level.

   Water quantity / level is assessed using the SHAP P1 protocol (Harding et al. 2009). A quantitative assessment of wetted area is gained by measuring the average wetted width (m) and multiplying by river length (m). The metric is wetted area (m^2). Water level is qualitatively assessed by assigning a 'low', 'medium' or 'high' rating based on the location of the water surface relative to perennial terrestrial plants (e.g., well below plants is low, inundating plants is high). The metric is flow status.

3. Habitat connectivity.

   A qualitative assessment of out-of-channel wetted habitat is made using an extract from the SHAP P3 protocols (Harding et al. 2009). An estimate of the spatial extent of riparian area with saturated or near saturated soils (i.e., soils that are soft underfoot) is recorded along a transect (> 50 m) parallel to the stream. The metric is % saturated soils.

Timescales of measurement and response

The assessment should be made annually (during baseflow when it is safe to enter the stream) for five years and then repeated every five years. As noted in the Restoration Indicators Toolkit, it may be many years (20+) before instream hydraulic habitat diversity is improved because of out of channel restoration activities. Water levels as measured annually, are unlikely to detect change, unless the flow regime has been significantly altered, e.g., due to large scale wetland restoration. Lateral habitat connectivity will increase as riparian vegetation develops, retaining more surface water in the riparian zone, if the geology and slope are amenable (5–20 years).

Method references

- instream habitat diversity (flow) – Clapcott J 2015. National rapid habitat assessment protocol development for streams and rivers. Prepared for Northland Regional Council/Envirolink. Cawthron Report No. 2649. 29 p.
- water quantity and habitat connectivity – Harding JS, Clapcott JE, Quinn JM, Hayes JW, Joy MK, Storey RG, Greig HS, Hay J, James T, Beech MA, Ozane R, Meredith AS, Boothroyd IKD 2009. Stream habitat assessment protocols for wadeable rivers and streams of New Zealand. University of Canterbury Press, Christchurch.

4.2.6. River fragmentation

Actions

Fish passage

Background

Upstream-downstream connectivity is important for maintaining healthy stream ecosystems. Headwaters provide organic materials and nutrients that support downstream processes, as well as key habitat for migratory fish; 30% of New Zealand's native fish require access to the sea via waterways to complete their lifecycle. Instream barriers, such as culverts, fords, dams and diversions, fragment these habitats, disrupting migration and impacting species distributions. Restoration activities focussed on improving fish passage seek to mitigate the effects of instream barriers by increasing upstream-downstream connectivity[4]. The effect on biodiversity and ecological integrity is via the provision of habitat, which would otherwise not be accessible to fish.

Methods

While the efficiency of any given fish passage can be determined by the carrying capacity of the upstream habitats and the number of recruits reaching the base of the structure, the increase in habitat connectivity is simply calculated as the increase in the proportion of the stream network available to fishes.

1. Habitat connectivity.
   A desktop exercise is undertaken to calculate the length of the stream network inland from the sea, until a fish barrier is encountered. This metric assumes that fish barrier remediation is prioritised from the coast working towards headwaters. The length of waterway can further be expressed as % of total stream length. However, the primary metric is distance from the coast.

Timescales of measurement and response

The assessment should be made annually and / or at the completion of fish passage remediation. Habitat becomes immediately available for fish migration and colonization. Whether or not the fish passage is effective is assessed by fish sampling upstream of the remediation [see Section 4.3.5 Fish].

Method references

- Length / proportion of stream network – No reference. Refer to the River Environment Classification (REC2) river network layer.

4.2.7. Pest species

Actions

Pest control

Background

Pest plants and animals threaten indigenous biodiversity. Pest plants can outcompete endemic plants and reduce ecosystem integrity. Introduced browsing / grazing

[4] Upstream-downstream connectivity is also enhanced through the maintenance of minimum flows – see also Altered hydrology.

mammals such as goats, deer, pigs, and possums can reduce the survival and growth of vegetation by eating foliage and / or stems of plants. Pest animals including mammalian predators and introduced fishes reduce the survival and reproductive success of indigenous invertebrates (terrestrial and freshwater), herpetofauna, fish, birds and bats. Pest indicators include the presence and abundance of pest species.

Methods

1. Pest plants.

   The abundance of pest plants is assessed using Modules 5 and 6 of the WETMAK monitoring kit (Denyer & Peters 2014)[5].

2. Pest animals.

   a. Tracking tunnels / chew cards

      As per Module 7 of the WETMAK toolkit (Denyer & Peters 2014), tracking tunnels and chew cards deployed for 2 weeks at a time can be used to monitor mammalian predators including rodents, mustelids (ferrets, stoats, and weasels), hedgehogs, cats and possums. These are installed for two weeks.

   b. Faecal pellet counts

      The counting of faecal pellets within the restoration area is recommended to detect and track the change in abundance of grazing / browsing pest animals such as deer, goats or pigs. Faecal pellet counts should be undertaken following modified protocols of Forsyth (2005) with 1 m radius plots completed every 10 m along 150 m of stream reach within the restoration area. If control of deer, goats, and / or pigs is being undertaken in wetland or non-linear habitats, then a minimum of 15 faecal pellet counts should be undertaken in 1 m plots spaced no less than 10 m apart.

   c. Fishing

      Pest fish can be detected using sampling methods outlined in Section 4.3.5.

Timescale of measurement and response

An assessment of pest plant abundance should be made annually for five years and then repeated every five years. It is anticipated active control of pest plants will be achieved within 5 years and then that 5 yearly samples will monitor for new incursions. Tracking tunnel and chew card monitoring should be undertaken annually, and up to four times per year if resources allow. This should be done for as long as pest animal control is being undertaken and then repeated every 5 years to monitor for new incursions. Seasonal monitoring is preferred for detecting different species that are active at different times of the year. Improvement is anticipated within 5 years. Likewise, faecal pellet counts should be undertaken annually for as long as pest animal control is being undertaken.

[5] If the species of pest is of interest, then the following reference is an authoritative guide to pest species identification– Champion et al. (2020) Freshwater invasive species of New Zealand 2020. https://niwa.co.nz/sites/niwa.co.nz/files/Freshwater%20invasive%20species%20of%20New%20Zealand%202020_0.pdf

Method references

- pest plants – Denyer K, Peters M 2014. WETMAK: A wetland monitoring and assessment kit for community groups
- pest animals
  - Denyer K, Peters M 2014. WETMAK: A wetland monitoring and assessment kit for community groups.
  - Forsyth DM 2005. Protocol for estimating changes in the relative abundance of deer in New Zealand forests using the Faecal Pellet Index (FPI). Landcare Research Contract Report: LC0506/027. Prepared for Department of Conservation. 24 p.

4.3. Outcome indicators – Indigenous biodiversity

A 3 to 5 yearly inventory of indigenous species present across the restoration area can determine whether there has been an increase in local biodiversity over time. The key metric for all biota is indigenous **taxa richness**. All methods described below include assessment of both indigenous and exotic species.

4.3.1. Stream algae / periphyton

Background

Periphyton refers to the community of algae and cyanobacteria attached to the streambed. It is an important food source for benthic fauna and contributes to habitat complexity. The relative and total abundance of periphyton taxa is driven by sunlight, nutrients, substrate stability and the presence / absence of grazers (animals that feed on different algal resources). Restoration activities that limit these drivers (e.g., mitigating vegetation clearance and nutrient pressures) are likely to positively affect periphyton communities and hence periphyton taxa richness.

Methods

Semi-quantitative visual assessment of periphyton cover is undertaken in hard-bottomed streams (i.e., dominated by gravel, cobbles, or boulders) using the National Environmental Monitoring Standards Periphyton v1.0.0 protocols (NEMS 2020a)[6]. Briefly, 20 underwater views are conducted within a survey reach and the presence (and % cover) of different periphyton categories (taxa) is recorded. The metrics that can be calculated from this method include % periphyton cover, % cover of different periphyton categories and weighted composite cover of periphyton (relevant for assessing ecological integrity). For assessing indigenous biodiversity, a simple taxa richness metric can be estimated based on the knowledge that each periphyton

[6] The NEMS periphyton protocols draw heavily on the methods documented in the *Stream Periphyton Monitoring Manual* (Biggs & Kilroy 2000).

category is made up of between three and seven typical taxa (Biggs & Kilroy 2000)[7]. This method is used in DOC Tier 1 inventory monitoring.

Timescales of measurement and response

Periphyton cover should be assessed annually for the first five years and then every five years after. While no or little change in periphyton richness is expected within the first five years post restoration, these initial data will provide a benchmark for assessing future change which is likely to occur once partial or full canopy cover develops (~10 years), nutrients are reduced (10–20 years), and / or the grazer community is altered due to pest control or fish passage remediation (unknown).

Method references

- NEMS 2020a. National Environmental Monitoring Standards Periphyton Sampling and Measuring Periphyton in Wadeable Rivers and Streams v1.0.0.
- DOC National Freshwater Field Team Manual 2021. – Transect Cover Assessments

4.3.2. Stream plants – macrophytes / bryophytes

Background

Stream plants include macrophytes (i.e., tall growing vascular species), bryophytes (i.e., moss, liverwort) and charophytes (e.g., *Nitella*). Plants provide habitat and cover for instream fauna, but excessive plant growth due to excess nutrients and sunlight can smother habitat and reduce water quality. Like terrestrial plants, indigenous aquatic plants are subject to competition from non-indigenous species. And like periphyton, restoration activities that limit light and nutrients are likely to positively affect stream plant communities and hence stream plant richness.

Methods

Semi-quantitative visual assessment of stream plants is undertaken in soft-bottomed streams (i.e., dominated by silt or sand) using the same transect design approach used in the NEMS Periphyton protocols, but recording bryophyte and macrophyte species. Briefly, 20 underwater views are conducted within a survey reach and the presence (and % cover) of different bryophyte and macrophyte taxa are recorded as well as macrophyte height. Samples of unknown species can be collected for future identification. The metrics that can be calculated from this method include total % cover of plants and % cover of different plants and % macrophyte volume (relevant for assessing ecological integrity). For assessing indigenous biodiversity, a simple taxa richness metric can be reported (i.e., number of indigenous species). The method is used in the DOC Tier 1 inventory monitoring and is based on the rapid macrophyte cover assessment method of Collier et al. (2007). This can be supplemented with pictorial guides to non-indigenous species found in Champion et al. (2020).

[7] If more accuracy in the number of periphyton species is desired, then a quantitative periphyton sample could be collected and sent for identification following the methods of Biggs and Kilroy (2000).

Timescales of measurement and response

Stream plants should be assessed annually for the first five years and then every subsequent five years. Like periphyton, change is likely to occur once partial or full canopy cover develops (~10 years), nutrients are reduced (10–20 years), and/or the grazer community is altered due to pest control or fish passage remediation (duration unknown).

Method references

- NEMS 2020a. National Environmental Monitoring Standards Periphyton Sampling and Measuring Periphyton in Wadeable Rivers and Streams v1.0.0.
- DOC National Freshwater Field Team Manual 2021. – Transect Cover Assessments

4.3.3. Benthic macroinvertebrates

Background

Benthic macroinvertebrates are small spineless fauna that live in and on the streambed including insects, molluscs, worms, crustaceans, mites, hydroids and springtails. The diversity and abundance of different fauna generally reflects habitat and resource availability. Each taxon has a relatively well-known sensitivity to / tolerance of environmental conditions making them useful for assessing stream ecosystem health. Streams in good condition generally have a high taxa richness and include a diversity of species that are sensitive to water temperature, nutrients, and other toxicants. Such diverse macroinvertebrate communities, which are dominated by sensitive species, are favoured by stable substrate and flow, and have a diversity of feeding preferences. Restoration activities that support sensitive species are likely to improve benthic macroinvertebrate diversity and abundance.

Methods

a. NEMS. A semi-quantitative assessment of benthic macroinvertebrate community composition is achieved using the NEMS Macroinvertebrate protocols (NEMS 2020b)[8]. Briefly, a kick-net is used to sample mesohabitats such as runs and riffles in hard-bottomed streams and woody debris, plants, bank margins and mud / sand / leaf litter in soft-bottomed streams. Between four and eight kick-net samples are collected in total from across all types of mesohabitat present (based on their relative abundance) and combined in a composite sample. The sample is sent to a laboratory to determine the taxa present and their relative abundance. Several metrics can be calculated from the data, but taxa richness is suitable for assessing indigenous biodiversity. This method is used in DOC Tier 1 inventory monitoring.
b. SHMAK. Alternatively, an estimation of macroinvertebrate taxa richness can be achieved using the Stream Health Monitoring and Assessment Kit (SHMAK) macroinvertebrate field protocol (NIWA 2019). Sample collection is like NEMS in

[8] The NEMS macroinvertebrate protocols are based on *Protocols for sampling macroinvertebrates in wadeable streams* (Stark et al. 2001).

that a kick-net is used to collect benthic macroinvertebrates from dominant mesohabitats. Then macroinvertebrates are identified on site but to a lesser level of accuracy than can be achieved by specialist taxonomists. Species diversity is likely to be underestimated using this method, although when the data are used to calculate ecosystem health metrics (e.g., Macroinvertebrate Community Index), scores are generally comparable to those calculated from data collected using NEMS methods (Storey et al. 2016).

Timescales of measurement and response

Benthic macroinvertebrates should be assessed annually for the first five years and then every five years after. While no or little change in macroinvertebrate diversity is expected within the first five years post restoration, this initial data will provide a benchmark for assessing future change which is likely to occur when canopy cover provides shade and food resources (~10 years), periphyton and plant communities change (10–20 years), banks stabilise, and a greater diversity and complexity of instream structures are present (10–20 years).

Method references

- NEMS 2020b. National Environmental Monitoring Standards Macroinvertebrates Collection and Processing of Macroinvertebrate Samples from Rivers and Streams v 1.0.0.
- DOC National Freshwater Field Team Manual 2021. – Transect Cover Assessments
- NIWA 2019. SHMAK Stream Health Monitoring and Assessment Kit User Manual. NIWA Christchurch. 84 p.

4.3.4. Stream mega-invertebrates

Background

Large invertebrates that are often not caught using benthic macroinvertebrate surveys include freshwater mussels (kākahi / kāeo) and freshwater crayfish (kōura). These species are particularly vulnerable to land use impacts (mainly due to sedimentation, loss of habitat and pollution) and pest fish impacts. Active translocation may be necessary to restore absent populations, otherwise J4N-funded restoration activities are likely to improve abundance due to an improvement of suitable habitat and food resources.

Methods

a. Freshwater mussels

A quantitative survey of freshwater mussels is undertaken searching a 50-m length of streambed using a bathyscope and targeting likely habitats (along banks, undercuts, macrophytes, shaded areas and logs) for 30 minutes or until 50 mussels are collected. This is similar to the Waikato Regional Council presence / absence Protocol One developed by Catlin et al. (2018). The metric is the number of indigenous mussel species present (*Echyridella menziesii*, *E aucklandica* and / or *E. onekaka*). This method is used in DOC Tier 1 inventory monitoring.

b. Freshwater crayfish

- Crayfish presence (and abundance) is assessed during fish surveys using electric fishing or spot lighting following the methods of Joy et al. (2013) (see below). The probability of detecting crayfish by electric fishing can be increased by using soft-bristled brooms to dislodge crayfish from vegetation, tree roots and cobbles etc and to sweep them into hand-held stop nets (Kelly 2019, Parata 2019). The metric is presence / absence of indigenous crayfish species (*Paranephrops planifrons* or *Paranephrops zealandicus*). It is very useful to record information about density, size distribution, and reproduction (i.e., if egg-bearing females are present).
- Alternatively, fern bundles (whakaweku) can be used to assess the presence and abundance of freshwater crayfish following the methods of Kusabs et al. (2018). Whakaweku are set in the survey reach for a minimum of two weeks to allow colonisation by crayfish, before retrieval and quantification of the catch.

Timescales of measurement and response

Mega-invertebrates should be assessed every five years. Dependent on neighbouring aquatic habitat (especially upstream) that may serve as a source of colonisers, no measurable change in mega-invertebrate diversity is expected within approximately 5–10 years in response to J4N-funded projects, unless active translocation is undertaken.

Method references

- DOC National Freshwater Field Team Manual 2021. – Mussels
- Joy M, David B, Lake M 2013. New Zealand Freshwater Fish Sampling Protocols. Part 1 Wadeable rivers and streams, Massey University.
- Kusabs IA, Hicks BJ, Quinn JM, Perry WL, Whaanga H 2018. Evaluation of a traditional Māori harvesting method for sampling kōura (freshwater crayfish, *Paranephrops planifrons*) and toi toi (bully, *Gobiomorphus* spp.) populations in two New Zealand streams. New Zealand Journal of Marine and Freshwater Research 52(4): 603-625.

4.3.5. Fish

Background

There are around 50 species of native fish and around 20 species of exotic fish in New Zealand's streams, lakes, rivers, and wetlands. Many fish are quite specialised, requiring specific resources and habitat structure and connectivity to fulfil their lifecycle. Fish habitat preferences do not overlap much and as such there may only be a handful of different species observed at any one site. Restoration activities that improve habitat diversity and connectivity, water quality and food resources may improve fish diversity and are likely to improve fish abundance.

Methods

a. A quantitative survey of freshwater fish (including kōura) is undertaken using single-pass electric fishing of 150-m stream length, following the standardised protocols of Joy et al. (2013). Electric fishing is known to bias catch of some species and size classes of fish over others but provides the best measure of species richness compared to other fishing methods. The metric is number of indigenous fish taxa. These methods are used in DOC Tier 1 inventory monitoring.
b. If electric fishing is not an option, then spotlighting can be conducted following standardised methods as also outlined in Joy et al. (2013). Many indigenous fish species are nocturnal and so spotlighting can be a good option if indigenous biodiversity is of interest.
c. Alternatively, a water sample for eDNA analysis of the fish community can be taken. The DOC Tier 1 inventory monitoring field methods outline how to collect three replicate samples per site using the Wilderlab® commercial test kit.

Timescales of measurement and response

Fish should be assessed annually for the first five years and then every subsequent five years. While no or little change in fish diversity is expected within the first five years post restoration, this data will provide a benchmark for assessing future change, which is likely to occur when canopy cover provides shade (reducing water temperatures) and food resources (~10 years), periphyton and plant communities change (10–20 years), banks stabilise, and a greater diversity and complexity of instream structures are present (10–20 years).

Method references

- Joy M, David B, Lake M 2013. New Zealand Freshwater Fish Sampling Protocols. Part 1 Wadeable rivers and streams, Massey University.
- DOC National Freshwater Field Team Manual 2021. – eDNA

4.3.6. Terrestrial and wetland vascular vegetation

Background

Terrestrial and wetland plants include trees, shrubs, ferns, herbs, graminids, and lycophytes. These plants provide habitat for fauna and the level of species diversity within plant communities is correlated to a system's resilience and diversity of habitat for fauna. If high diversity can be achieved in restoration sites, it will therefore provide a more diverse range of habitats to fauna and will be more resilient to degradation in the future. Indigenous terrestrial plants are subject to competition from non-indigenous species.

Methods

A terrestrial and wetland plant inventory will be recorded within the permanent 5 m x 5 m plots. Where possible, any plant species encountered within each plot will be identified to species or genus level and recorded.

Timescale of measurement and response

Site walkovers and species inventory should be undertaken 3-yearly for the first 10 years of the project (i.e., baseline, then 3-yearly). After 10 years, site walkovers and inventories can be reduced to every 5-years. Indigenous taxa richness is expected to increase immediately following restoration planting because new indigenous species will likely be introduced to the plant community during planting. Taxa richness is expected to continue to increase over following years and decades, as new species are reintroduced naturally, for example by birds and wind dispersal.

Method references

- Department of Conservation 2019. Field protocols for DOC Tier 1 Inventory & Monitoring and LUCAS plots. Version 14.

