Developing a citizen science monitoring programme for Te Awarua-o-Porirua Harbour and catchment

Review of citizen science methodologies for monitoring freshwater and marine environments

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Contents

Executive summary

Community care groups and catchment groups play a significant role in restoring and rehabilitating Te Awarua-o-Porirua Harbour and catchment. However, there is considerable scope for the community to take a more active role in environmental monitoring, including assessing the impact of their restoration efforts.

This report reviews current citizen science programmes and monitoring methods, both in New Zealand and worldwide, that could inform the future development of a citizen science programme for Te Awarua-o-Porirua catchment.

Many of the environmental indicators currently monitored in Te Awarua-o-Porirua Harbour catchment would be suitable for volunteers to monitor, with well-established methods available in other citizen science programmes. For some indicators, further research and method development will be necessary, while for others (e.g., heavy metals) direct measurements are not possible. There is an opportunity for a citizen science monitoring programme to include indicators that are often overlooked or not monitored regularly as well as to co-design novel indicators.

There are four different ways volunteers can contribute to growing the current pool of knowledge of the health of the Harbour and catchment and ensure restoration efforts are having a positive impact. These include contributing to existing monitoring networks, targeting species and ecological processes not otherwise monitored, contributing to the development of new indicators, and evaluating ecological and water quality restoration efforts.

1 Introduction

Community care and catchment groups are playing a significant role in restoring and rehabilitating Te Awarua-o-Porirua Harbour (Porirua Harbour) and its wider catchment. Volunteers have come together to build nest boxes for penguins, carry out weed and predator control, restore dunes and wetlands, and undertake riparian planting[1]. In addition, more than 40 schools in the catchment are actively involved in a harbour education network that supports the growth of the next generation of kaitiaki (PCC 2018).

Although volunteers have been very involved in restoration activities, environmental monitoring activities in New Zealand have traditionally been restricted to professionals. Community-based monitoring is a type of citizen science where members of the community collaborate with government agencies and local institutions to monitor, track and respond to issues of common concern (Conrad and Hilchey 2011). Community-based monitoring seeks to involve the public in decision-making, so that they can be involved in both collecting data and in using the information generated; promoting engagement at a community and at a wider level.

Community-based monitoring does occur in New Zealand to a limited degree, with the longest running project in New Zealand in Porirua Harbour. The 'Community Cockle Count' in Pāuatahanui Inlet began in 1992 under the leadership of the Guardians of Pāuatahanui Inlet. The cockle count demonstrated significant declines in the cockle population in comparison to surveys from the 1970s, although the population now appears to be trending upwards (Michael and Wells 2017). The cockle count is held every three years and provides an excellent example of the power of community-generated data.

Community volunteers in the Porirua Harbour catchment are also involved in monitoring lizard and bird populations and more recently, marine litter. However, there is considerable scope for volunteers to be involved in monitoring other measures of marine and freshwater ecosystem health. This could help expand existing monitoring networks to include more sites across the catchment and generate additional data to inform decision making on catchment management. Community monitoring can also be used to increase social capital and promote behaviour change (Stepenuck and Green 2015).

NIWA was engaged by Porirua City Council to assist with identifying opportunities for greater involvement of the community in monitoring activities in Porirua Harbour and its surrounding catchment. This is the second of two initial reports to inform the development of a proposed citizen science monitoring programme. The first report (Valois 2020) presents a summary of current monitoring activities in the Harbour and catchment while this second report reviews current citizen science methods and monitoring frameworks that would be suitable to inform the development of a citizen science monitoring programme. As well as summarising a range of freshwater and marine monitoring citizen science initiatives (Sections 2 and 3 respectively), there is also a focus on litter monitoring (Section 4), reflecting that litter is a significant pollution issue affecting Porirua Harbour (PCC 2012). Different ways volunteers could potentially contribute to improving current knowledge about the health of the harbour and catchment are also outlined (Section 5).