4.3.7. Terrestrial invertebrates

Background

Terrestrial invertebrates occupy a variety of habitats such as soil, leaf litter, air, as well as on / in plants. To adequately survey local invertebrate diversity, a variety of methods are therefore required. Due to the variety of monitoring methods that are required to survey terrestrial invertebrates, monitoring of terrestrial invertebrates is not expected of all J4N funded Ngā Awa projects but can be done if project teams have a specific interest in invertebrates.

Methods

Collection methods for each of the four recommended methods are provided in Bulbert et al. (2007).

a. Manual searches (Hand collection)

   An initial search for plant-dwelling and ground-based invertebrates can be done manually by searching plants, leaf litter and ground surfaces and storing them in jars with preservative.

b. Foliage beating

   Foliage beating is the beating of foliage with a stick and collecting falling invertebrates on a collection tray underneath the plant. It can provide data on taxa richness for invertebrates living on plants such as beetles, bugs, ants and spiders. This should only be done when it is not windy and foliage is not wet.

c. Malaise trapping

   Malaise traps are a 'tent-like' flight intercept trap useful for catching flying insects such as beetles, bugs, and flies. It is important that malaise traps are placed in set locations for each survey as their efficacy is susceptible to small changes in location. Malaise trapping should be done over a 24-hour period.

d. Pitfall traps

   Pitfall traps are containers dug into the ground and set at ground level to catch ground travelling insects. A liquid preservative is included in the bottom of the trap to preserve insects that enter the traps and prevent them from escaping. Pitfall traps should contain a cover to prevent water entering and it is recommended that a mesh is included to help prevent lizards, frogs and other nontarget fauna entering the traps as bycatch. Pitfall trapping should be done over a 24-hour period.

Timescale of measurement and response

Invertebrate surveys can be undertaken as part of a 3 to 5 yearly species inventory. Indigenous taxa richness is expected to increase over time as pest numbers decrease and availability of suitable habitat increases (5+ years).

Method references

- Bulbert M, Gollan J, Donnelly A, Wilkie L 2007. Invertebrate Collection Manual. A guide to traditional invertebrate collection methods. Australian Museum.

4.3.8. Herpetofauna

Background

New Zealand is home to approximately 110 species of native skinks and geckos and four species of native frog, all of which are endemic, and many are threatened with extinction. Finding lizards and frogs is notoriously difficult due to their cryptic behaviour and camouflage. Additionally, these animals are slow (several years to decades) to migrate across landscapes, relative to more mobile animals such as birds, bats, and many invertebrates. Active translocation may be necessary for these animals if their reintroduction is a key objective of a J4N-funded restoration project.

Methods

a. Tracking tunnel for incidental herpetofauna monitoring.

   Tracking tunnels are recommended to be used to monitor for skinks and frogs within restoration areas. Despite tracking tunnels not being targeted monitoring tools for skinks and frogs, these animals can be detected using this method and it can be combined with pest species monitoring.

b. Artificial cover objects (ACOs) and pitfall traps for skink monitoring.

   If lizard diversity is a key objective of a restoration project, we recommend that skinks are monitored with a combination of ACOs and pitfall traps. ACOs and pitfall traps can both be set up (pitfall trap closed) and left in place permanently within the restoration area with ACOs checked quarterly and pitfall traps opened and checked over consecutive nights during a set monitoring period in spring / summer. As these methods of monitoring involves handling of skinks for identification, a lizard handling permit would be required from the Department of Conservation under the Wildlife Act (1953).

c. Spotlighting or canopy searches for gecko monitoring.

If gecko diversity is a key objective of a restoration project, we recommend spotlighting to detect the presence of geckos. This method has inherent health and safety risks and is not recommended in areas with steep terrain or near water. If the site is not suitable for spotlighting, daytime canopy searches can be undertaken instead, however, it is very difficult to find geckos using this method.

d. Manual frog searches.

In areas where frog habitation is considered possible (e.g., shaded streams with forested riparian margins at least 10 m wide) and frog diversity is a key objective of a restoration project, manual searches along stream margins and seepages is the recommended monitoring method for these animals. Manual searches should be focussed on habitats where frogs are considered most likely and include lifting rocks or woody debris of manageable size, assisted visually by a headlamp to improve the likelihood of detecting frogs. All lifted items are to be replaced in the same location to minimise disturbance of the habitat. A Wildlife Act permit is required from DOC for any monitoring that may require handling of native frogs. Frog monitoring can only be undertaken by experienced herpetologists due to the conservation status of New Zealand's frogs, the threat of introduced disease and the potential to impact fragile habitats, and so the involvement of a herpetologist would likely be a requirement of any Wildlife Act permit.

Timescale of measurement and response

Tracking tunnel monitoring should include two weeks of monitoring every three months i.e., tracking cards left in tunnels for two weeks and then checked and removed. Tracking tunnels can remain left in place in between monitoring events. ACOs are recommended to be checked every three months or at the same time as pitfall trap monitoring. Pitfall trap monitoring should be undertaken between November to March when skinks are most active. Two rounds of monitoring should be undertaken annually within this period, with each round of monitoring consisting of four consecutive days of checking traps. Spotlighting and canopy searches should be done monthly from October to March, inclusive, and consist of one night / day per month of four spotlighting / search hours. Manual frog searches should be conducted once every three years.

Detectable improvements in indigenous lizard species richness within restoration areas is not expected to occur within the first decade, unless species are relocated to the site. Detectable improvements in indigenous frog species richness is not expected to occur within 30 years, unless frog species are relocated to the site.

Method references

- Greene T, McNutt K eds. 2012. Biodiversity Inventory and Monitoring Toolbox. Department of Conservation, Wellington, New Zealand – Herpetofauna.

4.3.9. Bats

Background

Bats are the only native land mammals in New Zealand. We have two species in New Zealand, the long-tailed bat, and the lesser short-tailed bat, both of which are endemic to New Zealand and have a 'Threatened' or 'At Risk' conservation status. Long-tailed bats are widespread across New Zealand and can persist in more fragmented habitats but live in smaller colonies (e.g., c. 100 individuals). The lesser short-tailed bat only survives in a few known locations in large intact forests but live in much larger colonies (e.g., 1000+ individuals). Loss of habitat and predation pressure are key threats to these species. Restoration of riparian and wetland habitats is a key conservation tool for long-tailed bats, along with pest control. Streams, wetlands, and vegetation provide key foraging, commuting and roosting habitat and it is expected that J4N-funded Nga Awa projects will be beneficial for long-tailed bats.

Methods

Acoustic monitoring of bats is recommended for projects that have a particular interest in whether bats are present in the area. Acoustic monitoring can be undertaken as per the DOC Tier 1 inventory monitoring protocols; however, newer omnidirectional bat monitors should be used instead of the directional models described in the Tier 1 field protocols (DOC 2013). Monitors should be spaced across the restoration area at least 100 m apart in locations where bats are likely to visit e.g., near water, along linear vegetation features (e.g., shelterbelts, forest edges, tracks), near large trees (i.e., potential roost sites).

Timescale of measurement and response

Monitoring should be done annually and include a monitoring period of at least 14 consecutive nights. Due to the potential for some monitors to fail during the survey and bad weather, it can be valuable to leave monitors out for longer (e.g., 21 nights). Bats may already be present within the landscape but if not, they may be attracted back within 10 years, as riparian and wetland vegetation becomes well established.

Method references

- Greene T, McNutt K (eds.) 2012. Biodiversity Inventory and Monitoring Toolbox. Department of Conservation, Wellington, New Zealand – Bats.

4.3.10. Birds

Background

New Zealand's indigenous birds are an iconic component of New Zealand's identity. Habitat loss and predation pressure are key threats to our indigenous bird species and replanting of riparian and wetland habitats, as well as pest control, can provide valuable habitat to help protect our indigenous birds. As many species are conspicuous within the landscape, they are typically easier to monitor than other indigenous fauna and monitoring of our birds is included in the DOC Tier 1 monitoring.

Methods

Five-minute bird counts (5MBC), acoustic surveys and incidental bird observations are recommended to provide an inventory of the local bird diversity and should be undertaken in general accordance with the DOC Tier 1 monitoring protocols. The Tier 1 protocols may need some modification however to suit site conditions, such as the layout of the sampling design. Bird monitoring should be used to compose an annual bird species list composed over a 12-month period, beginning from the first round of 5MBC surveys.

a. Five-minute bird count.

   These counts are a standardised monitoring protocol commonly used across the country. It is recommended that five 5MBCs are undertaken at set locations at least 200 m apart within the restoration area every three months. If restoration sites are less than 800 m long, then as many monitoring sites as possible are to be established 200 m apart. Only birds within the restoration area should be recorded and not birds observed on or flying over neighbouring land. All species recorded in 5MBCs will be added to the annual bird species list for the restoration area.

b. Incidental bird observations.

   Any incidental bird observations of species within the restoration area that have not yet been recorded during the year’s 5MBC surveys should be recorded and added to the annual species list (no reference).

c. Acoustic surveys for cryptic species.

   If any cryptic species (e.g., kiwi, bittern, spotless crake) are a focus of the restoration project, remote monitoring is recommended using acoustic recorders. Acoustic recorders should set to record over a two-week period in habitats the target species is considered most likely to inhabit. Acoustic surveys are recommended in spring when birds are most active and vocal, and acoustic recording devices should be set on the correct frequency for the target species. Acoustic recording devices should be set to record from one hour before sunrise until one hour after sunrise and one hour before sunset until one hour after sunset.

Timescale of measurement and response

Five-minute bird counts should be undertaken every three months. Incidental observations can be made during any time spent within the restoration area. Acoustic surveys should be undertaken annually in spring over a two-week period. Bird diversity has the potential to increase when planted trees and shrubs begin to flower and fruit. Common species such as tui, fantails, and grey warbler may return to the site within five years. Other less common species in disturbed habitats are likely to take longer to reappear and the timing is largely dependent on the proximity of the site to population sources. Species such as kereru, kākā and NZ falcon might return within 5–20 years if populations of these species are present within 15 km.

Method references

- Department of Conservation 2013. Field protocols for Tier 1 monitoring - invasive mammal, bird, bat, RECCE surveys. Version 14.
- O'Donnell CFJ, Williams EM 2015. Protocols for the inventory and monitoring of populations of the endangered Australasian bittern (*Botaurus poiciloptilus*) in New Zealand. Department of Conservation Technical Series 38. Department of Conservation, Wellington. 40 p.

4.4. Outcome indicators – Indigenous abundance / dominance

A 3 to 5 yearly semi/quantitative survey of indigenous species present across the restoration area can determine whether there has been an increase in local biodiversity over time. The key metric for all biota is indigenous **taxa abundance** or **indigenous taxa dominance** calculated from the relative abundance of indigenous to non-indigenous species. The **number and density of plants** is also a key metric because plants provide critical habitat and food resources for other taxa.

For all biotic indicators the field methods are mostly the same as those described in the previous section [see Section 4.3. Indigenous biodiversity]. Any variations in methods, metrics and expected timescales are described below. For vascular vegetation, indigenous dominance can be estimated relatively easily by comparing the abundance / density of indigenous vs non-indigenous species. Animals can be more stochastically dispersed, and relationships of dominance are harder to assess robustly using annual surveys within small restoration areas.

4.4.1. Stream algae / periphyton

Methods

Same as for Indigenous biodiversity (see Section 4.3.1). Additionally, the relative abundance of non-indigenous taxa should be recorded including didymo (*Didymosphenia geminata*), water net (*Hydrodictyon reticulatum*) and lake snow (*Lindavia intermedia*); the latter two are rarely found in flowing water but can be identified in the field with photo guides found in Champion et al. (2020).

Metrics

For reporting indigenous abundance / dominance we recommend '% cover of different periphyton categories' as an estimate of indigenous abundance and dominance (i.e., relative abundance) relative to exotic species.

Timescales of measurement and response

Same as for Indigenous biodiversity (see Section 4.3.1).

4.4.2. Stream plants – macrophytes / bryophytes

Methods

Same as for Indigenous biodiversity (see Section 4.3.2).

Metrics

For reporting Indigenous abundance / dominance we recommend '% cover of different plants' be used to calculate indigenous abundance and dominance (i.e., relative abundance) relative to exotic species.

Timescales of measurement and response

Same as for Indigenous biodiversity (see Section 4.3.2).

4.4.3. Benthic macroinvertebrates

Methods

Same as for Indigenous biodiversity (see Section 4.3.3).

Metrics

For reporting Indigenous abundance / dominance we recommend 'species abundance' or 'species density' be used to calculate indigenous abundance and dominance (i.e., relative abundance) compared to non-indigenous species identified.

Timescales of measurement and response

Same as for Indigenous biodiversity (see Section 4.3.3).

4.4.4. Stream mega-invertebrates

Methods

Same as for Indigenous biodiversity (see Section 4.3.4).

Metrics

For reporting Indigenous abundance / dominance we recommend 'species abundance' or 'species density / catch per unit effort' be used to calculate indigenous abundance and dominance (i.e., relative abundance) relative to exotic species.

Timescales of measurement and response

Same as for Indigenous biodiversity (see Section 4.3.4).

4.4.5. Fish

Methods

Same as for Indigenous biodiversity (see Section 4.3.5).

It is important to note that available eDNA methods are not currently able to provide data to assess abundance.

Metrics

For reporting Indigenous abundance / dominance we recommend 'species abundance' or 'species density / catch per unit effort' be used to calculate indigenous abundance and dominance (i.e., relative abundance) relative to exotic species.

Timescales of measurement and response

Same as for Indigenous biodiversity (see Section 4.3.5).

4.4.6. Terrestrial and wetland vascular vegetation

Methods

Same as for Indigenous biodiversity (see Section 4.3.6).

Metrics

The density of plant species per square metre should be recorded. This will provide data to also calculate indigenous abundance and dominance (i.e., relative abundance) relative to exotic species.

Timescales of measurement and response

Same as for Indigenous biodiversity (see Section 4.3.6).

4.4.7. Terrestrial invertebrates

Methods

Same as for Indigenous biodiversity (see Section 4.3.7).

Metrics

For reporting Indigenous abundance / dominance we recommend 'species abundance' or 'species density / catch per unit effort' be used to calculate indigenous abundance and dominance (i.e., relative abundance) relative to exotic species.

Timescales of measurement and response

Same as for Indigenous biodiversity (see Section 4.3.7).

4.4.8. Herpetofauna

Methods

Same as for Indigenous biodiversity (see Section 4.3.8).

Metrics

For reporting Indigenous abundance / dominance we recommend 'species abundance' or 'species density / catch per unit effort' be used to calculate indigenous abundance and dominance (i.e., relative abundance) relative to exotic species.

Timescales of measurement and response

Same as for Indigenous biodiversity (see Section 4.3.8).

4.4.9. Bats

Methods

Same as for Indigenous biodiversity (see Section 4.3.9).

Metrics

For reporting Indigenous abundance / dominance we recommend 'species abundance' or 'species density / catch per unit effort' be used to calculate indigenous abundance.

Timescales of measurement and response

Same as for Indigenous biodiversity (see Section 4.3.9).

4.4.10. Birds

Methods

Same as for Indigenous biodiversity (see Section 4.3.10).

Metrics

For reporting Indigenous abundance / dominance we recommend 'species abundance' or 'species density / catch per unit effort' be used to calculate indigenous abundance and dominance (i.e., relative abundance) relative to exotic species.

Timescales of measurement and response

Same as for Indigenous biodiversity (see Section 4.3.10).

4.5. Outcome indicators – Ecological integrity

A 3 to 5 yearly semi/quantitative survey of multiple in-stream and terrestrial components are needed to determine whether there has been an improvement in ecological integrity over time. The state of core components / factors can be reported, or data can be combined to provide an integrated score.

For many core component / factors, the field methods are mostly the same as those described in the previous sections [see Section 4.2. Proximate pressure indicators] and [see Section 4.3. Indigenous biodiversity]. Additional methods, metrics and expected timescales are described below. Key indicators include a **stream ecosystem health index** and a **wetland condition index**.

4.5.1. Stream ecosystem health index

Background

The freshwater biophysical ecosystem health framework has five core components that together provide an integrated assessment of ecological integrity. These include: aquatic life, physical habitat, water quality, water quantity, and ecological processes. Many of these components are measured during an assessment of proximate pressures and biodiversity outcomes as shown previously in Figure 6. However, metrics that are calculated to assess ecological integrity may differ from those used to assess biodiversity. These are noted here. The Freshwater Ecosystem Health framework report (Clapcott et al. 2018) provides guidance on how to combine metric scores to achieve an integrated assessment of stream ecological integrity.

Methods and metrics – Water quality

- Same as for Increased temperature – Water temperature (see Section 4.2.2),
- Same as for Nutrients – Nutrients (see Section 4.2.3),
- Same as for Nutrients – Dissolved oxygen (see Section 4.2.3),
- Same as for Erosion and Sedimentation – Visual clarity (see Section 4.2.4).

Timescales of measurement and response – Water quality

Same as for Proximate pressure indicators (see sections noted above).

Methods and metrics – Water quantity

- Same as for Altered hydrology – water quantity / level (see Section 4.2.5),
- An additional assessment of stream hydrology can be obtained by pairing the restoration site to the nearest hydrology recording site. Naturalised flow metrics can be compared to measured and calibrated flow metrics and known water allocation to provide a measure of flow alteration (see Booker 2015 and Booker et al. 2016 for further details).

Timescales of measurement and response – Water quantity

Same as for Proximate pressure indicators.

Method references – Water quantity

- Booker D 2015. Hydrological indices for national environmental reporting. Prepared for Ministry for the Environment. NIWA Client Report No. CHC2015015.
- Booker D, Henderson RD, Whitehead AL 2016. National water allocation statistics for environmental reporting Prepared for Ministry for the Environment. NIWA Client Report No. 2017065CH.

Methods and metrics – Physical habitat

- Same as for Increased temperature – Instream survey (see Section 4.2.2). Note that all 10 components of the Rapid Habitat Assessment (RHA) should be assessed to provide a stream habitat quality score.
- Same as for Erosion and Sedimentation – Riparian soil condition (see Section 4.2.4). Note that all elements of the Stream Habitat Assessment Protocols P2D method should be assessed to provide a riparian habitat quality score.
- Same as for Erosion and Sedimentation – Bank erosion (see Section 4.2.4). Note this is part of the RHA.
- Same as for Erosion and Sedimentation – Substrate / deposited sediment (see Section 4.2.4). Note that a key metric from this assessment in the percent cover of deposited fine sediment.
- Same as for Altered hydrology – Instream habitat diversity (flow) (see Section 4.2.5). Note this is part of the RHA.
- Same as for River fragmentation – Habitat connectivity (see Section 4.2.6).

Timescales of measurement and response – Physical habitat

A habitat quality score could respond relatively rapidly (< 10 years) due to an increase in the shade score if riparian planting is undertaken. Other components of the RHA assessment are likely to take one, two or more decades as terrestrial vegetation diversity and abundance develops, in turn stabilising banks and increasing the diversity and abundance of favourable instream habitat. Habitat connectivity could response rapidly (<5 years), with the remediation of fish barriers.

Methods and metrics – Aquatic life

- Same as Indigenous biodiversity – Algae / periphyton (see Section 4.3.1). The relevant metrics are % periphyton cover, % cover of different periphyton categories, and weighted composite cover of periphyton.
- Same as Indigenous biodiversity – Stream plants (see Section 4.3.2). The relevant metrics are total % cover of plants and % cover of different plants and % macrophyte volume.

- Same as Indigenous biodiversity – Benthic macroinvertebrates (see Section 4.3.3). The relevant metrics are the Macroinvertebrate Community Index (MCI) and the Average Score per Metric (ASPM).
- Same as Indigenous biodiversity – Fish (see Section 4.3.5). The relevant metric is Fish Index of Biotic Integrity.

Timescales of measurement and response – Aquatic life

Same as for Indigenous biodiversity (see sections noted above). It is important to note that assessments of ecological integrity are best undertaken consistently in summer or early autumn, when flows tend to be low, making aquatic surveys easier and safer.

Methods and metrics – Ecological processes

- Nutrient processing. This process indicator is still in development and not recommend for J4N-funded projects.
- Organic matter processing. Standardised cotton strip assays are recommended for estimating organic matter processing in streams. Cotton strips are deployed in-stream for a minimum of 7 days and then sent to a laboratory to determine the breaking strain following the methods outlined in Parkyn et al. (2010). A temperature logger is also deployed, and data combined with the breaking strain of the cotton strips to calculate the metric of % cotton tensile strength loss per degree day.
- Ecosystem metabolism. The total amount of organic carbon produced (productivity) and consumed (respiration) in a river is estimated from changes in dissolved oxygen (DO) concentration. This is assessed by the placement of a DO datasonde for 1 to 7 days in summer (the time of maximum primary productivity) following the methods outlined in Parkyn et al. (2010). Key metrics are daily rates of gross primary productivity and ecosystem respiration.

Timescales of measurement and response – Ecological processes

In small streams, riparian planting is likely to improve stream organic matter processing and metabolism with partial or full canopy cover (shade) and increased leaf litter input (10+ years). These ecological processes are also influenced by other factors such as flow and instream habitat diversity (to support healthy flora and fauna) so will continue to improve as these other components of the ecosystem recover.

Method references – Ecological processes

- Parkyn S, Collier K, Clapcott J, David B, Davies-Colley R, Matheson F, Quinn J, Shaw W, Storey R 2010. The restoration indicators toolkit: Indicators for monitoring the ecological success of stream restoration. National Institute of Water and Atmospheric Research, New Zealand. 134 p.

4.5.2. Wetland condition index

Background

The wetland condition index (WCI) is a semi-quantitative metric comprising five ecological indicators based on the major threats and stressors known to degrade wetlands. The five component indicators measure change in hydrology, physicochemical parameters, ecosystem intactness, browsing, predation and harvesting regimes, and native plant dominance. All these components are measured during an assessment of proximate pressures and biodiversity outcomes as shown below. Additional WCI indicators required to assess each of the five components as well as guidance on how to combine assessments to calculate the WCI are provided in the wetland restoration handbook (Peters & Clarkson 2012).

Methods and metrics – Hydrology

- Same as for Water quantity / level (see Section 4.2.5),
- Same as for Habitat connectivity (see Section 4.2.5),
- Additional WCI hydrological integrity indicators (all scored 0–5) include:
  - Impact of man-made structures that alter hydrological regime,
  - Water table depth,
  - Dryland plant invasion.

Timescales of measurement and response – Hydrology

Same as for Proximate pressure indicators (see sections as noted above).

Methods and metrics – Physicochemical parameters

- Same as for Vegetation clearance (see Section 4.2.1),
- Same as for Erosion and sedimentation (see Section 4.2.4),
- Same as for Instream water quality – nutrients (see Section 4.2.3),
- Additional WCI physicochemical parameters (all scored 0–5) include:
  - Fire damage,
  - Degree of sedimentation / erosion,
  - Nutrient levels,
  - von Post index (relevant to peat bogs only).

Timescales of measurement and response

Same as for Proximate pressure indicators (see sections noted above).

Methods & metrics – Ecosystem intactness

- Same as for Vegetation clearance (see Section 4.2.1),
- Same as for Altered hydrology – habitat connectivity (see Section 4.2.5),

- Additional WCI ecosystem intactness indicators (all scored 0–5) include:
  - Loss in area of original wetland,
  - Connectivity barriers.

Timescales of measurement and response – Ecosystem intactness

Same as for Proximate pressure indicators (see sections noted above).

Methods and metrics – Browsing, predation and harvesting

- Same as for Pest species (see Section 4.2.7),
- Same as for Vegetation clearance (see Section 4.2.1),
- Same as for Indigenous biodiversity: terrestrial and wetland vascular vegetation, terrestrial invertebrates, herpetofauna, bats, and birds (see Section 4.3)
- Additional WCI browsing, predation and harvesting regime indicators (all scored 0–5) include:
  - Damage by domestic or feral animals,
  - Introduced predator impacts on wildlife,
  - Harvesting levels.

Timescales of measurement and response

Same as for Proximate pressure and Indigenous biodiversity indicators (see sections notes above).

Methods & metrics: Native plant dominance

- Same as for Indigenous biodiversity: terrestrial invertebrates and wetland vascular vegetation (see Section 4.3),
- Additional WCI dominance of native plant indicators (all scored 0–5) include:
  - Introduced plant canopy cover,
  - Introduced plant understorey cover.

Timescales of measurement and response

Same as for Proximate pressure and Indigenous biodiversity indicators.

Method references

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6. APPENDICES

6.1. Objectives identified in the Te Mana o te Taiao - Aotearoa New Zealand Biodiversity Strategy 2020

The following 13 objectives are identified within the Biodiversity Strategy:

1. Governance, legislation and funding systems are in place and enable delivery of the strategy outcomes;
2. Treaty partners, whānau, hapū, iwi and Māori organisations are rangatira and kaitiaki;
3. Biodiversity protection is at the heart of economic activity;
4. Improved systems for knowledge, science, data and innovation inform our work;
5. Mātauranga Māori is an integral part of biodiversity research and management;
6. Aotearoa New Zealand is making a meaningful contribution to biodiversity globally;
7. All New Zealanders have the skills, knowledge and capability to be effective;
8. Resourcing and support are enabling connected, active guardians of nature;
9. Collaboration, co-design and partnership are delivering better outcomes;
10. Ecosystems and species are protected, restored, resilient and connected from mountain tops to ocean depths;
11. Management ensures that biological threats and pressures are reduced through management.
12. Natural resources are managed sustainably; and
13. Biodiversity provides nature-based solutions to climate change and is resilient to its effects.

6.2. Review of monitoring frameworks and methods for assessing in-stream biodiversity and overall stream health

6.2.1. Department of Conservation Freshwater Ecosystems of New Zealand model of ecological integrity

To assess the ecological integrity of river and wetland ecosystems, the Department of Conservation (DOC), alongside other government agencies and Crown research institutes led by DOC, developed spatial measures of land use pressure (e.g., land use intensity, percentage catchment clearance). The underlying assumption is that measures of human pressure on freshwater ecosystems serve as surrogates for measures of the state of biodiversity because ecosystems under the least pressure have the most ecological integrity, and so retain the most biodiversity. In addition to estimates of human pressures, the Freshwater Ecosystems of New Zealand (FENZ) database (Leathwick et al. 2010) contains estimates for every stream segment in the digital national river network of:

- physical environment and biological characteristics (e.g., substrate size, slope, riparian shade, probability of occurrence of macroinvertebrate and fish species)
- classifications that group together rivers and streams, lakes and wetlands having similar ecological character
- rankings of biodiversity value that indicate areas that would provide protection of a full range of representative freshwater ecosystems while taking account of human pressures and landscape connectivity.

Subsequent studies quantified the relationship between land use pressures and the ecological integrity of rivers and streams using multiple indicators (Clapcott et al. 2012) and shallow coastal lakes (Drake et al. 2011). Measures used to indicate the ecological integrity of rivers included water quality (nutrients, clarity), and biological (macroinvertebrates, fish) and functional (ecosystem metabolism, nutrient and organic matter processing) components (Table 6). For rivers, a multi-metric index of ecological integrity was calculated by the weighted averaging of observed/expected (O/E) scores for component indicators at the site level. The multi-metric index showed predictable unidirectional relationships with land use pressures and was used to predict the ecological integrity of all stream segments at the national scale (Clapcott et al. 2014). This ecological integrity (EI) index was not specifically designed to assess the effectiveness of riparian restoration. However, the EI index is relevant in that it provides an integrated assessment of river condition and FENZ may be used to a) support selection of sites for restoration and b) provide background information to support broader management decisions on a catchment-scale and c) assist reporting on J4N projects. Further modelling by Clapcott et al. (2014) demonstrated the relative importance of riparian shade as a mediator of land use effects on response variables. For example, riparian shade explained between 2% (nutrients), 5%

(macroinvertebrates) and 12% (organic matter processing) of the total variation in indicator responses explained by environmental variables.

Table 6. Indicators and methods used to assess stream ecological integrity to test Freshwater Ecosystems of New Zealand estimates of biodiversity value.

Core elements	Indicators	Monitoring methods
Water quality	Nutrients Temperature Water clarity	Sample collection for standard laboratory analysis Spot measures Black disc water clarity
Biota	Macroinvertebrate Community Index Invertebrate taxonomic richness Percentage of EPT[1] taxa Percentage of macroinvertebrate taxa reproducing only once Fish IBI[2] Percent native fish taxa Fish taxa richness	Stark et al. 2001 protocols Joy et al. 2013 protocols
Stream function	Ecosystem metabolism Delta 15^{N} of primary consumers Organic matter processing	Continuous dissolved oxygen and water temperature Stable isotope analysis Cotton strip assay

[1] EPT = ephemeroptera, plecoptera, trichoptera, [2] IBI = index of biotic integrity

Table 7. Assessment of the methods used to test the Freshwater Ecosystems of New Zealand framework against suitability for measuring biodiversity outcomes of Jobs for Nature projects.

Key element	Score	Reason
1. Representativeness	2	Provides a variety of indicators to assess invertebrates and fish.
2. Consistency	2	Mostly standardised methods but not a standardised set of methods so difficult to make consistent across a national scale.
3. Flexible	1	Relied on standardised methods where available. No advice on how to align less extensive methods.
4. Robust	2	Most of the recommended methods are commonly used for monitoring but some are still in 'development' e.g., stable isotopes.
5. Informative	2/3	Provides a more integrated assessment of ecosystem integrity through a multi-metric index but some components are hard to communicate, e.g., stream function.
6. Fit-for-purpose	2	Likely to provide evidence of biodiversity changes over time and provide earlier responses in water quality before biodiversity elements.
7. Align to DOC	2	Framework developed to test FENZ (assumption that anthropogenic pressures equate to biodiversity loss) but not strongly aligned to current DOC Tier 1 biodiversity monitoring in streams / rivers.
8. Skill level	1	Most methods require expert training.
9. Resources required	1	Most methods require substantial field and / or laboratory resources.

6.2.2. Department of Conservation Tier 1 Inventory and Monitoring: rivers and streams

The Department of Conservation has developed a biodiversity monitoring and reporting system as part of Natural Heritage Management System (NHMS). It consists of a hierarchical integrated monitoring system with broad-scale Tier 1 monitoring to inform the status and trends of key indicators on public conservation land, Tier 2 monitoring associated with select high priority managed areas through DOC's ecosystem and species optimisation projects, and Tier 3 monitoring at a small number of sites designated for development of management practices (e.g., ecosystem or species restoration). Using a nested hierarchy, DOC aims to collect information with different levels of scope and spatial coverage to report on gains and losses in biodiversity across all areas of its responsibility.

The Tier 1 monitoring programme is based on the NZ Biodiversity Assessment Framework (Lee et al. 2005) and components include environmental quality, indigenous dominance, species representation, ecosystem representation, and resilience to climate change (Lee & Allen 2011). A pilot Tier 1 programme is currently (2020/2021) being applied nationally in rivers and streams using priority measures outlined in the Outcome Monitoring Framework (www.doc.govt.nz/omf) including: i) sedimentation and sediment quality, ii) ecosystem primary productivity, iii) waterway biological function, iv) water physicochemical factors, and v) habitat availability.

An initial assessment of the practicality of implementation and meaningfulness of specific metrics was undertaken by Kelly et al. (2021), with the following metrics recommended in Table 8, noting their suitability to report on broad-scale status and trends in the conservation estate. Metric suitability is not assessed in relation to sensitivity to stream riparian restoration efforts. The DOC biodiversity framework uses a reference benchmark approach, which is important for setting targets and / or measuring change over time. Reference benchmarks are determined by observations from designated reference sites or predictions from models.

Table 8. Measures and indicators monitored in rivers as part of the Department of Conservation Tier 1 pilot programme.

Core elements (measures)	**Indicators (metrics)**	**Monitoring methods**
Sedimentation and sediment quality	Substrate stability Substrate diversity Sediment composition Sediment contaminants Fine sediment depth	Pfankuch index Clapcott et al. 2011 Sample collection for laboratory determination of dry matter, TN, TP, TOC[4], Total PAHs, DDT, PCBs5
Ecosystem primary productivity	Periphyton (Chl-*a*, biostatus) Macrophytes and bryophytes (biostatus)	Biggs & Kilroy 2000 Collier et al. 2007
Waterway biological function	Macroinvertebrates (MCI[1], %EPT[2]) Fish populations (Fish IBI[3])	Stark et al. 2001 protocols Joy et al. 2013 protocols
Water physicochemical factors	Water temperature (mean) Water clarity Turbidity pH *E.coli* Nutrients Organic carbon Dissolved ions	Spot measures Black disc clarity Sample collection for laboratory determination (ANZECC 2000)
Habitat availability	Substrate composition Habitat quality (riparian) Mesohabitat analysis Stream discharge	Harding et al. 2009 protocols

[1] MCI = Macroinvertebrate Community Index; [2] EPT = Ephemeroptera, Plecoptera, Trichoptera; [3] IBI = Index of Biotic Integrity; [4] TN = total nitrogen, TP = total phosphorus, TOC = total organic carbon; [5] PAHs = polycyclic aromatic hydrocarbons, DDT = dichlorodiphenyltrichloroethane, PCBs = polychlorinated biphenyls.

Table 9. Assessment of the Department of Conservation (DOC) Tier 1 indicators and methods for rivers and streams for suitability to measure biodiversity outcomes of Jobs for Nature projects.

Key element	Score	Reason
1. Representativeness	3	Provides a wide variety of indicators including those to assess periphyton, macrophytes, invertebrates and fish.
2. Consistency	3	Standardised methods.
3. Flexible	1	Relies on standardised methods where available. No advice on how to align less extensive methods.
4. Robust	3	All the recommended methods are commonly used for monitoring.
5. Informative	2/3	Addresses priority measures outlined in the Outcome Monitoring Framework but no guidance on integration or reporting.
6. Fit-for-purpose	2	Likely to provide evidence of biodiversity changes over time and probable earlier responses in water quality and / or habitat before biodiversity elements.
7. Align to DOC	3	Framework developed by DOC.
8. Skill level	1	Most methods require expert training.
9. Resources required	1	Most methods require substantial field and / or laboratory resources.

6.2.3. National Environmental Monitoring and Reporting programme

In New Zealand, national-scale indices for assessing and reporting freshwater quality have previously been advanced through the National Environmental Monitoring and Reporting (NEMaR) programme (Hudson et al. 2012). 'Water quality' in the NEMaR programme refers to an assessment of ecological integrity as defined by Schallenberg et al. (2011), in that it is not limited to physico-chemical state and extends to include condition and ecological health. Core freshwater indicators are recommended for assessing river condition (Table 10). However, indicators were not chosen on their sensitivity to detect change due to riparian restoration, nor to specifically assess biodiversity. A parallel report provides guidance on how indicators could be combined into sub-indices (e.g., for macroinvertebrates, fish, hydrology, habitat) to assess overall stream condition (Ballantine 2012).

Table 10. Indicators for assessing and reporting river condition identified during the National Environmental Monitoring and Reporting programme. Adapted from Hudson et al. (2012).

Core elements (measures)	Indicators (metrics)	Monitoring methods
Hydrology	Abstraction index Flow Connectivity	N/A
Habitat	Percent sediment cover Stream Ecological Valuation	Clapcott et al. 2011 Neale et al. 2011
Biota	Fish percent alien species Fish observed/expected native species Fish populations (Fish IBI[1]) Fish taxon richness Macroinvertebrates (QMCI, EPT[2]richness) Macroinvertebrate taxon richness	N/A Stark et al. 2001 protocols
Water physicochemical factors	*E. coli* Water clarity, turbidity Electrical conductivity pH Nutrients Dissolved copper, zinc, cadmium Water temperature (mean) Organic carbon Dissolved ions	Spot measures Black disc clarity Sample collection for laboratory determination
Optional	Temperature, dissolved oxygen concentration Gross primary productivity, respiration Percent periphyton cover	Continuous measurement Biggs & Kilroy 2000

[1] IBI = Index of Biotic Integrity; [2] QMCI = Quantitative Macroinvertebrate Community Index; EPT = Ephemeroptera, Plecoptera, Trichoptera.

Table 11. Assessment of the National Environmental Monitoring and Reporting indicators and methods for rivers and streams for suitability to measure biodiversity outcomes of Jobs for Nature projects. DOC = Department of Conservation.

Key element	Score	Reason
1. Representativeness	2	Provides a variety of indicators including those to assess invertebrates and fish as well as other elements of freshwater condition.
2. Consistency	2/3	Standardised methods but not all applicable to all stream types.
3. Flexible	1	Relies on standardised methods where available. No advice on how to align less extensive methods.
4. Robust	2/3	All the recommended methods are commonly used for monitoring but some not widely applied.
5. Informative	2	Provides guidance on integration and reporting but not widely used.
6. Fit-for-purpose	1/2	Likely to provide evidence of biodiversity changes over time and probable earlier responses in water quality and / or habitat before biodiversity elements.
7. Align to DOC	2	Framework developed for Ministry for the Environment reporting. Probably outdated now.
8. Skill level	1	Most methods require expert training.
9. Resources required	1	Most methods require substantial field and / or laboratory resources.

6.2.4. Ecosystem Health framework

The ecosystem health framework was developed to provide a consistent approach for assessing the ‘ecosystem health’ of fresh waters, as a compulsory value in the National Policy Statement for Freshwater Management 2020. It focusses on the biophysical component of ecosystems providing a measure of ‘ecological integrity’: a healthy freshwater ecosystem has ecological integrity when it can maintain its structure and function over time in the face of external stress. The framework adopts a reference condition approach and includes five core components: aquatic life, physical habitat, water quality, water quantity, and ecological processes (Clapcott et al. 2018).

The framework is consistent (broadly applicable across all fresh waters, not just rivers and streams), representative (integrates multiple components that together assess ecosystem health), robust (informed by science), informative (easily understood), flexible (suitable for varied application), and scalable (from reach- to national-scale assessments) (Table 13). The framework also provides guidance on implementation, which was recently demonstrated in the Tukituki catchment (Clapcott et al. 2020). Key steps in implementation include identifying the scale of assessment, establishing reference conditions, identifying indicators and metrics for each core component, data aggregation, harmonisation and integration, and ecosystem health reporting. Potential indicators and metrics for rivers and streams are recommended based on a rating of their sensitivity to human impacts, robustness, current use, ease of application, calibration to reference conditions, scale of impact, and scale of measurement (Table 12). The framework was not designed specifically to assess the effects of riparian restoration on biodiversity but does provide an integrated / overall assessment of stream condition. The framework recommends the use of standardised monitoring methods.

Table 12. Recommended indicators and metrics for each of the five core components of the Ecosystem Health framework in rivers and streams.

Core element (component)	Indicator (metrics)	Monitoring methods
Aquatic life	Fish (Fish IBI[1], observed/expected) Macroinvertebrates (MCI, %EPT[2]) Plants (% native macrophytes, biomass, % filamentous)	Joy et al. (2013) Stark et al. (2001) Collier et al. (2007) Biggs & Kilroy (2000)
Water quality indictors	Dissolved oxygen (minimum) pH Clarity / turbidity Nutrients (TN, TP, DRP, DIN[3])	NEMS
Water quantity indicators	Mean annual low flow Flood frequency Water allocation index (integrated water quantity variable)	Booker (2015)
Physical habitat	Substrate (% fine sediment) Riparian state Channel form and floodplain connectivity Diversity and abundance	Clapcott et al. (2011) Clapcott (2015)
Ecological processes	Gross primary productivity Ecosystem respiration Organic matter decomposition	Young et al. (2006) Clapcott et al. (2010)

[1] IBI = Index of Biotic Integrity; [2] MCI = Macroinvertebrate Community Index; EPT = Ephemeroptera, Plecoptera, Trichoptera; [3] TN = total nitrogen, TP = total phosphorus, DRP = dissolved reactive phosphorus, DIN = dissolved inorganic nitrogen.

Table 13. Assessment of the Ecosystem Health framework indicators and methods for rivers and streams for suitability to measure biodiversity outcomes of Jobs for Nature projects.