[1] https://www.naturespace.org.nz/

2 Citizen science programmes – freshwater environments

Community-based monitoring of freshwater environments has a long history in New Zealand, with significant support provided in 1999 with the release of NIWA's Stream Health Monitoring and Assessment Kit (SHMAK), the formation of Auckland Council's Wai Care stream health programme, and Mountains to Sea Conservation Trust's 'Whitebait Connection' programme. There are also many volunteer groups who have formed their own programmes (e.g., Wānaka Swimmers/Down the Drain project and Tomahawk Lagoon Citizen Science Team in Otago).

2.1 Stream Health Monitoring and Assessment Kit (SHMAK)

SHMAK is a monitoring kit for use in wadeable streams developed by NIWA and includes methods for measuring physical, chemical and biological indicators of stream health. The original kit released in 1999 focussed on basic measures of water quality (e.g., water temperature, visual clarity), benthic macroinvertebrates, periphyton and supporting habitat-related variables. The upgraded kit, released in 2019, includes test kits for measuring nitrate, phosphate, and *E. coli,* as well as and methods for monitoring aquatic plants (macrophytes) and fish (Fig 2-1). It is also supported by a set of training videos and a website[2] where volunteers can upload, graph and share their monitoring data.

Figure 2-1: Volunteer methods for measuring phosphate (left), nitrate (middle) and *E. coli* (right) in streams as part of SHMAK.

2.2 Leaf Pack Network

The Stroud Research Centre has developed two monitoring tools for measuring benthic invertebrate diversity. The Leaf Pack Network[3] is an international network of teachers, students and citizen monitors investigating their local stream ecosystem. Volunteers can build and place leaf packs or rock packs to monitor invertebrate colonisation and also contribute to a broader understanding of how invertebrate communities use stream resources.

2.3 Restoration Indicator Toolkit

The Restoration Indicator Toolkit (Parkyn et al. 2010) includes key indicators for measuring the ecological success of stream restoration. The toolkit is a guidebook only (no actual equipment) and enables users to design a monitoring programme and compare progress with theoretical targets in the recovery of various ecological attributes. The toolkit includes measures of riparian health which are often outside of the scope of (or missing from) routine freshwater monitoring programmes. These measures therefore offer an opportunity for community groups to monitoring more holistically than what is possible by routine council State of the Environment monitoring.

[2] https://nzwatercitizens.co.nz/
[3] https://leafpacknetwork.org/

2.4 Fish Passage Assessment Tool

The Fish Passage Assessment Tool[4] was developed by NIWA (with regional councils and the Department of Conservation) to provide an easy-to-use tool for recording instream structures and assessing their likely impact on fish movements and river connectivity. Data are collected using the Fish Passage Assessment Survey available in the NIWA Citizen Science app[5]. The information collected using the app is automatically uploaded to a national fish passage database. Assessments are relatively quick (5-15 minutes per structure identified).

2.5 Wetlands Monitoring and Assessment Kit (WETMAK)

WETMAK[6] is an online resource aimed at community groups working on wetland restoration projects in New Zealand. WETMAK provides advice on monitoring techniques and methods for assessing the impact of restoration activities. It includes methods for monitoring changes in hydrology, peat decomposition, vegetation and weeds and animal pests. The toolkit is available in different formats and can be download as an entire resource or, alternatively, as specific modules.

2.6 Whitebait Connection

Mountains to Sea Conservation Trust (and Mountains to Sea Wellington) deliver the Whitebait Connection programme[7] which includes methods for fish surveys (using spotlighting), inanga habitat surveys, spawning activity surveys, and for monitoring pest species that could pose a risk to inanga eggs. The programme also includes support for installing temporary spawning habitat, maintaining spawning sites, and long-term habitat restoration.

2.7 Stream walk assessments

Stream walk assessments are protocols for collecting information on physical conditions of in-stream and stream-side characteristics. These assessments are useful in that they are quick, provide information immediately and without equipment, and can be used to assess an entire length of stream. The information can be used to identify resource needs and issues of concern (e.g., erosion, lack of riparian vegetation, sources of direct discharges). The stream walk itself provides an opportunity to increase public awareness of stream health through visually engaging with potential impairments. A stream walk assessment specific to the Porirua catchment could be developed.