Key element	Score	Reason
1. Representativeness	2/3	Provides a wide variety of indicators including those to assess aquatic plants, invertebrates and fish as well as other elements of stream health.
2. Consistency	3	Standardised methods.
3. Flexible	2	Relies on standardised methods where available. Provides advice on alternate methods (but not specifically tested).
4. Robust	3	All the recommended methods are commonly used for monitoring and framework tested.
5. Informative	3	Provides guidance on integration and reporting.
6. Fit-for-purpose	2	Likely to provide evidence of biodiversity changes over time and probable earlier responses in water quality and / or habitat before biodiversity elements.
7. Align to DOC	2/3	Framework developed specifically to achieve an integrated assessment of stream health. Builds from FENZ and NEMaR and overlap in methods used in DOC Tier 1 monitoring.
8. Skill level	2/3	Most methods require expert training but guidance on alternate methods provided.
9. Resources required	1	Most methods require substantial field and / or laboratory resources but guidance on alternate methods provided.

6.2.5. SEV: Stream Ecological Valuation

The Stream Ecological Valuation (SEV; Storey et al. 2011) provides field methods to assess 14 key instream process, such as hydraulic, biogeochemical, habitat provision and biodiversity provision functions (Table 14). Additionally, a user's guide (Neale et al. 2011) provides direction on site selection, required equipment, field measurement, and the calculation and reporting of results. While not specifically designed to assess riparian restoration outcomes, a similar functional approach is the framework underpinning natural channel design in stream restoration projects (Harman et al. 2012); the assumption being that restoration of hydrology, hydraulic, and geomorphological functions are required to support physicochemical and biological functions (defined as biodiversity and the life histories of biota). The SEV method was designed to be used by those with formal training in ecological field methods. The SEV method is consistent (includes standard methods), representative (assesses multiple ecological function), robust (informed by science), informative (easily understood and including guidance on interpretation) but limited in flexibility (to evaluation of smaller streams) (Table 15).

Table 14. The core elements (ecological functions) and indicators assessed in the Stream Ecological Valuation.

Core elements (Ecological functions)	Indicators	Monitoring methods
Hydraulic	Natural flow regime Floodplain effectiveness Connectivity for natural species migrations Natural connectivity to groundwater	SEV 2011
Biogeochemical	Water temperature control (shade) Dissolved oxygen levels Organic matter input Instream particle retention Decontamination of pollutants	SEV 2011
Habitat provision	Fish spawning habitat Habitat for aquatic fauna	SEV 2011 Harding et al. 2009 Collier et al. 2007
Biodiversity	Fish fauna intact Invertebrate fauna intact Riparian vegetation intact	Stark et al. 2001 Joy et al. 2013

Table 15. Assessment of the Stream Ecological Valuation indicators and methods for rivers and streams for suitability to measure biodiversity outcomes of Jobs for Nature projects.

Key element	Score	Reason
1. Representativeness	2/3	Provides a variety of indicators including those to assess aquatic plants, invertebrates and fish as well as other elements of stream health.
2. Consistency	2/3	Standardised methods and framework specific methods and algorithms.
3. Flexible	1	Relies on standardised methods.
4. Robust	3	Some of the recommended methods are commonly used for monitoring and the framework specific methods has been widely tested.
5. Informative	3	Provides guidance on integration and reporting.
6. Fit-for-purpose	2	Likely to provide evidence of biodiversity changes over time and probable earlier responses in water quality and / or habitat before biodiversity elements.
7. Align to DOC	2	Framework specifically focussed on stream functions but some overlap in methods used in DOC Tier 1 monitoring.
8. Skill level	2	Methods require some training.
9. Resources required	2	Includes some specialised methods that require substantial field and / or laboratory resources but some methods are field based assessments requiring minimal resources.

6.2.6. Kaupapa Māori monitoring frameworks and indicators

There are numerous kaupapa Māori based monitoring frameworks used to assess freshwater environments (Rainforth & Harmsworth 2019). They have been developed and applied by, or in partnership with, tangata whenua to meet Māori aspirations and requirements, and to answer questions that are important to iwi and hapū. Most frameworks look beyond the biophysical aspects of ecosystem health and demonstrate the holistic nature of Te Ao Māori and mātauranga Māori. Examples of kaupapa Māori assessments of the state and health of a waterbody include:

- Taonga species monitoring – targeted assessment of the abundance and health of specific species (e.g., Kusabs et al. 2018)
- Cultural Health Index – developed by Ngai Tahu to assess river values of cultural importance, which requires ongoing site visits by multi-generational tangata whenua (Tipa & Teirney 2006)
- Mauri Compass – a framework to report the current state of waterways focussed on tuna (eel) as mahinga kai in Turanganui a Kiwa (Gisborne) rohe (https://www.mauricompass.com/)
- Wai Ora Wai Māori – developed by Waikato-Tainui for monitoring the metaphysical, physical and economic elements of mahinga kai (Awatere et al. 2017).

Inherent in the application of kaupapa Māori based monitoring frameworks is the involvement of tangata whenua. It is their choice to apply existing methods, or to develop new place-based approaches. Also, monitoring using mātauranga Māori often involves collecting or using sensitive data and so intellectual property arrangements are needed to protect iwi / hapū interests. No methods specifically look to assess the effectiveness of riparian restoration, but like other integrated frameworks (e.g., ecosystem health, stream ecological valuation) they provide an overall assessment of stream health, but through a Māori world view. Indicators often assess biophysical elements that might be responsive to riparian restoration (Table 16). Because Kaupapa Māori frameworks are so varied, our assessment against key criteria reflects this range (Table 17).

Table 16. Example of indicators that measure biophysical elements applied in kaupapa Māori based freshwater monitoring frameworks.

Framework	Biophysical indicators	Monitoring methods
Taonga species monitoring	Fish presence / abundance Fish population structure Habitat availability	Field-based visual assessment Mixed fishing methods
Cultural Health Index	Species diversity Riparian vegetation Riverbed condition / sediment Channel form Flow and habitat variety Water clarity and water quality	Field-based visual assessment
Mauri Compass	Eel presence, abundance, health, growth rate Water quality Habitat availability Biodiversity	Field-based visual assessment Spot water quality samples Mixed fishing methods Stream Health Monitoring and Assessment Kit (NIWA 2019)
Wai Ora Wai Māori	Mahinga kai (e.g., koura, watercress) presence, abundance and health Habitat availability	Field-based visual assessment

Table 17. Assessment of the Kaupapa Māori indicators and methods for rivers and streams for suitability to measure biodiversity outcomes of Jobs for Nature projects. DOC = Department of Conservation.

Key element	Score	Reason
1. Representativeness	2/3	Provides a variety of indicators including those to assess aquatic plants, invertebrates and fish as well as other elements of stream health.
2. Consistency	1/2	Place or region-specific assessments likely to be altered for local application. Some components consistent across regions, e.g., the cultural health index.
3. Flexible	3	Relies on identification of core elements by tangata whenua.
4. Robust	2	Variable metrics and methods of scoring indicators but is susceptible to personal biases of assessors.
5. Informative	2	Standardised method of scoring allows the results of assessments to easily be interpreted and compared to other sites where the same framework has been applied. Most informative to local iwi / hapū.
6. Fit-for-purpose	1	Likely to provide some evidence of in-stream biodiversity change due to riparian restoration.
7. Align to DOC	1	Minimal overlap with DOC methods.
8. Skill level	2	Requires mana whenua mātauranga.
9. Resources required	3	Minimal resources are required.

6.2.7. Restoration Indicators Toolkit

The restoration indicators toolkit (Parkyn et al. 2010) describes a range of indicator methods which can be used to monitor improvement in stream restoration projects, where improvement is assessed as the degree of change toward a reference benchmark. Indicators represent three main elements including habitat, water quality and biogeochemical functioning, and biota (Table 18). While designed for application by local government, indicators that are suitable for application by community groups are also identified.

Table 18. Indicators in the Restoration Indicators Toolkit identified as specifically relevant to riparian restoration. Indicators suitable for community groups marked with an asterisk.

Core element	Indicator	Monitoring methods
Habitat	Shade of water surface* Water and channel width* Bed particle size * Mesohabitat types* Bank erosion and condition* Organic matter abundance* Longitudinal profile variability* Residual pool depth Water clarity* Leaf retention*	Harding et al. (2009) including amendments Black disc water clarity Quinn et al. (2007)
Biogeochemical functioning and water quality	Water temperature* Faecal indicators* Nutrients Dissolved oxygen Ecosystem metabolism Organic matter processing*	Continuous logger Spot samples NEMS Young et al. (2006) Clapcott et al. (2010)
Biodiversity	Periphyton* Macrophytes* Benthic macroinvertebrates* Mega-invertebrates Fish* Terrestrial plant diversity and survival of plantings*	Collier et al. (2007) Stark et al. (2001) Joy et al. (2013) Hurst & Allen (2007)

Indicators are ranked by their level of general applicability across different environment types and linked to different restoration activities (e.g., channel modification, riparian management, barrier removal) and goals (e.g., biodiversity, recreation, and fisheries). Indicator methods are based on best available information at the time of publication. Additionally, the timescale of monitoring and recovery of specific indicators is suggested (Figure 14). A radar diagram is suggested as a simple tool to combine the results from monitoring multiple indicators and illustrate restoration success (Figure 15). An assessment against key criteria highlights the usefulness of the Restoration Indicators Toolkit for informing biodiversity monitoring (Table 19)

Indicator	Water temperature
Goal	Aquatic biodiversity
Applicability	Wide range of restoration projects
Scale of monitoring	Continuous logger during summer period
Metric	Cox-Rutherford Index (°C)
Scale of recovery	Short (stream size dependent)

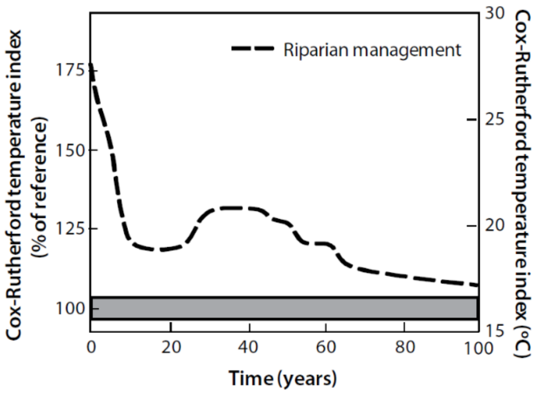

Figure 14. Example of information provided in the Restoration Indicator Toolkit for a water temperature indicator including the hypothetical recovery curve.

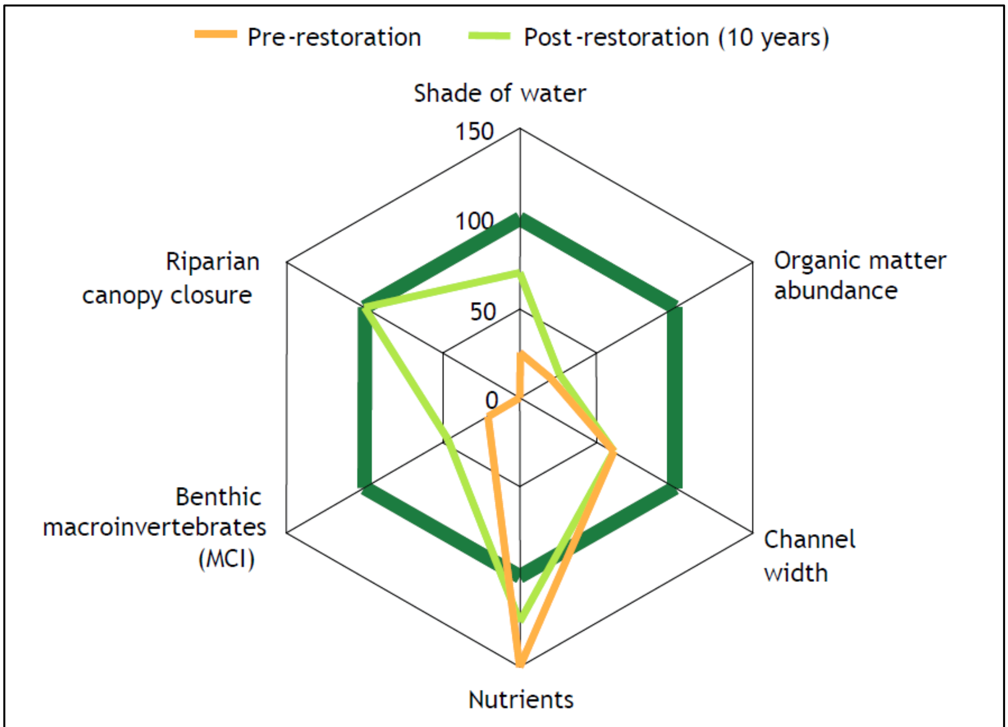

Figure 15. Example of a radar diagram which can be used to summarise results of stream restoration monitoring. From the Restoration Indicators Toolkit (Parkyn et al. 2010).

Table 19. Assessment of the restoration indicators toolkit indicators and methods for rivers and streams for suitability to measure biodiversity outcomes of Jobs for Nature projects. DOC = Department of Conservation.

Key element	Score	Reason
1. Representativeness	2/3	Identifies specific biodiversity metrics but also supporting measures.
2. Consistency	2	Identifies level of applicability and focus on indicators that can be broadly applied.
3. Flexible	2/3	Introduces some different methods to apply the same indicators based on resource availability.
4. Robust	2/3	Informed by best available information and usually adopt standardised methods.
5. Informative	2/3	Provides guidance for some methods on the application of results to guidelines values. Provides a simple example of how to present results in an easily understood way.
6. Fit-for-purpose	2	Covers a broad range of stream indicators some measure the relative abundance of native to non-native species or taxa abundance. Others measure processes which support biodiversity.
7. Align to DOC	2/3	Mostly overlap with indicators and methods used in DOC Tier 1 monitoring.
8. Skill level	1/2/3	Mixed and highly dependent on each indicator, but provides options for community group application.
9. Resources required	1/2/3	Mixed and highly dependent on each indicator, but provides options for community group application.

6.2.8. SHMAK: Stream health monitoring and assessment kit

The Stream Health Monitoring and Assessment Kit (SHMAK) was developed to provide landowners and community groups with scientifically robust yet simple tools to monitor stream health (Biggs et al. 1998). It has evolved over 20 years to include new methods and resources suitable for broader application. For example, the latest iteration includes a revised suite of equipment and a user guide to assess visual water clarity, new indicators of stream health, including rubbish, dissolved nutrients, and faecal indicator bacteria, an accompanying suite of training videos, and data entry and management tools via a dedicated new website: NZWaterCitizens.co.nz. The latest SHMAK (NIWA 2019) provides useful advice on when, what, and where to monitor when assessing riparian restoration, and is strongly aligned to the restoration indicators toolkit (Parkyn et al. 2010). For example, to monitor Biodiversity seven core indicators are recommended over varying time scales (Table 20).

Table 20. When to apply recommended indicators and methods to assess biodiversity response to riparian restoration in the Stream Health Monitoring and Assessment Kit (NIWA 2019).

Core element	Indicator	Time scale	Method
Biodiversity	Periphyton Macrophytes Macroinvertebrates Fish (Temperature, clarity and DO – see below)	Monthly Annual Annual Annual	Visual assessment Visual assessment Kick net and onsite identification Spotlighting / trapping
Water quality	Water temperature Dissolved oxygen Clarity Water quality	Continuous Monthly Monthly Monthly	Continuous logger or spot measurement in late afternoon Clarity tube or black disc Nitrate microtest® Phosphate checker® Petrifilm™ Select *E. coli* count plate
Natural habitat	Stream habitat	Annual	Visual assessment of fine sediment, habitat availability, flow types, bank stability, bank vegetation, riparian buffer width and shade Substrate composition

Table 21. Assessment of the Stream Health Monitoring and Assessment Kit indicators and methods for rivers and streams for suitability to measure biodiversity outcomes of Jobs for Nature projects.

Key element	Score	Reason
1. Representativeness	2/3	Provides a variety of indicators including those to assess aquatic plants, invertebrates and fish as well as other elements of stream health.
2. Consistency	2	Standard methods for citizen science application.
3. Flexible	2	A variety of methods but designed to be applied with limited resources.
4. Robust	2	Aligned to standardised methods and metrics.
5. Informative	2	Provides examples of how to present results in an easily understood way.
6. Fit-for-purpose	2	Covers a broad range of stream indicators and some measure local biodiversity. Likely to provide evidence of responses in water quality and / or habitat before biodiversity elements.
7. Align to DOC	2	Aligned to indicators / metrics used in DOC Tier 1 monitoring but using amended methods.
8. Skill level	3	Suitable for citizen science after minimal training.
9. Resources required	2/3	Field based methods requiring few resources.

6.2.9. Standardised monitoring methods suitable for assessing in-stream biodiversity response to riparian restoration

Many of the frameworks and methods listed above refer to standard monitoring methods which have been developed for consistent and robust assessment using specific indicators. Because they have been developed to detect change in indicators over time, it is assumed they will be sensitive to any change due to riparian restoration. In this section we provide a brief overview of these monitoring methods, but do not assess their suitability against the key assessment criteria.

NEMS: National Environmental Monitoring Standards

The National Environmental Monitoring Standards (NEMS) project aims to ensure consistency in the way environmental monitoring data are collected and handled throughout New Zealand. Regional councils and the Ministry for the Environment have formed a steering group and multiple working groups to develop Best Practice Guidelines including technical standards, methods and other requirements associated with the continuous monitoring of environmental parameters. Standards relevant to river monitoring include:

- hydrology (water level, rating curves, flow measurement)
- continuous dissolved oxygen, water temperature, turbidity and suspended sediment
- periphyton
- macroinvertebrates
- discrete river water quality (i.e., ‘grab’ or ‘spot’ samples of physico-chemical parameters, nutrients, optical properties, anions and cations, metals and metalloids, microbiological properties).

Many of the NEMS standards build from existing methods and provide a central online repository to access standardised methods (http://www.nems.org.nz/). Developed primarily for regional councils, the standards usually require professional training and equipment. If applied in a restoration monitoring program designed to detect change over time, these methods should provide sufficient data to assess restoration success.

Other methods not yet in NEMS

The main assessment methods applied in streams and rivers in New Zealand are described in the following documents.

Habitat assessment protocols:

- Sediment assessment methods (Clapcott et al. 2011) provides 6 different methods to assess deposited fine sediment which require a range of skills and resources. The SAM2 method is recommended for assessing the sediment attribute in the NPS-FM 2020.

- Stream habitat assessment protocols for wadeable rivers and streams of New Zealand (Harding et al. 2009) provides three tiers of protocols to assess hydrology and morphology, instream habitat, and riparian habitat.
- National rapid habitat assessment protocol development for streams and rivers (Clapcott 2015) provides a rapid visual assessment protocol which provides an overall habitat quality score based on 10 stream habitat components including deposited sediment, invertebrate habitat diversity and abundance, fish cover diversity and abundance, hydraulic heterogeneity, bank erosion, bank vegetation, riparian width and shade.
- National rapid river pressures assessment protocol for streams and rivers. (Holmes et al. 2020) developed to accompany the rapid habitat assessment protocol this rapid visual assessment measures the pressures / drivers that impact habitat status including nuisance benthic algae and macrophytes and riparian plants, instream structures and disturbance, discharges and drains, bank modification, livestock and human riparian disturbance, rubbish, land use and flood plain modification / constraint.
- Longfin tuna and brown trout habitat quality indices for interpreting habitat quality score data (Holmes 2016) provides an algorithm to calculate fish habitat suitability based on data collected using the rapid habitat assessment protocol.

Biodiversity protocols include:

- Regional guidelines for ecological assessments of freshwater environments: aquatic plant cover in wadeable streams (Collier et al. 2007) are widely applied nationally to assess macrophyte diversity and 'clogginess'.
- New Zealand Freshwater Fish Sampling Protocols (Joy et al. 2013) outline standardised methods for measuring freshwater fish communities using backpack electric fishing, spotlighting and trapping.
- In 'Evaluation of a traditional Māori harvesting method for sampling kōura and toi toi populations in two New Zealand streams' (Kusabs et al. 2018) outline both traditional Māori methods, and electric fishing methods for sampling mega-invertebrates.

Ecosystem process protocols include:

- Functional indicators of river ecosystem health (Young et al. 2006) describe how to measure ecosystem metabolism using continuous measures of dissolved oxygen and water temperature as well as measures of organic matter breakdown.
- In 'Exploring the response of functional indicators of stream health to land-use gradients' Clapcott et al. (2010) describe how to apply a cotton strip assay as a standardised measure of organic matter breakdown.
- In 'Factors influencing retention of coarse particulate organic matter in streams' Quinn et al. (2007) describe how to measure leaf litter retention.

6.3. Review of monitoring methods for assessing terrestrial biodiversity outcomes of riparian restoration

6.3.1. FORMAK: Forest Monitoring Manual

FORMAK was developed with support from the Ministry for the Environment (MfE) to provide a simple methodology for landowners and community groups to monitor and assess trends in forest ecosystems. It was developed from a selection of monitoring options presented in the Native Forest Monitoring Guide (Handford 2000).

FORMAK assesses a site's vegetation (including pest plants), birds, and animal pests (Table 22). The data collected through vegetation monitoring can demonstrate whether a restoration site has become or is on a trajectory to becoming a functional forest habitat, especially when monitoring is applied regularly over long time periods. The collection of data on saplings and epicormic growth[9] is a key element of this, as it demonstrates a site's ability to be self-sustaining. The method requires monitoring to be undertaken on transect lines, which makes it ideal for adapting to an individual site's size and shape, without compromising data integrity across a broader scale. Transect lines are a prescribed length of 20 m; however, this will likely need to be modified depending on the width of riparian restoration to adequately monitor the plant community at restoration sites. For example, if the restored riparian width is only 10 m either side of a stream, the transect could be split into two 10-m transects along either side of the stream.

The method used to assess vegetation changes over time is considered simple enough to use by a range of practitioners with little training. However, it does require surveyors to have a certain level of plant and bird identification skill. Better information on changes in species diversity through time would be collected if the method is applied by skilled ecologists.

A simple five-minute bird count repeated throughout monitoring transects is the prescribed method for assessing bird species presence and abundance. As with the vegetation monitoring, repeated and long-term application can determine whether indigenous bird diversity is increasing as riparian vegetation develops.

Data collected on pest species (animals and plants) presence, abundance and distribution is a key aspect of this monitoring method that can identify 'hand brakes' (threats) to the site's biodiversity outcomes. Monitoring these elements will allow restoration practitioners to easily identify if the self-sustainability of the site is at risk, enabling targeted and rapid adaptive management. Continued application of these elements will also allow practitioners to assess if the 'threat' has been effectively minimised.

[9] An epicormic shoot or bud grows from underneath the bark of a trunk, stem, or branch of a plant.

Pest animal monitoring is completed via a wax block transect. This method can provide information on the presence, abundance and distribution of possums and rodents but does not target mustelids, feral cats and hedgehogs which are also key predators of indigenous fauna.

Lastly, FORMAK recommends regular collection of photos at static photo points. This method of restoration monitoring has been proven to be a useful tool in tracking restoration success and supports effective communication of outcomes to a wide audience through a visual medium.

An assessment of the FORMAK method against the key assessment criteria of a suitable monitoring methodology is provided in Table 23.

Table 22. Indicators and methods used to assess terrestrial biodiversity elements in the FORMAK monitoring protocol.

Biodiversity element	**Indicators**	**Monitoring methods**
Vegetation	Canopy species and cover Understory species and cover Ground cover Species diversity Height Diameter at breast height (DBH) Sapling and epicormic shoot tally Pest plant presence, abundance and distribution	Photopoints Simple count Permanent vegetation plots (transect lines)
Birds	Species presence / absence Species abundance index Species distribution	Five-minute bird counts
Pest animals	Species presence / absence Species abundance index Species distribution	Wax block transect Foliar browse

Table 23. Assessment of the FORMAK monitoring methodology for suitability to measure biodiversity outcomes of Jobs for Nature projects.

Key element	Score	Reason
1. Representativeness	2/3	FORMAK provides detailed information on vegetation and can provide useful index of bird species abundance and pest animal abundance. It does not provide any information regarding herpetofauna, bat or invertebrate diversity.
2. Consistency	3	Prescribes a specific monitoring method to be used and detailed documentation to explain monitoring protocols.
3. Flexible	2/3	The monitoring protocols are standardised for forest ecosystem assessment and may be transferable to riparian restoration monitoring with minimal modification. Some modification will likely be required so vegetation plots (transect lines) are designed to work within the size constraints of restored riparian habitats e.g., shortened from 20 m to the width of the planted riparian margin or split over two banks.
4. Robust	3	The standardised methodologies of FORMAK make it easy to compare differences in space and time (condition trajectory).
5. Informative	2/3	FORMAK provides standard data collection sheet but no standard reporting format exists. However, photo points are considered to be a useful tool for communication of success.
6. Fit-for-purpose	2/3	Likely to provide evidence of biodiversity changes over time but some modification of the methodology may be useful to adequately monitor biodiversity outcomes of riparian restoration e.g., modified transect length and / or pest monitoring protocols.
7. Align to DOC	2	Some overlap with DOC methods. Many of the same indicators are measured but in different ways e.g., plant species, canopy cover, ground cover, and number of saplings are all recorded but data is collected along transect lines rather than 20 x 20 m plots.
8. Skill level	2	Requires a good knowledge of New Zealand plant and bird species, however, with targeted training, methods can be applied by community members and landowners.
9. Resources required	3	Minimal resources required and, those that are, are relatively cheap.

6.3.2. Department of Conservation Tier 1 Inventory and Monitoring: Vegetation and fauna

The Department of Conservation undertakes regular inventory and monitoring of terrestrial biodiversity across New Zealand as part of their Tier 1 monitoring programme. The aim of the Tier 1 inventory and monitoring programme is to provide repeatable and unbiased ecological-integrity-indicator estimates using indicators and measures the NZ Biodiversity Assessment Framework (Lee et al. 2005). The Tier 1 monitoring assesses vegetation, birds, bats, and invasive mammals at designated monitoring sites including a variety of habitats (DOC 2013; DOC 2019) (Table 24).

The Tier 1 monitoring has the advantage of having been tried and tested across the country since 2011 and a large database already exists of past monitoring results. As with FORMAK, the Tier 1 monitoring has a prescribed methodology for the specified constituents of the terrestrial biodiversity community. A Tier 1 monitoring site is established around a permanent 20 x 20 m vegetation plot. Vegetation metrics are detailed and require a skilled ecologist to maintain data consistency and integrity. The 20 x 20 m vegetation plot may be too large for riparian sites. Modifying the size of the vegetation plot may reduce the value of the data when compared to true forest sites, where a 20 x 20 m plot is used. The effects of modification of the plot size should be considered prior to national application or uptake of the method. Transect lines extend out from each of the four corners of the vegetation plot for pest animal surveys (possum, ungulate, rabbit and hare) further expanding the size of the monitoring site.

The Tier 1 monitoring does not monitor for rats and mustelids, which are the primary threat to indigenous birds or other components of indigenous biodiversity such as lizards, bats and invertebrates. This method does not specifically assess pest plants, although this information will be incidentally collected through the vegetation plots. Five-minute bird counts are undertaken from the centre of the vegetation plots and the ends of the four transect lines.

As with the FORMAK method, regular and repeated application of the method through time, will allow restoration practitioners to track the trajectory of the biodiversity outcomes, as well rapid identification of pest animal threats.

An assessment of the Tier 1 Inventory and Monitoring method against the key assessment criteria of a suitable monitoring methodology is provided in Table 25.

Table 24. The monitoring methods included within the Tier 1 Inventory and Monitoring and the indicators measured by the various methods.

Biodiversity element	Indicators	Monitoring methods
Vegetation	Canopy cover Species diversity Stem density % cover per tier Tree height Canopy height Diameter at breast height (DBH) Coarse wood debris abundance and decay status Sapling abundance Pest plant presence, abundance and distribution	Permanent vegetation plots
Birds	Species presence / absence Species abundance index Species distribution	Five-minute bird counts
Pest animals	Species presence / absence Species abundance index Species distribution	Faecal pellet counts and DNA swabs Possum monitoring devices e.g., traps, wax tags or chew cards

Table 25. Assessment of the Department of Conservation (DOC) Biodiversity inventory and monitoring toolbox for suitability to measure biodiversity outcomes of Jobs for Nature projects.

Key element	Score	Reason
1. Representativeness	2/3	Provides detailed information on vegetation and can provide useful index of bird species abundance. Monitors the abundance of some pest animal species but does not include mustelids or rodents, which may be more important threats to measure than ungulates. It doesn't provide any information regarding herpetofauna, bat or invertebrate diversity.
2. Consistency	3	Prescribes a specific monitoring method to be used and detailed documentation to explain monitoring protocols
3. Flexible	1/2	Large vegetation monitoring plots (20 x 20 m) may not be suitable for all riparian sites. Modification of the plot size may reduce data integrity across a national scale.
4. Robust	3	The standardised methodologies of Tier 1 monitoring make it easy to compare temporal and spatial data.
5. Informative	3	Nationwide reporting completed since 2015.
6. Fit-for-purpose	2/3	Likely to provide evidence of biodiversity changes over time but modification of the methodology may be necessary to monitor biodiversity outcomes within riparian habitats e.g., change in layout of monitoring sites to fit within riparian margins and / or modification of pest monitoring protocols.
7. Align to DOC	3	DOC monitoring protocols
8. Skill level	2	To date, methods have been implemented by trained DOC workers. Could be implemented by community members with sufficient training. Requires a good knowledge of New Zealand plant and bird species.
9. Resources required	3	Minimal resources required and, those that are, are relatively cheap.

6.3.3. Biodiversity Inventory and Monitoring Toolbox

The DOC biodiversity inventory and monitoring toolbox (Greene & McNutt 2012) doesn't provide a set of monitoring protocols for monitoring terrestrial biodiversity but instead consists of a comprehensive list of monitoring options available for terrestrial biodiversity monitoring. Individual toolboxes are available for vegetation, bats, herpetofauna, invertebrates, pest animals and several monitoring options are presented for each aspect of terrestrial biodiversity (Table 26). Monitoring protocols can be selected from the several toolbox options depending on the level of information desired regarding terrestrial biodiversity. The monitoring options included are standardised methods commonly used across the country in a variety of environments, including riparian habitats.

Most monitoring options are relatively simple and can be undertaken by moderately skilled personnel, e.g., five-minute bird counts and artificial cover object (ACO) monitoring. However, some methods, such as bat captures, require a high level of skill and experience plus additional approvals such as wildlife and animal welfare permits. The toolbox also includes some monitoring methods that are more difficult to standardise and keep consistent across projects and time e.g., incidental observations of bats. However, these methods would still provide a valuable information source for community projects.

While the toolbox approach is flexible and allows restoration practitioners to adapt the monitoring to their site's individual restoration outcomes and size / shape, the lack of standardisation across all sites nationwide will make meaningful national reporting on restoration success difficult.

An assessment of the Biodiversity Inventory and Monitoring toolbox against the key assessment criteria for suitability to measure biodiversity outcomes of J4N projects is provided in Table 27.

Table 26. The monitoring methods included within the Biodiversity Inventory and Monitoring Toolbox and the indicators measured by the various methods.

Biodiversity element	**Indicators**	**Monitoring methods**
Vegetation	Canopy cover Species diversity Stem density % cover per tier Height Diameter at breast height (DBH) Pest plant presence, abundance and distribution	Aerial canopy survey Permanent vegetation plots RECCE plots
Birds	Species presence / absence Species abundance index Survival and reproduction rates Species distribution	Five-minute bird counts Mist netting
Herpetofauna	Species presence / absence Species abundance index Species distribution	Artificial cover objects Pitfall traps Funnel trapping Spotlighting Hand searches
Bats	Species presence / absence Species abundance index Species distribution	Transect lines Acoustic monitoring Roost exit counts – camera, infrared sensor, visual observation Bat capture - harp traps and mist nets
Invertebrates	Species presence / absence Species abundance index Species distribution	Hand collecting Sweep netting Pitfall traps Malaise traps Light trapping
Pest animals	Species presence / absence Species abundance index Species distribution	Pellet counts Tracking tunnels Trapping Foliar browse

Table 27. Assessment of the Department of Conservation Biodiversity inventory and monitoring toolbox for suitability to measure biodiversity outcomes of Jobs for Nature projects.

Key element	Score	Reason
1. Representativeness	3	Provides a broad variety of methods to effectively monitor vegetation, birds, bats, herpetofauna, invertebrates and pest animals.
2. Consistency	2	Mostly standardised methods but not a standardised set of methods so difficult to make consistent across a national scale. Includes some methods that are difficult to standardise e.g., incidental bat observations.
3. Flexible	3	The broad variety of recommended methods provide monitoring options to apply depending on the environment and resourcing available.
4. Robust	2/3	All of the recommended methods are commonly used for monitoring, however, the data collected from some methods can be difficult to compare against past or future data e.g., incidental observations.
5. Informative	2	No clear reporting template for monitoring but some standard reporting templates for specific fauna e.g., Amphibian & Reptile Distribution (ARDS) cards. The variety of options available in the toolbox allow for informative data to be collected on each of the key elements of terrestrial biodiversity, however, a lack of standardisation of the overall methodology makes effective national-level reporting difficult.
6. Fit-for-purpose	3	Likely to provide evidence of biodiversity changes over time.
7. Align to DOC	3	Framework developed by DOC.
8. Skill level	1/2	Many methods can be completed by community members following some training. Other methods require expert training e.g., bat capture.
9. Resources required	1/2/3	Many methods can be completed with minimal resources, but some require the use of technical equipment and trained experts.

6.3.4. WETMAK: Wetlands Monitoring and Assessment Toolkit

WETMAK (Denyer & Peters 2015) is a monitoring toolkit designed specifically for community groups undertaking wetland restoration. It builds on the Wetland Restoration handbook (Peters & Clarkson 2012) and currently contains seven modules focussed primarily on the development of a monitoring programme plus vegetation and pest animal monitoring (Table 28). The first four modules of WETMAK takes the user through the process of mapping existing features, completing an overview assessment of the site, and undertaking a rapid vegetation survey. This is considered useful for establishing a baseline and allowing diverse vegetation communities to be mapped and described. As this method has been developed for wetlands, the application of this method in riparian environments may be difficult for inexperienced practitioners or may be superfluous if the vegetation communities are generally the same across the country.

Module 6 prescribes permanent vegetation monitoring plots. The monitoring method covers the basic suite of vegetation metrics. However, it does not specify collection of data on seedlings, saplings or epicormic growth. This will make tracking the trajectory of the vegetation towards a self-sustaining community difficult.

Module 5 covers weed surveying and module 7 covers pest animal monitoring. These monitoring modules are comprehensive and will allow the tracking of pest species abundance and distribution through time to allow for effective management. Modules 5 and 7 do not prescribe specific monitoring protocols but provide options that may work in riparian environments.

The method suggests that additional modules monitoring fish, birds, invertebrate and herpetofauna may be added in the future, however the method does not currently provide for these. The method also mentions five-minute bird counts (to monitor birds) and the use of tracking tunnels to monitor for the presence of herpetofauna (as a by-product if these are used for pest animal monitoring) but these monitoring methods are not explicitly recommended or described in any detail.

The variety of methods suggested in the WETMAK method will allow for flexibility of monitoring sites of different sizes and shapes. The current focus on vegetation and pest animals will only allow for monitoring and reporting of vegetation restoration objectives. The lack of a single prescribed method for monitoring pest animals will make national reporting on restoration results difficult.

An assessment of WETMAK against the key assessment criteria of a suitable monitoring methodology to assess biodiversity outcomes of J4N projects is provided in Table 29.

Table 28. Monitoring methods recommended in WETMAK to assess biodiversity response to wetland restoration.

Biodiversity element	Indicator	Monitoring methods
Vegetation	Canopy cover Species diversity Stem density % cover per tier Height Diameter at breast height (DBH) Pest plant presence, abundance and distribution	Broad vegetation map (of restoration area) Rapid vegetation assessment (based on Atkinson 1985) Photo points Permanent vegetation plots
Pest animals	Species presence / absence Species abundance index Species distribution	Tracking tunnels Chew cards Wax tags Trapping

Table 29. Assessment of WETMAK against the key assessment criteria for suitability to measure biodiversity outcomes of J4N projects.

Key element	Score	Reason
1. Representativeness	1/2	Includes a variety of methods to monitor vegetation and pests. Does not cover invertebrates, birds, bats or herpetofauna. Five-minute bird counts are mentioned as a tool for monitoring birds and tracking tunnels are mentioned as a tool for monitoring herpetofauna, however, neither of these methods are explicitly recommended.
2. Consistency	2	Does not prescribe pest animal protocols but lists a variety of methods that could be used, so difficult to make consistent across sites.
3. Flexible	3	The broad variety of recommended methods provide monitoring options to apply depending on the environment and resourcing available.
4. Robust	3	All recommended methods are commonly-used monitoring methods for terrestrial biodiversity.
5. Informative	2	Concise and clear reporting template but currently only covers vegetation and pest animals, excluding birds, herpetofauna, bats and invertebrate. Does not specify monitoring of regeneration.
6. Fit-for-purpose	2/3	Can provide necessary evidence of biodiversity outcomes for vegetation and pests. Will not provide evidence of improvements in herpetofauna, bat, and invertebrate diversity.
7. Align to DOC	2	Some overlap with DOC methods for vegetation and pests.
8. Skill level	2	Requires a good knowledge of New Zealand plant species and some level of skill in interpreting pest monitoring results, however, with targeted training, methods can be applied by community members and landowners.
9. Resources required	3	Many methods can be completed with minimal resources, but some require the use of technical equipment and trained experts.

6.3.5. BIORAP - Guidelines for Undertaking Rapid Biodiversity Assessments in Terrestrial and Marine Environments in the Pacific

The BIORAP protocols (SPREP 2014) provide guidance on rapid biodiversity assessments in the Pacific. Recommendations are targeted at Pacific Island member countries and territories; however, the guidelines were developed by New Zealand ecologists and include a variety of methods commonly and effectively used in New Zealand.

The primary advantage of the BIORAP guidelines is it focusses on methods of rapid biodiversity assessment. As such, the monitoring recommendations have been developed with the objective of recommending the minimum monitoring necessary to cover the key components of terrestrial ecosystems. Rapid vegetation monitoring a per Atkinson (1985) is recommended as it provides a quick way to identify metrics such as species diversity, structural class (e.g., forest, scrub, grassland), and indicative community composition of the relevant tiers of the plant community (Table 30). Quantitative survey methods (e.g., RECCE plots and point-intercept transect lines) are only recommended if survey time and terrain permits. BIORAP recommends bird monitoring is done with MacKinnon lists and transect counts which would provide information regarding changes in species diversity, abundance, and distribution over time. A variety of methods are recommended for monitoring lizards, bats, and invertebrates that would provide information on diversity, abundance, and distribution and how these change over time. However, a set methodology for monitoring these elements is not prescribed but several options are provided to be used as necessary depending on the needs and resourcing of individual projects. The recommended methods for pest monitoring include tracking tunnels supported by information collected from pest control efforts, e.g., how quickly bait is being consumed and / or traps are being set off by animals.

The primary disadvantage is it is not targeted at New Zealand ecosystems and suggests some methods that are directed at fauna that are not present in New Zealand, e.g., snakes and megabats. However, these elements can be easily modified to accommodate New Zealand fauna, or removed entirely.

Most methods recommended in the BIORAP can be undertaken by community members following some training, e.g., pest animal tracking tunnels and trapping. Others require expert knowledge such as bat capture.

The BIORAP guidelines suggest several methods for each metric, so allows for flexibility of monitoring programmes to be tailored to the site and restoration outcomes. However, the lack of a prescribed method will make reporting at a national scale difficult.