2.8 Low-cost continuous monitoring devices

Across the United States, grassroots water monitoring communities are involved in developing Do-it-Yourself (DIY) sensors for environmental monitoring. The Mayfly data logger (EnviroDIY[8]) is sold online as a start kit for $90 USD. The sensors (water temperature, dissolved oxygen, pH, conductivity, turbidity) are purchased separately. New Zealand does not have DIY communities to the same extent as the United State does but the availability of low-cost sensors is increasing. Auckland Council's Wai Care is trialling a sensor that measures water level, air and water temperature, and conductivity. WaiNZ has developed the Riverwatch device[9] for continuous water monitoring but the current cost (~$5,500) is prohibitive for most volunteer groups.

[4] https://niwa.co.nz/freshwater/management-tools/fish-passage-assessment-tool
[5] https://play.google.com/store/apps/details?id=nz.co.niwa.citizenscience
[6] https://www.landcare.org.nz/resource-item/wetmak
[7] https://www.whitebaitconnection.co.nz/
[8] https://www.envirodiy.org/mayfly/
[9] https://riverwatch.nz/design

3 Citizen science programmes – marine environments

Citizen science is a popular tool for marine research and conservation around the world (Thiel et al. 2014). Although communities are often very involved in coastal restoration projects in New Zealand, routine monitoring activities are less common. In a review of the Marlborough District Council's estuarine State of the Environment monitoring programme, Forrest and Stevens (2019) recommended the adoption of citizen science to provide supporting information on changes in estuary health over time. Citizen marine monitoring protocols have been developed by NIWA (Estuary Monitoring by Communities; Schwarz et al. 2005) and the NZ Landcare Trust (Turning the Tide; Robertson and Peters 2006) however, neither initiative is currently supported by any funding to enable a long-term programme to be maintained. The only nationwide supported programme for monitoring is the University of Otago's Marine Metre Squared project.

3.1 Marine Metre Squared (MM2)

Marine Metre Squared (MM2)[10], launched nationally in 2013, is a citizen science project developed by University of Otago's Marine Studies Centre. It allows the public to monitor the intertidal communities on both rocky and sandy/muddy shores by counting the flora and fauna that are found both on the surface and just below the surface within a 1m X 1m quadrat. It also includes methods for measuring Redox Potential Discontinuity (RPD) to indicate the depth of oxygenated (i.e., healthy) sediments. Field guides and an iNaturalist project are included in MM2 to assist with identifications and a database for data storage. The MM2 tools have been used to study the impacts of dredging on rocky intertidal habitat within the Otago Harbour, with monitoring showing that species abundance was negatively impacted. As well as establishing good baseline data, the monitoring also revealed new information about the breeding period for triplefin and distribution of muricid snails, and has demonstrated the use of citizen science-friendly sediment traps (Smith et al. 2017).

3.2 Ngā Waihotanga Iho

Ngā Waihotanga Iho, the Estuarine Monitoring Toolkit for Iwi[11], was developed by NIWA to provide tangata whenua with tools to measure environmental changes in their estuaries. The toolkit is based on sound science principles and is simultaneously underpinned by tangata whenua values. The modules (e.g., habitat mapping, sediments, plants, shellfish, fish, water quality, bacteria and coastal science) are designed so that hapū and community groups can pick and choose which are of greatest use for their particular estuary and are also intended as educational resources for students.

3.3 Community cockle count

Every three years, since 1992, there has been a 'Community Cockle Count' in the Pāutahanui Arm of Porirua Harbour organised by the Guardians of the Pāuatahanui Inlet. Volunteers, under the guidance of an experienced team leader, dig quadrats in the intertidal zone, sampling the same transect as previous years. All cockles are counted and measured and then returned to the quadrat, with data interpreted and reported by NIWA (e.g., Michael and Wells 2017).