An assessment of BIORAP against the key assessment criteria for suitability to measure biodiversity outcomes of J4N projects is provided in Table 31.

Table 30. Recommended monitoring methods for terrestrial biodiversity in the BIORAP guidelines

Biodiversity element	Indicator	Monitoring methods
Vegetation	Canopy cover Species diversity Stem density % cover per tier Height DBH	Broad vegetation map Rapid vegetation assessment (site walkover) Permanent vegetation plots
Birds	Species presence / absence Species abundance index	MacKinnon Lists Transect Counts
Herpetofauna	Species presence / absence Species abundance index	Spotlighting Hand searches Litter plots Glue traps and transects (banned in New Zealand under animal welfare grounds)
Bats	Species presence / absence Species abundance index Survival and reproduction rates	Acoustic monitoring Bat capture – mist nets or harp traps Roost searches
Invertebrates	Species presence / absence Species abundance index	Site-dependent but a variety of: Hand collecting Sweep netting Pitfall traps Light trapping Malaise trapping Spotlighting
Pest animals	Species presence / absence Species abundance index	Tracking tunnels Trapping Bait stations

Table 31. Assessment of BIORAP against the key assessment criteria for suitability to measure biodiversity outcomes of Jobs for Nature projects.

Key element	Score	Reason
1. Representativeness	2	Designed for Pacific region, which includes some fauna that are not present in New Zealand e.g., snakes and megabats.
2. Consistency	2/3	Provides a variety of methods and recommends does not prescribe specific protocols but lists a variety of methods that could be used.
3. Flexible	3	The broad variety of recommended methods provide monitoring options to apply depending on the environment and resourcing available.
4. Robust	2/3	Most recommended methods have been validated and are common practice in New Zealand but others are less so or are prohibited e.g., MacKinnon lists and glue traps.
5. Informative	2	No clear reporting pathway or template. The range of monitoring methodologies recommended could, however, provide useful information regarding biodiversity outcomes.
6. Fit-for-purpose	3	Likely to provide evidence of biodiversity changes.
7. Align to DOC	3	Large overlap with DOC methods.
8. Skill level	1/2	Many methods can be completed by community members following some training. Other methods require expert training.
9. Resources required	1/2/3	Many methods can be completed with minimal resources, but some require the use of technical equipment and trained experts.

6.3.6. Cultural Health Index – terrestrial biodiversity

The component of the CHI (Tipa & Teirney 2006) relevant to terrestrial biodiversity is the 'Riparian vegetation' indicator of the cultural stream health measure.
A 100-m wide riparian margin is assessed as part of the cultural stream health measure. The vegetation is assessed in terms of its indigenous and exotic ratio. The 'Use of the riparian margin' is also included as an indicator as heavy use of the riparian margin (e.g., for human recreation, or for livestock grazing) can impact stream health.

To assess the cultural environmental value of riparian restoration, it is suggested that additional indicators are included in cultural assessments more aligned with the domain of Tāne Mahuta as described in the Ngā Atua Domain Framework (Tiakina te Taiao 2011; Awatere & Harmsworth 2014). Elements of the Tāne Mahuta domain relevant to riparian restoration may include:

- catchment-wide vegetation and the connectivity of the riparian restoration within the wider landscape
- birds and insects
- ngahere / taonga

- pests.

An assessment of CHI against the key assessment criteria for suitability to measure biodiversity outcomes of J4N projects is provided in Table 32.

Table 32. Assessment of the Cultural Health Index for suitability to measure biodiversity outcomes of Jobs for Nature projects.

Key element	Score	Reason
1. Representativeness	1	Only assesses indigenous vs exotic vegetation ratio and doesn't cover other aspects of biodiversity found in riparian habitats.
2. Consistency	2/3	Has a specific process to follow to assess the health of stream.
3. Flexible	3	Site values can be assessed based on site-specific contexts.
4. Robust	2	Has set metrics to measure and a standardised method of scoring indicators but is susceptible to personal biases of assessors.
5. Informative	2	The standardised method of scoring allows the results of assessments to easily be interpreted and compared to other sites. Has been tested on several rivers around the country and results reported.
6. Fit-for-purpose	1/2	Likely to provide a small amount of evidence of terrestrial biodiversity changes.
7. Align to DOC	1	Minimal overlap with DOC methods.
8. Skill level	2	Requires mana whenua assessment.
9. Resources required	3	Minimal resources are required.

6.4. Description and comparison of terrestrial monitoring methods

Table 33. Vegetation monitoring methods.

Monitoring method	Description
Photo points	Photo points are fixed locations where photographs are taken over time to show the change in vegetation. They are an effective method for showing large changes in vegetation and require a low level of skill to complete. Photo points, however, provide limited information regarding the plant community composition (e.g., species diversity, canopy height and stem density).
Aerial canopy survey	Aerial canopy surveys can be used to identify changes in vegetation over time through the comparison of aerial imagery. Aerial canopy surveys provide very little information about a plant community beyond the very broad vegetation type (e.g., pasture, scrub, exotic forest, native forest) but can provide useful information regarding the extent of various vegetation types (particularly following ground-truthing of a site). Aerial surveys can be limited in their effectiveness for monitoring changes over time if no recent imagery of a site of interest is available. This can be countered by collecting aerial imagery of a site via a drone survey, but this will likely add additional survey costs.
Rapid vegetation assessment	Various forms of rapid vegetation assessment exist but most methods are typically based on Atkinson (1985) which provides information on the most abundant and conspicuous species within a plant community within each vegetation tier. Rapid vegetation assessments typically include: • A site walkover identifying any species observed at the site (or collecting samples of unidentified species). • A broad description of the plant communities based on dominant species in each tier. • An identification of the land cover type e.g., forest, treeland, shrubland or grassland. • An estimate of canopy height. Rapid vegetation surveys require plant identification skills but are easier to undertake than more comprehensive vegetation survey methods (permanent plots, transect surveys, RECCE plots).
Permanent vegetation plots	Permanent vegetation plots provide a detailed assessment of the vegetation within a set area. When surveyed multiple times over time, they provide detailed information about a plant community within the specified plots and how it changes over time. Information collected in permanent vegetation plot surveys can vary depending on the objectives of the surveying but will typically include a range of the following: • Species list • Estimated species height • Estimated species cover per tier • Native / exotic cover • Diameter at breast height (DBH) of trees > 3 cm DBH • Height of trees with DBH > 3 cm • No. of saplings per species within the plot • No. of seedlings per species within the plot • Coarse woody debris • Ground cover – leaf litter, bryophytes, live vegetation, bare ground, and rock

Monitoring method	**Description**
	• Non-vascular species collection Permanent vegetation plot surveys require plant identification skills as well as a good understanding of the protocols to follow to ensure that monitoring is consistent over time. Several permanent plots are required over an area to ensure that the data collected is representative of the whole plant community and can therefore require a large time investment to complete.
RECCE plots	RECCE plots are a common standardised method of survey vegetation. In addition to the data collected in the permanent vegetation plots above, RECCE plots also collect data on: • Plant species • Estimated species height • Estimated species cover per tier RECCE plots are used commonly around the country by DOC, research institutes, local authorities and others but require a high level of identification skill and a good understanding of the methodology.
Transect lines	Transect lines are similar to permanent plots in that they have a set area to be surveyed within the site of interest. The key difference being that transect lines are a linear survey area rather than a square plot. Transect lines are often used along environmental gradients (e.g., a soil moisture gradient) to identify changes in vegetation correlated to environmental changes. Transect line survey can either include surveying a set area either side of the transect e.g., 1 m or a single point on the transect and identifying any species growing directly above those points (also known as a transect-point survey). Transect-point surveys also include the measurement of trees / shrubs in proximity to the transect point to adequately monitor larger plants.
Vegetation map	Data collected regarding the vegetation of a site can be used to produce a vegetation map showing the extent of the various vegetation types and locations of weeds in the site of interest. This can provide area estimates of different vegetation types, guide management actions (e.g., weeding), and can help to keep track of geographical vegetation changes over time. Vegetation mapping provides a certain level of skill in some form of mapping software (e.g., Google Earth, ArcGIS, QGIS).

Table 34. Bird monitoring methods.

Monitoring method	**Description**
Five-minute bird count	Five-minute bird counts (5MBCs) are a common standard monitoring unit used across the country where every bird seen or heard in a five-minute period is recorded. 5MBCs can provide an index of species abundance when repeated multiple times in an area and, if done enough, can detect changes in species abundance over time. As it is a short period of survey time, 5MBCs provide a snapshot in time of the local bird community and, therefore, require multiple surveys to be completed to provide an accurate representation of the bird community at a site. As 5 MBCs require the surveyor to identify bird species by sight and sound, they require a high level of skill and can be significantly impacted by differences in surveyor abilities.
MacKinnon lists	A simple monitoring method where multiple bird species lists are created consecutively whilst walking a transect. Bird species are listed in order of observation until 20 species are recorded and then a new list is started. MacKinnon lists are not widely used in New Zealand and, in many areas, it would be uncommon to observe 20 bird species, however, this number could potentially be reduced for a New Zealand context. The MacKinnon lists method has the advantage of surveying a range of areas in one survey and likely needs fewer repetitions than five-minute bird counts to provide an accurate representation of the local bird community.
Playback calls	Playback calls are another form of monitoring that can be used to detect some rare or cryptic species. They draw on the territorial nature of some bird species by playing recordings of a call from another bird in the hope that it will provoke them to retaliate with their own call. Playback calls are cheap and simple to use as calls are available online and the surveyor simply needs to listen for a similar call to the call they have just played. For playback calls to be effective, however, they need to be played at a suitable time of day and in proximity to the target species, whose presence / location is typically not known.
Acoustic monitoring	Acoustic recorders can be deployed at a site to record continuously over a set period. This type of monitoring is often undertaken to target rare and / or cryptic species that are not likely to be detected by other methods. Acoustic monitoring requires the use of acoustic recorders and the ability of surveyors to analyse recordings for bird calls. They, therefore, require a high level of skill, and a significant investment in data (recording) analysis.
Incidental bird observations	Recording a list of incidental bird observations whilst in an area is a good way to collect a near complete list of bird species in the area. If the number of birds observed and the length of time spent on site are also recorded, it is possible to generate an index of species' abundances following several site visits. Incidental bird observations require a level of skill as surveyors will need to be able to identify any bird they encounter.
Transect counts	Transect counts involve a surveyor walking a specified distance along a specified route and recording any observations of birds, nests and other evidence of birds (e.g., droppings, burrows, footprints). By constantly moving, it is possible for a surveyor to cover a large area and larger sample sizes than many other monitoring methods and the specified distance and route provides a standardisation to this method that makes the data comparable over multiple surveys.

Monitoring method	Description
	As with other bird monitoring methods, transect counts require level of skill in identifying bird species.
Mist netting	Mist netting is a method of trapping live birds as they are flying. Once captured, birds can be banded and population dynamics can be estimated based on statistical analysis of capture-recapture data. Mist netting requires a high level of expertise, surveyors are required to handle live birds, it is labour intensive, and a DOC-issued permit under the Wildlife Act is required.
Annual list of bird species	The amalgamation of bird observations into a single annual bird list can provide an index of annual diversity of an area. If efforts in recording bird species are consistent over time, annual species lists can provide an indication of changing diversity within an area. Annual species lists don’t provide any information on species abundance within an area

Table 35. Herpetofauna monitoring methods.

Monitoring method	Description
Artificial cover objects	Artificial cover objects (ACOs) are objects placed deliberately within a habitat to attract herpetofauna to take refuge underneath. ACOs are relatively cheap, simple to use and cause little habitat disturbance but do require a level of skill to capture and identify any herpetofauna discovered. A well-designed layout of ACOs has the potential to provide data of herpetofauna presence, distribution, an index of abundance, population trends, and estimates of survival within an area. ACOs typically need to be left within a habitat for several months to give animals time to 'move in', hence, monitoring with ACOs needs to be planned several months in advance. Once established, ACOs require minimal maintenance.
Pitfall traps	Pitfall traps are containers dug into the soil and baited to trap live fauna. These traps are mostly used in New Zealand for skinks (and invertebrates). Pitfall traps are relatively cheap but labour-intensive as they require time to set up and must be regularly checked once set to avoid animals being trapped for extended periods of time. Pitfall traps are far less destructive than habitat searches and can provide data on skink populations similar to ACO monitoring (i.e., presence, distribution, an index of abundance, population trends, and estimates of survival). Due to the live trapping of animals, more ethical consideration needs to be made when using pitfall traps e.g., traps should not be set if heavy rains are forecast that present a risk of drowning, and / or they should be set out of direct sunlight to avoid dehydration. As pitfall trapping requires the handling and identification of skinks, monitoring with pitfall traps requires a high level of skill and a DOC-issued permit under the Wildlife Act.
Funnel traps	Funnel trapping is similar in principle to pitfall traps but is of varying efficacy for different animals and can be set in locations where pitfall traps cannot e.g., on vegetation, scree, debris. Funnel traps are the most effective tool for capturing geckos. They can also be used to trap frogs but often lead to desiccation and are therefore not recommended for frogs. Funnel traps are easier to set up than pitfall traps but can be more labour intensive to check (depending on their design). As with pitfall trapping, funnel trapping requires a level of skill to handle and identify lizards and a DOC-issued permit under the Wildlife Act.
Spotlighting	Spotlighting is a common method of surveying for nocturnal geckos, skinks and frogs where torches are used to detect the reflection of herpetofauna eyeshine. The number of animals detected and search effort can be used to provide an index of abundance. In essence, spotlighting is relatively cheap but requires a level of skill in terms of distinguishing herpetofauna eyeshine from other fauna and therefore would likely need to be done by a trained herpetologist.
Litter plots	Litter plots are 5 m by 5 m plots manually searched by several (usually four) herpetologists at once. Several plots are spread across the monitoring area and the standardised size provides good sampling units for statistical analysis. The requirement for several skilled herpetologists to conduct the search together is the primary drawback of this monitoring method.
Tracking tunnels	Tracking tunnels are short tunnels with an ink pad in the centre of the base. As animals walk through the tunnel, they leave ink prints on the second half

Monitoring method	Description
	of the card. They are a cheap and simple method for identifying herpetofauna and other animals but require a level of skill to interpret prints.
Hand searches	Hand searches are the fastest way to find and identify herpetofauna as you actively search through suitable habitat for lizards and / or frogs. It is also the most destructive form of searching and can adversely impact sizeable areas of habitat, depending on the level of search effort. Hand searching for herpetofauna requires one to have a good understanding of the habitats that lizards and frogs may inhabit, as well as handling and identification skills. A DOC-issued permit under the Wildlife Act is also required for handling herpetofauna.

Table 36. Bat monitoring methods.

Monitoring method	Description
Acoustic monitoring	Native bats are often surveyed using acoustic bat monitors (ABMs) deployed for a specific length of time to record any echolocation calls of bats. The primary advantage of acoustic monitoring is that once deployed, ABMs can monitor an area for bat activity for multiple weeks thereby surveying for an extended period with minimal labour inputs. Staff / volunteers are not required to work outside of normal working hours. Acoustic monitoring with ABMs can inform us of bat presence within an area and the number of echolocation calls recorded can provide and index of bat activity within an area. However, as ABM surveys cannot provide any index of bat population size. Acoustic monitoring for bats requires a level of skill and ABMs need to be deployed correctly and the data collected need to be analysed for bat echolocation calls. Spectrograms can be analysed using DOC's BatSearch of AutoBat software.
Transect lines	Transect line surveys include walking a specified distance along a specified route and recording any observations of bats. These are typically done with the assistance of handheld bat monitors that detect echolocation calls. Transect line surveys have the advantage of potentially providing an abundance index as observations may provide some information about the number of bats detected. The specified distance and route provide standardised measures that can be kept consistent over multiple surveys and enable changes in bat activity and abundance over time to be detected. The disadvantage of transect line surveys compared to acoustic monitoring is they require more man hours to survey over the same length of time and at dusk or at night when bats are active, which requires an investment in staff management and safety.
Direct observation	Aside from transect line surveys, direct observation of bats can occur through a variety of other survey methods such as dusk and dawn surveys of potential roost sites, spotlighting, and the use of night vision equipment to observe bats in the dark. Unless the site of interest is a known roost location or 'hotspot' for bat activity, these methods are typically labour-intensive relative to the amount of information collected.
Bat capture (harp traps and mist nets)	Bat capture surveys can provide information on the population size and demographics. Once captured, bats are typically banded (long-tailed bats) or PIT tagged (short-tailed bats), sexed, weighed and their reproductive status identified (juvenile or adult). If monitoring is repeated over multiple years, this data can be used to estimate population sizes, survival rates, and reproductive rates. Bat capture surveys are labour-intensive and expensive to undertake and are only used on a handful of projects around the country by skilled experts. A DOC-issued permit under the Wildlife Act is also required.
Thermal imaging camera traps	Thermal imaging cameras can be useful monitoring tools at sites of known or suspected bat roosts. Set in a location of a known or expected roost, thermal imaging cameras can provide information on population size and demographics without the disturbance of capturing, handling, and banding / tagging bats. Thermal imaging cameras are relatively expensive and setting them up at known / suspected roost sites requires a level of skill and logistical barriers such as climbing trees and the associated health & safety risks.

Table 37. Invertebrate monitoring methods.

Monitoring method	**Description**
Hand searching	Hand searching for invertebrates can be done by manually searching through potential habitats e.g., lifting rocks, logs and leaf litter. It is a simple method of monitoring and by standardising the time or area of searches can provide an index of diversity and abundance. However, a large amount of sampling needs to be done to account for the large variation in invertebrate diversity and abundance in space and a level of skill is required to identify invertebrates. Hand searching is a relatively destructive method of monitoring on potential invertebrate habitats.
Sweep netting	Sweep netting is the use of a net to capture individual insect or a collection of invertebrates. This method is typically used in conjunction with other manual search methods (i.e., hand searching, foliage beating, spotlighting) and can be useful for determining if a species is present but is difficult to standardise. Sweep netting is a cheap and simple method of surveying but requires a level of skill to identify invertebrates.
Foliage beating	Foliage beating is undertaken by hitting the foliage of plants with a stick to dislodge invertebrates from the plant and be collected in trays below. This is a cheap and simple monitoring method and provides information on invertebrate diversity. Foliage beating is, however, difficult to standardise so is rarely used for quantitative monitoring and requires a level of skill to identify invertebrates.
Spotlighting	Spotlighting is a night-time hand searching method completed with assistance of a torch and can be more effective for finding certain invertebrate species. Spotlighting has additional health & safety risks associated with night-time working.
Pitfall traps	Pitfall traps can be used to monitor the activity of invertebrate species on the ground and can estimate an index of relative abundance to monitor change in a site over time. Insects are typically caught and killed in a preservative solution and sent to a lab to be identified. Pitfall traps are a cheap, simple and standardised method for trapping ground dwelling invertebrates but are not suitable for most flying and arboreal insects or for long-term studies as they can reduce invertebrate populations over time, and they require specialist taxonomists for identification.
Malaise traps	A malaise trap is a tent-like trap primarily used to catch flying insects. They are a standardised method of monitoring that can provide a variety of information on invertebrate population dynamics if used correctly. Malaise traps can be left in place for several days to weeks and collect a large sample of invertebrates. Malaise trap monitoring is relatively simple, however, a level of skill is required to identify invertebrates and, if several traps are required, it can become expensive. Malaise trapping also has the disadvantage of trapping and killing large numbers of invertebrates.
Light trapping	Light trapping is a long-standing monitoring method for moths and other flying insects such as adult aquatic insects. Data collected from light trapping surveys can provide information on invertebrate diversity over time and space.

Monitoring method	Description
	Light traps are relatively cheap and simple to use but require a level of skill in identifying species and its effectiveness is impacted by bad weather and the presence of other light sources.

Table 38. Pest animal monitoring methods.