3.4 Citclops (Citizens' Observatory for Coast and Ocean Optical monitoring)

The Citclops project was developed to enable citizens' participation in acquiring environmental data in coastal and oceanic areas through the use of existing devices, such as smart phones, as sensors. A

[10] https://www.mm2.net.nz/
[11] https://niwa.co.nz/te-k%C5%ABwaha/research-projects/ng%C4%81-waihotanga-iho-iwi-estuarine-monitoring-toolkit

smartphone app called "EyeOnWater" was developed as part of this project where citizens use the camera on their smart device to take a photograph of the water and then classify its colour using comparison bars. The smartphone app was recently (2017) released in Australia by CSIRO[12]. A citizen's photograph, together with the weather conditions (e.g., rain) in which the photograph was taken are then uploaded to a website[13]. The website also has a section for uploading visual water clarity data and a new section on sea lettuce colour observations. The EyeOnWater app and website have received thousands of observations worldwide, contributing to ongoing long-term analysis in conjunction with climate research (Ceccaroni et al. 2020).

3.5 eBird

Although not specific to estuarine birds, the ebird platform[14] is used by citizen scientists to record the presence of birds in a variety of habitats. eBird comprises an international online checklist that can be accessed in real time via the eBird app and is widely used by Birds New Zealand. Launched in 2002 by the Cornell Lab of Ornithology, eBird is now one of the largest and most rapidly growing biodiversity databases globally with more than 100 million observations reported each year. The Pāuatahanui Inlet is a hotspot for ebird observations with 60 different bird species recorded in the Wildlife Reserve. In 2016, a survey for spotless crake was undertaken in the Pāuatahanui Inlet and the observations noted (along with other bird species) were uploaded to eBird.

3.6 Seagrass monitoring

Porirua Harbour is the only estuary in the lower North Island that still has significant seagrass beds and monitoring is important for early detection of any decline in seagrass condition or extent. Seagrass monitoring is a common citizen science activity throughout the world (e.g., Seagrass-Watch, SeagrassSpotter, Community Seagrass Initiative, Sailing for Seagrass – see Jones et al. 2018 for a review) and has been carried out in the Pāuatahanui Inlet in the past following a seagrass translocation trial. In light of the importance of seagrass for ecosystem health (e.g., for both food and shelter for fish, shellfish and crustaceans) and habitat restoration being a key goal in the Porirua Harbour and Catchment Strategy and Action Plan (PCC 2012), establishing a new seagrass citizen science programme would be a great way of engaging the community with the harbour's ecology. Co-monitoring of light and visual water clarity alongside seagrass cover and condition would be useful. There are several known cases of community-based Secchi depth visual clarity measurements in coastal environments around New Zealand, including formerly at the Paremata Bridge.

3.7 Saltmarsh monitoring

The Tamar Saltmarsh Monitoring Program is a citizen science programme that started in 2016 as part of an effort to better map, monitor and manage saltmarsh ecosystems in Tasmania, Australia. It includes methods for measuring bird and plant diversity, human impacts, photo-point monitoring and weed incursions (Dykman and Prahalad 2018).

In the United Kingdom, a saltmarsh monitoring programme, supported by the Salt Marsh app[15], was developed for citizen scientists to conduct plant and soil surveys. The survey allows for calculation of stored carbon in saltmarshes through the Saltmarsh Carbon Stock Predictor. It also links to learning modules on carbon storage and climate change.

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[12] https://research.csiro.au/eyeonwater/eye-on-water-australia/
[13] http://www.citclops.eu/
[14] https://ebird.org/home
[15] https://www.saltmarshapp.com/

3.8 King tide monitoring

King tide monitoring is undertaken by volunteers in Auckland where water level gauges provide a focal point for communities, providing information about sea level rise[16]. Participants can photograph the water level gauge and upload to social media. The water level on any given tide can be measured against tide levels marked on the gauge that include historic high tides and projected high tides in 2120 based on future global emissions. Overseas, examples of king tide monitoring include "Catch the King[17]" and the King Tides Program[18]. King tide monitoring can be an easy way to connect people with their coast and think about climate change without requiring a large time commitment.

[16] https://auckland.kingtides.org.nz/blog/
[17] https://www.vims.edu/kingtide/
[18] https://wsg.washington.edu/king-tides-help-people-visualize-sea-level-rise-around-coastal-washington/

4 Citizen science programmes – litter

Keep New Zealand Beautiful (KNZB) was originally founded as the Litter Council in 1969 to promote litter control in New Zealand and over the past 50 years, litter (i.e., rubbish) clean ups have been organised by schools, businesses and community groups to remove litter from the environment. The clean ups report the amount of litter they collect in number of bags or litres or kilograms of litter. In September 2019, KNZB published its National Litter Audit which represents the most comprehensive national litter study to date, based on collection of over 190,000 tonnes of litter (KNZB 2019). An ideal monitoring programme for litter would monitor litter from 'source to sink', including catchment streams and receiving coastal waters, to understand how much and what types of litter are being exported to the sea.

4.1 Litter Intelligence

Sustainable Coastlines, formed in 2009, developed a standardised monitoring and reporting method for marine litter called Litter Intelligence[19]. This methodology involves collecting all of the litter > 5mm in size deposited at the high tide line along a beach over a 100 m length, including 10 m each side of the high tide line. All litter collected within the bounds of the site is identified and counted. The first sampling effort collects the standing stock of litter with subsequent sampling efforts (at three-monthly intervals) used to calculate accumulation rates. Over 120 beaches across New Zealand are currently being monitored for marine litter as of June 2020.

Litter Intelligence is expanding in 2020/21 to include stormwater traps (gross pollutant traps) and stream litter. Stormwater traps are provided by the company Stormwater360 and have been used by Mountains to Sea Wellington (MTSW) to promote litter monitoring in schools. End of pipe stormwater nets have also been developed by a number of different companies and are currently used by Hutt City Council in their catchment litter programme (Fig 4-1).

Figure 4-1: Stormwater drain nets (left) can collect litter before it enters a stream or estuary. Volunteers can sort, identify and weigh litter items (right).

[19] https://litterintelligence.org/

4.2 Palmy's Plastic Pollution Challenge

Manawatū River Source to Sea (an entity of Environment Network Manawatū River) is working together with Massey University's Zero Waste Academy to engage the public in urban stream litter monitoring. They have developed a method that focusses on random sampling of a 100 m^2 area of a stream. It includes sampling of both the stream bed and stream banks, and collection of litter samples. To date, over 40 sites in and around Palmerston North have been sampled[20].

4.3 Litter Trackers

Litter Trackers is a collaborative project between RMIT University and Melbourne Water, supported by the Government of Victoria, Australia. Plastic bottles containing GPS trackers are released in various streams together with schools and community groups to simulate the movement of litter[21]. Litter Trackers does not provide monitoring data but could be a useful community engagement exercise in the Porirua Harbour catchment. It could also provide useful information on the role of stream characteristics in mobilising and trapping plastics, including estimates of how long litter remains in the various catchment streams before being exported to the Harbour.

4.4 Microplastic monitoring

The Australian Microplastic Assessment Project (AUSMAP)[22] is a citizen science initiative for collecting microplastics on beaches. Volunteers collect and sieve beach sand and sort samples to look at the amount and colours of microplastics found. Samples are also sent away for further analysis of contaminants by laboratory professionals. The Civic Laboratory for Environmental Action Research (CLEAR) has developed many protocols for citizen-led microplastic sampling, including DIY equipment[23].

[20] https://enm.org.nz/about/palmy-plastic-challenge
[21] https://www.rmit.edu.au/research/research-institutes-centres-and-groups/research-groups/aquest/rmit-litter-trackers
[22] https://www.ausmap.org/
[23] https://civiclaboratory.nl/citizen-science/

5 Designing a citizen science monitoring programme

This section briefly describes some specific indicators and frameworks that could be applied to citizen monitoring within the Porirua Harbour and catchment. In some cases, indicators will need to be developed further (e.g., measures of stream riparian health and characteristics of the buffer zones surrounding the Harbour).

5.1 Selecting suitable indicators

The 2015 Te Awarua-o-Porirua Harbour and Catchment Strategy and Action Plan (PCC 2015) outlined a number of indicators of marine and freshwater health along with current state of Harbour and stream health and target levels for various indicator measured to be met. Many of these indicators can be monitored by volunteers, with the Marine Metre Squared programme providing suitable protocols for monitoring of most marine indicators (Table 5-1). Additional protocols will need to be developed for monitoring seagrass and saltmarsh health, and estuarine birds. Table 5-1 includes more freshwater indicators than what are outlined in PCC (2015) including invasive species, fish passage barriers and riparian health measures. For riparian health, many different types of variables can be measured, including soil and invertebrate diversity, plant diversity, and plant health. The most suitable of these indicators for a volunteer monitoring programme requires further investigation.