Monitoring method	Description
Tracking tunnels	Tracking tunnels are a cheap tool for monitoring the presence of a variety of pest species as they walk over an ink card and leave tracks behind. Tracking tunnels can be used to monitor rodents, mustelids and hedgehogs. They are easy to use but require a level of skill to interpret. A disadvantage of tracking tunnels is that they are not suitable in wet areas as the tracking ink will run so they need to be deployed in dry areas. Tracking tunnels offer the benefit of also detecting skinks, weta, and frogs.
Chew cards	Chew cards can be used to monitor pests by baiting pests to bite the cards, subsequently leaving bite marks that can be identified. Chew cards are a cheap monitoring option for a wide variety of pest animals including rodents, mustelids, possums, cats, and hedgehogs and can be more effective at detecting pests than tracking tunnels. Chew cards do require a level of skill to interpret bite marks and larger bites can obscure smaller bites.
Wax tags	Wax tags are like chew cards in that they use bite marks to identify the presence of pest species. Wax tags are typically used to monitor for rodents and possums and can provide better defined bite marks than chew cards. As with chew cards, they require a level of skill to interpret, and large bite marks can obscure smaller bites.
Faecal pellet counts	Faecal pellet counts can be used to identify pest species present and provide an index of their abundance. Identifiable pellets can be left by deer, goats, possums, rats, pigs, hares and rabbits; however, pellet counts are primarily useful for quantifying deer, hares and rabbits.
Foliar Browse Index	Foliar Browse Index monitoring provides an index of possum abundance via change in canopy foliage. Foliar browse surveys are typically undertaken in well-established forests. They require a good understanding of the Foliar Browse Index methodology, however, once understood, they are relatively straight forward and quick to complete.
Wax block transect	A standardised method of monitoring using wax blocks spaced 2 m apart along a transect line and left for two nights before being collected. Bite marks in the blocks can be used to identify species presence and an index of abundance. A relatively cheap and simple method of pest animal control but has the same disadvantage of wax tag and chew card monitoring in that large bite marks can obscure smaller bites.
Trapping	Trapping of pest animals can confirm their presence and provide an index into their abundance. It also works in conjunction with active pest control. The development of an effective trapping programme requires good knowledge of pest animals; however, the implementation of approved pest animal traps does not require a high level of skill. Non-self-resetting traps can be labour-intensive to maintain but provide exact information on pest kills as each animal killed must be manually removed from the trap (N.B., frequency of trap checking should be recorded). Self-resetting traps can dramatically reduce labour requirements but (with the use of counters) can only provide an index of the number of pests killed and cannot provide data on the exact number and species of animals killed (i.e., because carcasses are often scavenged).
Bait stations	Bait stations can be used to detect the presence of pest animals by filling stations with a non-toxic pre-feed to identify if pests are present. If the bait is

Monitoring method	**Description**
	removed, the station can be reverted to a pest control tool and refilled with toxic baits. The rate at which the feed is eaten can also provide an index of the abundance of pests.
Incidental observations	Incidental observations of pests and / or pest faecal pallet can provide information on pest presence. It is difficult, however, to convert incidental observations into robust data.

6.5. The indicator selection decision support tool for different scenarios of restoration actions and outcomes (goals).

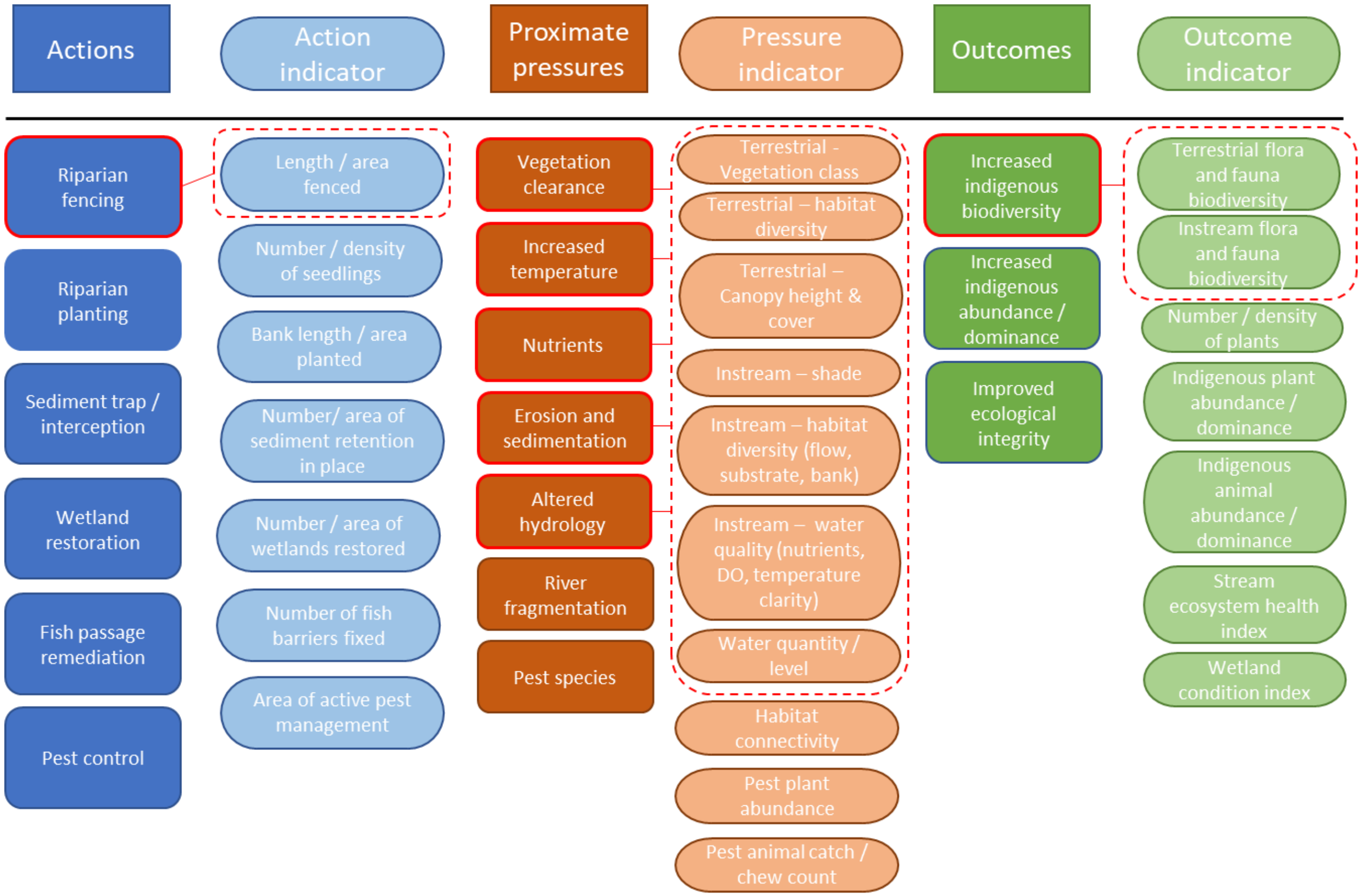

Figure 16. Action is riparian fencing and outcome is increased indigenous biodiversity.

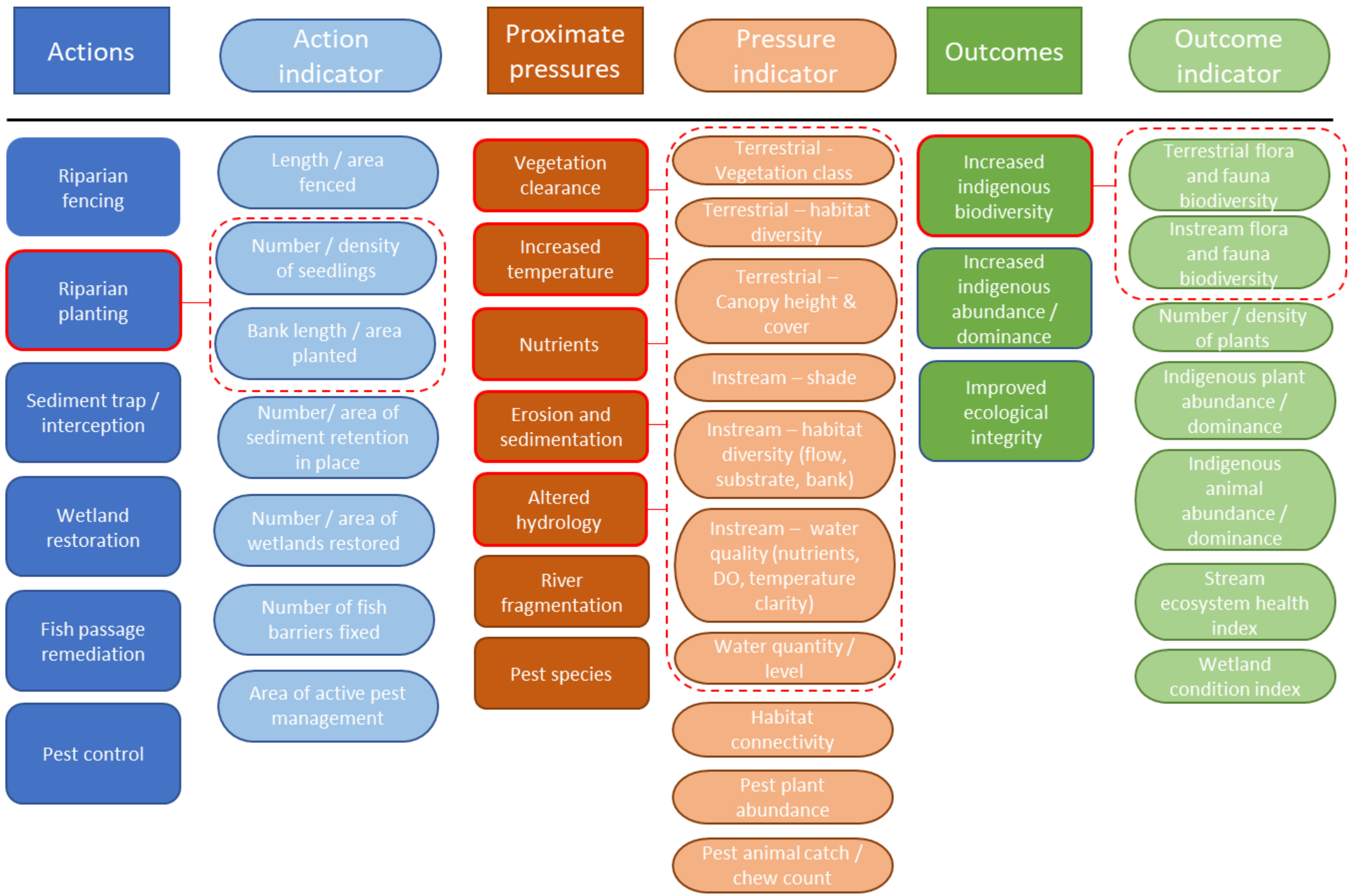

Figure 17. Action is riparian planting and outcome is increased indigenous biodiversity.

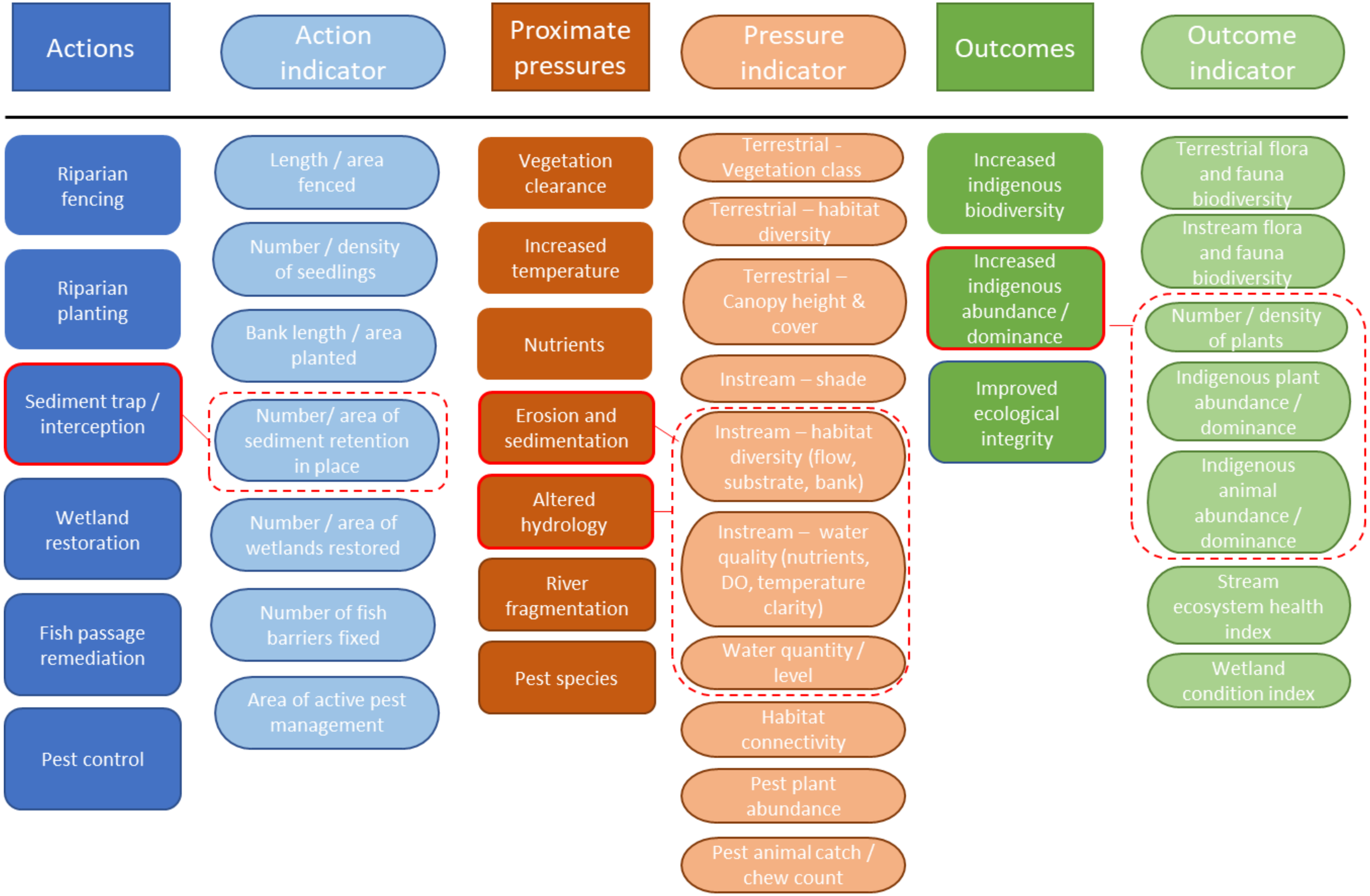

Figure 18. Action is sediment trap / interception and outcome is increased indigenous abundance / dominance.

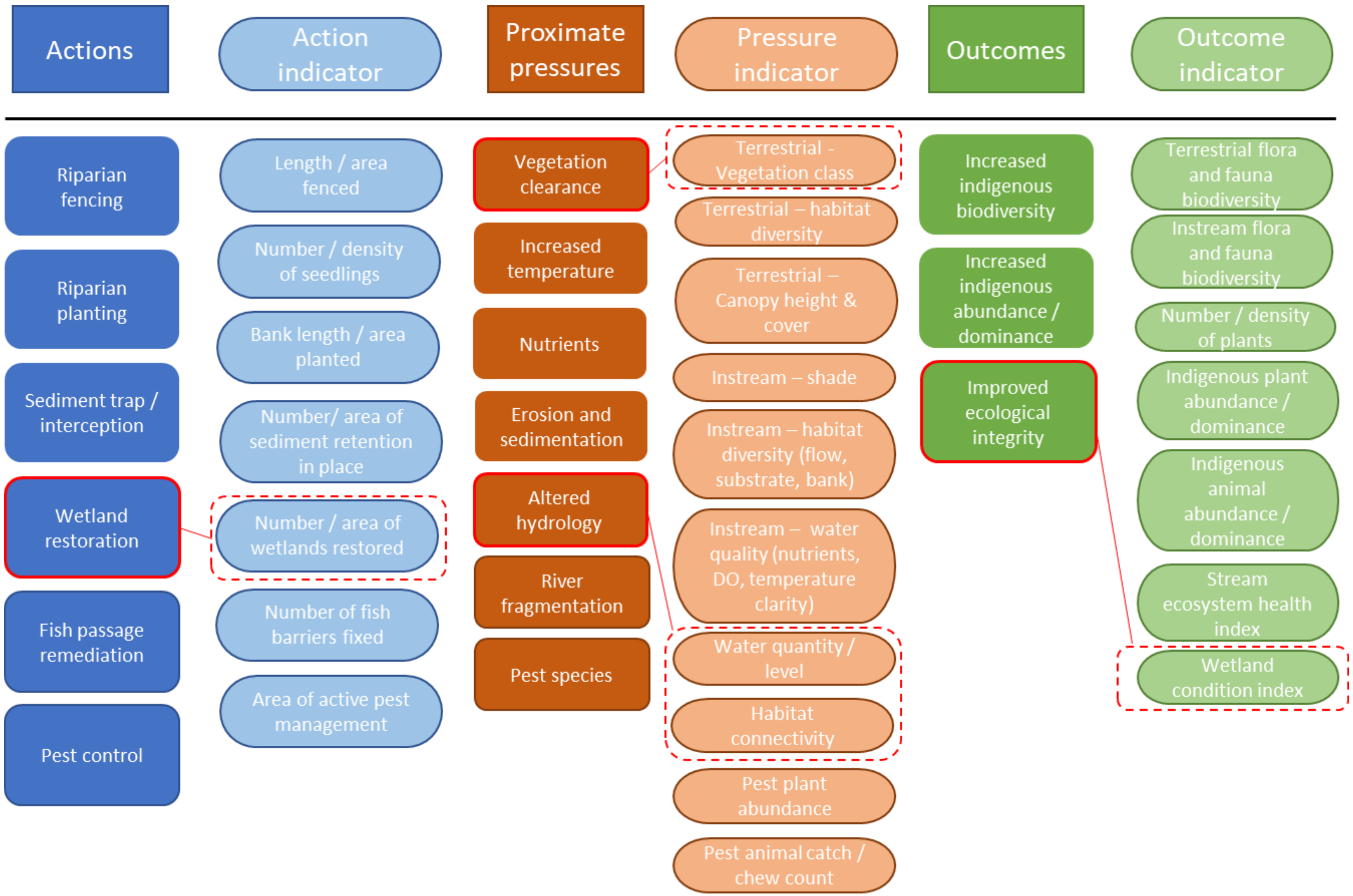

Figure 19. Action is wetland restoration and outcome is improved ecological integrity.

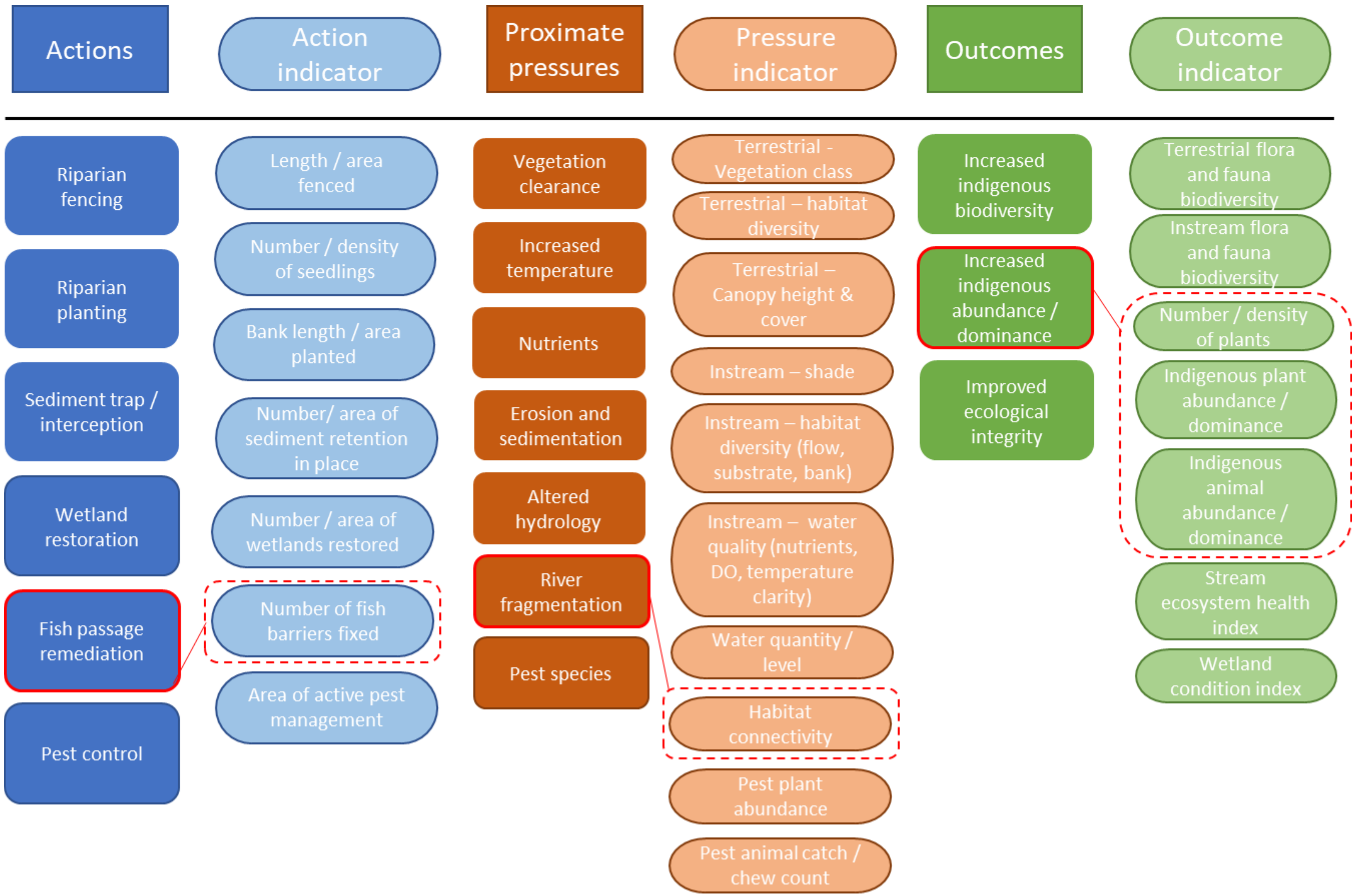

Figure 20. Action is fish passage remediation and outcome is increased indigenous abundance / dominance

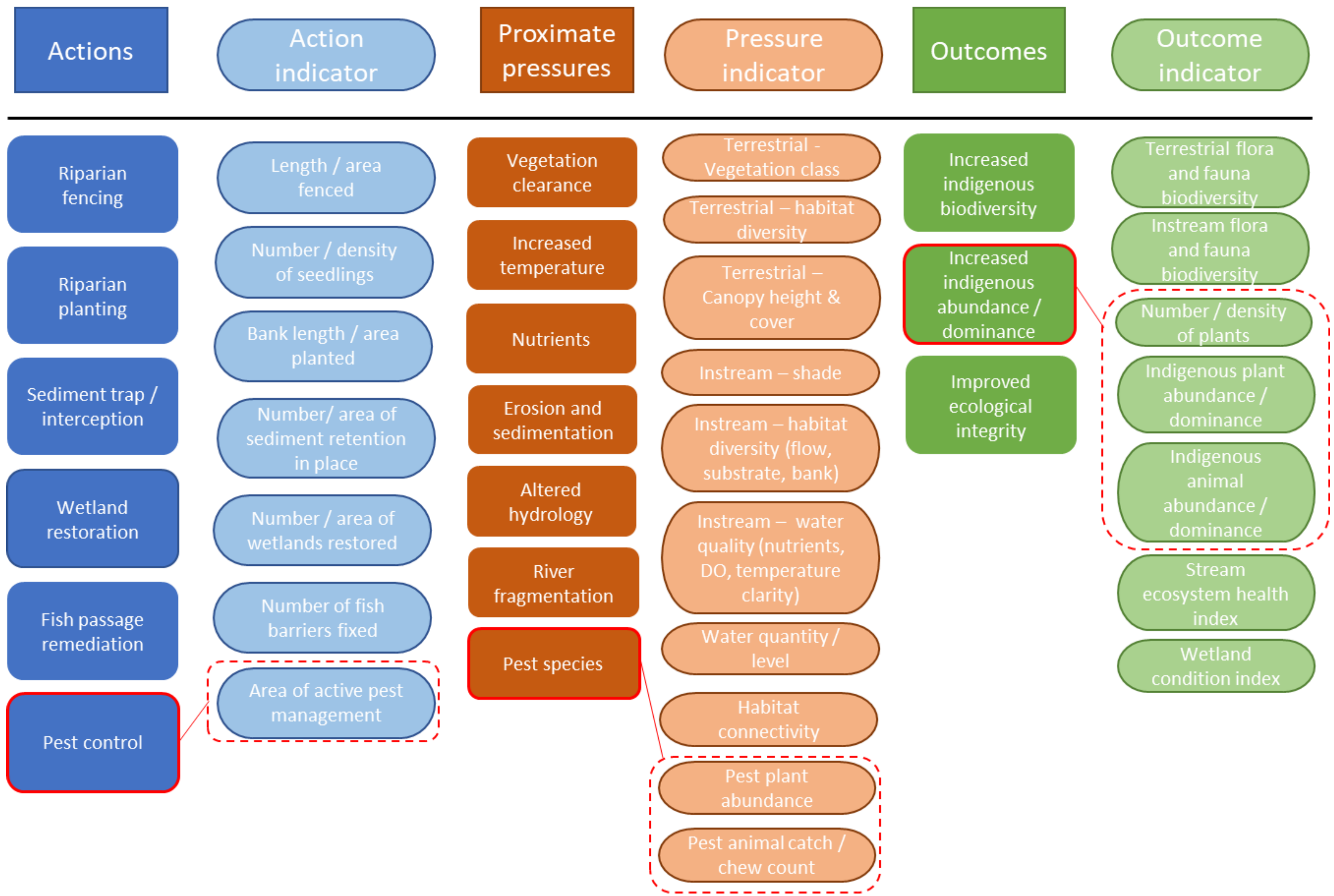

Figure 21. Action is pest control and outcome is increased indigenous abundance / dominance.

6.6. Field protocols

6.6.1. Action indicators

Riparian fencing – spatial extent

- *No reference*

Riparian planting – spatial extent

- *No reference*

Riparian planting – seedling abundance and density

- *Department of Conservation. 2019. Field protocols for DOC Tier 1 Inventory & Monitoring and LUCAS plots. Version 14. (https://nvs.landcareresearch.co.nz/Content/FieldProtocolsDOCTier1InventoryAndMonitoringAndLUCASPlots2019.pdf*

Sediment trap/interception – number and spatial extent

- *No reference*

Wetland (re)establishment – number and spatial extent

- *No reference*

Fish passage remediation – number

- *No reference*
- *Franklin P, Gee E, Baker C, Bowie S 2018. New Zealand Fish Passage Guidelines. For structures up to 4 metres. NIWA Client Report No: 2018019HN. 160 p. (https://niwa.co.nz/static/web/freshwater-and-estuaries/NZ-FishPassageGuidelines-upto4m-NIWA-DOC-NZFPAG.pdf)*

Pest control – spatial extent

- *No reference*

6.6.2. Proximate pressure indicators

Vegetation clearance – vegetation classification

- Hanford & Associates 2004. FORMAK: Forest Monitoring Manual. (https://www.formak.co.nz/index.html)
- New Zealand Land Cover Database classes at version 5.0 (https://lris.scinfo.org.nz/document/22491-lcdb-classes-at-version5/)

Vegetation clearance – canopy height and cover

- *Department of Conservation. 2019. Field protocols for DOC Tier 1 Inventory & Monitoring and LUCAS plots. Version 14. (https://nvs.landcareresearch.co.nz/Content/FieldProtocolsDOCTier1InventoryAndMonitoringAndLUCASPlots2019.pdf*

Vegetation clearance – terrestrial habitat diversity

- *Department of Conservation. 2019. Field protocols for DOC Tier 1 Inventory & Monitoring and LUCAS plots. Version 14.*

(https://nvs.landcareresearch.co.nz/Content/FieldProtocolsDOCTier1InventoryAndMonitoringAndLUCASPlots2019.pdf

- *Smale MC, Dodd MB, Burns BR, Power IL 2008. Long-term impacts of grazing on indigenous forest remnants on North Island hill country, New Zealand. New Zealand Journal of Ecology 32(1): 57- 66.*

Increased temperature – instream shade

- *Clapcott J 2015. National rapid habitat assessment protocol development for streams and rivers. Prepared for Northland Regional Council/Envirolink. Cawthron Report no. 2649. 29 p* (https://envirolink.govt.nz/assets/Envirolink/1519-NLRC174-National-Rapid-Habitat-Assessment-Protocol-for-Streams-and-Rivers.pdf)

Increased temperature – instream water quality (temperature)

- *DOC National Freshwater Field Team Manual – Water sample collection.*
- *Parkyn S, Collier K, Clapcott J, David B, Davies-Colley R, Matheson F, Quinn J, Shaw W, Storey R 2010. The restoration indicators toolkit: Indicators for monitoring the ecological success of stream restoration. National Institute of Water and Atmospheric Research, New Zealand. 134 p (https://niwa.co.nz/sites/niwa.co.nz/files/import/attachments/Restoration-Indicators-4-WEB.pdf)*

Nutrients – instream water quality (nutrients)

- *DOC National Freshwater Field Team Manual – Water sample collection.*
- *NIWA 2019. SHMAK Stream Health Monitoring and Assessment Kit User Manual. NIWA Christchurch. 84 p (https://niwa.co.nz/static/web/SHMAK_Manual.pdf)*

Erosion and sedimentation – terrestrial habitat diversity (riparian soil condition)

- *Harding JS, Clapcott JE, Quinn JM, Hayes JW, Joy MK, Storey RG, Greig HS, Hay J, James T, Beech MA, Ozane R, Meredith AS, Boothroyd IKD 2009. Stream habitat assessment protocols for wadeable rivers and streams of New Zealand. University of Canterbury Press, Christchurch* (https://envirolink.govt.nz/assets/Envirolink/Stream20Habitat20Assessment20Protocols.pdf)

Erosion and sedimentation – instream habitat diversity (bank erosion)

- *Clapcott J 2015. National rapid habitat assessment protocol development for streams and rivers. Prepared for Northland Regional Council/Envirolink. Cawthron Report no. 2649. 29 p (https://envirolink.govt.nz/assets/Envirolink/1519-NLRC174-National-Rapid-Habitat-Assessment-Protocol-for-Streams-and-Rivers.pdf)*

Erosion and sedimentation – instream habitat diversity (substrate/ deposited sediment)

- *Clapcott JE, Young RG, Harding JS, Matthaei CD, Quinn JM, Death RG 2011. Sediment Assessment Methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values. Nelson, New Zealand,* *Cawthron Institute (https://www.envirolink.govt.nz/assets/R4-1-Sediment-Assessment-Methods-Protocol-and-guidelines.pdf)*

- *Clapcott J 2015. National rapid habitat assessment protocol development for streams and rivers. Prepared for Northland Regional Council/Envirolink. Cawthron Report no. 2649. 29 p (https://envirolink.govt.nz/assets/Envirolink/1519-NLRC174-National-Rapid-Habitat-Assessment-Protocol-for-Streams-and-Rivers.pdf)*

Erosion and sedimentation – instream water quality (clarity)

- *DOC National Freshwater Field Team Manual – In situ measurements.*
- *NIWA 2019. SHMAK Stream Health Monitoring and Assessment Kit User Manual. NIWA Christchurch. 84 p (https://niwa.co.nz/static/web/SHMAK_Manual.pdf)*

Altered hydrology – instream habitat diversity (flow)

- *Clapcott J 2015. National rapid habitat assessment protocol development for streams and rivers. Prepared for Northland Regional Council/Envirolink. Cawthron Report no. 2649. 29 p. (https://envirolink.govt.nz/assets/Envirolink/1519-NLRC174-National-Rapid-Habitat-Assessment-Protocol-for-Streams-and-Rivers.pdf)*

Altered hydrology – water quantity/level

- *Harding JS, Clapcott JE, Quinn JM, Hayes JW, Joy MK, Storey RG, Greig HS, Hay J, James T, Beech MA, Ozane R, Meredith AS, Boothroyd IKD 2009. Stream habitat assessment protocols for wadeable rivers and streams of New Zealand. University of Canterbury Press, Christchurch. (https://envirolink.govt.nz/assets/Envirolink/Stream20Habitat20Assessment20Protocols.pdf)*

Altered hydrology – habitat connectivity

- *Harding JS, Clapcott JE, Quinn JM, Hayes JW, Joy MK, Storey RG, Greig HS, Hay J, James T, Beech MA, Ozane R, Meredith AS, Boothroyd IKD 2009. Stream habitat assessment protocols for wadeable rivers and streams of New Zealand. University of Canterbury Press, Christchurch. (https://envirolink.govt.nz/assets/Envirolink/Stream20Habitat20Assessment20Protocols.pdf)*

River fragmentation – habitat connectivity

- *River Environment Classification (https://niwa.co.nz/freshwater-and-estuaries/management-tools/river-environment-classification-0)*

Pest species – pest plant abundance

- *Denyer K, Peters M 2014. WETMAK: A wetland monitoring and assessment kit for community groups. (https://www.landcare.org.nz/resource-item/wetmak)*

Pest species – pest animal catch/chew count

- *Denyer K, Peters M 2014. WETMAK: A wetland monitoring and assessment kit for community groups. (https://www.landcare.org.nz/resource-item/wetmak)*

- Forsyth DM 2005. Protocol for estimating changes in the relative abundance of deer in New Zealand forests using the Faecal Pellet Index (FPI). Landcare Research Contract Report: LC0506/027. Prepared for Department of Conservation. 24 p. https://www.doc.govt.nz/globalassets/documents/conservation/threats-and-impacts/animal-pests/fpi-protocol.pdf

6.6.3. Outcome indicators

Indigenous biodiversity – instream flora and fauna diversity

Stream algae / periphyton

- *NEMS 2020a. National Environmental Monitoring Standards Periphyton Sampling and Measuring Periphyton in Wadeable Rivers and Streams v1.0.0. https://www.nems.org.nz/documents/periphyton/*
- *DOC National Freshwater Field Team Manual – Transect Cover Assessments*

Stream plants

- *NEMS 2020a. National Environmental Monitoring Standards Periphyton Sampling and Measuring Periphyton in Wadeable Rivers and Streams v1.0.0. https://www.nems.org.nz/documents/periphyton/*
- *DOC National Freshwater Field Team Manual – Transect Cover Assessments*

Benthic macroinvertebrates

- *NEMS 2020b. National Environmental Monitoring Standards Macroinvertebrates Collection and Processing of Macroinvertebrate Samples from Rivers and Streams v 1.0.0. https://www.nems.org.nz/documents/macroinvertebrates/*
- *NIWA 2019. SHMAK Stream Health Monitoring and Assessment Kit User Manual. NIWA Christchurch. 84 p. (https://niwa.co.nz/static/web/SHMAK_Manual.pdf)*

Stream mega-invertebrates

- *DOC National Freshwater Field Team Manual – Mussels*
- *Joy M, David B, Lake M 2013. New Zealand Freshwater Fish Sampling Protocols. Part 1 Wadeable rivers and streams, Massey University. https://niwa.co.nz/static/web/New_Zealand_Freshwater_Fish_Sampling_Protocols.pdf*
- *Kusabs IA, Hicks BJ, Quinn JM, Perry WL, Whaanga H 2018. Evaluation of a traditional Māori harvesting method for sampling kōura (freshwater crayfish,* Paranephrops planifrons*) and toi toi (bully,* Gobiomorphus *spp.) populations in two New Zealand streams. New Zealand Journal of Marine and Freshwater Research 52(4): 603-625.*

Fish

- *Joy M, David B, Lake M 2013. New Zealand Freshwater Fish Sampling Protocols. Part 1 Wadeable rivers and streams, Massey University. https://niwa.co.nz/static/web/New_Zealand_Freshwater_Fish_Sampling_Protocols.pdf*
- *DOC National Freshwater Field Team Manual – eDNA*

Indigenous biodiversity – terrestrial flora and fauna diversity

Terrestrial vegetation – # / density of plants

- *Department of Conservation 2019. Field protocols for DOC Tier 1 Inventory & Monitoring and LUCAS plots. Version 14. https://nvs.landcareresearch.co.nz/Content/FieldProtocolsDOCTier1InventoryAndMonitoringAndLUCASPlots2019.pdf*

Terrestrial invertebrates

- *Bulbert M, Gollan J, Donnelly A, Wilkie L 2007. Invertebrate Collection Manual. A guide to traditional invertebrate collection methods. Australian Museum. https://media.australian.museum/media/dd/Uploads/Documents/9382/The+Invertebrate+Collection+Manual.d7d0215.pdf*

Herpetofauna

- *Greene T, McNutt K (editors) 2012. Biodiversity Inventory and Monitoring Toolbox. Department of Conservation, Wellington, New Zealand – Herpetofauna https://www.doc.govt.nz/our-work/biodiversity-inventory-and-monitoring/herpetofauna/*

Bats

- *Greene T, McNutt K (editors) 2012. Biodiversity Inventory and Monitoring Toolbox. Department of Conservation, Wellington, New Zealand – Bats https://www.doc.govt.nz/our-work/biodiversity-inventory-and-monitoring/bats/*

Birds

- *Department of Conservation 2013. Field protocols for Tier 1 monitoring - invasive mammal, bird, bat, RECCE surveys. Version 14. https://www.doc.govt.nz/globalassets/documents/our-work/monitoring/field-protocols-tier-1-monitoring-recce-surveys.pdf*
- *O'Donnell CFJ, Williams EM 2015. Protocols for the inventory and monitoring of populations of the endangered Australasian bittern (Botaurus poiciloptilus) in New Zealand. Department of Conservation Technical Series 38. Department of Conservation, Wellington. 40 p. https://www.doc.govt.nz/Documents/science-and-technical/docts38entire.pdf*

Ecosystem integrity – Additional methods not captured above

Water level / quantity

- *Booker D 2015. Hydrological indices for national environmental reporting. Prepared for Ministry for the Environment. NIWA Client Report No. CHC2015015. https://dc.niwa.co.nz/niwa_dc/srv/api/records/ec20c95c-2cf2-a322-f0fd-602fc3809a5d*
- *Booker D, Henderson RD, Whitehead AL 2016. National water allocation statistics for environmental reporting Prepared for Ministry for the Environment. NIWA Client Report No. 2017065CH. https://environment.govt.nz/assets/Publications/Files/national-water-allocation-statistics.pdf*

Ecological processes

- *Parkyn S, Collier K, Clapcott J, David B, Davies-Colley R, Matheson F, Quinn J, Shaw W, Storey R 2010. The restoration indicators toolkit: Indicators for monitoring the ecological success of stream restoration. National Institute of Water and Atmospheric Research, New Zealand. 134 p (https://niwa.co.nz/sites/niwa.co.nz/files/import/attachments/Restoration-Indicators-4-WEB.pdf)*

Stream ecosystem health framework

- *Clapcott J, Young R, Wilcox M, Sinner J, Storey R, Quinn J, Daughney C, Canning A 2018. Freshwater biophysical ecosystem health framework. Prepared for Ministry for the Environment. Cawthron Report no. 3194. 89 p. https://environment.govt.nz/assets/Publications/Files/freshwater-ecosystem-health-framework.pdf*

Wetland condition index

- *Peters M, Clarkson B (eds) 2012. Wetland Restoration: A Handbook for New Zealand freshwater systems. Manaaki Whenua Press. https://www.landcareresearch.co.nz/publications/wetland-restoration/*