Te Awarua-o-Porirua Harbour and Catchment Strategy and Action Plan includes harbour litter amounts as an indicator but litter monitoring should occur in both freshwater and marine environments for a 'source to sink' approach. The methods will differ for each environment. Marine monitoring is restricted to beaches due to safety issues. In wadeable streams, litter is collected from within the stream and along the stream banks. Freshwater litter monitoring can also include stormwater monitoring, involving traps or nets.

Table 5-1: Possible indicators for volunteer monitoring of marine and freshwater health.

Stressor	Variable	Monitoring programme/method
Marine Monitoring		
Sedimentation	Sedimentation rate	MM2/Sediments and Seashores project
	Salt marsh area and health*	Tamar Saltmarsh Monitoring Program
	Seagrass area	Seagrass citizen science programmes
	Mud content	Grain size monitoring requires lab space
	Benthic fauna diversity	MM2
Disease risk	Faecal indicator bacteria	Ngā Waihotanga Iho
Eutrophication	Macroalgae cover	MM2 with some modification
	RPD depth	MM2
	Benthic invertebrates (subtidal)	MM2
Toxins	Benthic invertebrates (subtidal)	MM2
Habitat loss	Vegetated terrestrial buffer	Investigate further
	Shellfish area	Community Cockle Count
	Saltmarsh health*	Tamar Saltmarsh Monitoring Program
	Seagrass coverage	Seagrass watch or similiar
	Inanga spawning areas	Whitebait connection
	Bird diversity	eBird/Tamar Saltmarsh Monitoring Program
	Terrestrial buffer composition	Investigate further
	Sea level rise	King tide monitoring
Biodiversity	Benthic invertebrates (subtidal)	MM2
	Birds	eBird
Litter	Marine debris	Litter Intelligence
	Microplastics	AUSMAP
Freshwater		
Sedimentation	Eroding banks	Stream Walk protocols
	Sediment (suspended)	SHMAK clarity measurements
	Sediment (deposited)	Investigate further (Cawthron methods)
	Benthic macroinvertebrates	SHMAK or Leaf/Rock pack monitoring
Disease risk	Faecal indicator bacteria	SHMAK
	Optical brighteners	Cotton test
Eutrophication	Stream nutrients	SHMAK (could include lab samples)
	Periphyton	SHMAK
	Macrophytes	SHMAK
	Benthic macroinvertebrates	SHMAK or Leaf/Rock pack monitoring
Habitat loss	Riparian health*	Restoration indicator toolkit
	Stream temperature	SHMAK
	Fish passage barriers	Fish passage app
Biodiversity	Benthic macorinvertebrates	
	Fish	Whitebait connection
	Riparian taxa (invertebrates, birds)	Investigate further
Invasive species	Invasive macrophytes	SHMAK
	Invasive fish	Whitebait Connection
	Pest mammals	TrapNZ or similiar
Litter	Stream and stormwater litter	Palmy Plastic Pollution Challenge/SHMAK
	Litter mobilisation	Litter tracker
	Microplastics	CLEAR/AUSMAP

* Measures of saltmarsh and riparian health include many different indicators and will require further investigation.

5.2 Choosing a monitoring framework

There are four different ways a citizen science monitoring programme could be structured, each providing different types of knowledge and allowing for different types of participation. A monitoring programme could incorporate all four structures depending on the ultimate goals of the programme and of the participants.

5.2.1 Contribute to existing monitoring networks

Volunteer monitoring is often promoted as an opportunity to expand existing monitoring efforts, collecting the same data but either across a greater number of sites or collecting data more often than professionals.

As summarised in Valois (2020), existing benthic ecological monitoring in Porirua Harbour mostly occurs at five-yearly intervals. However, as noted by Stevens and Robertson (2016), the decline in estuary quality associated with gross eutrophic conditions means that even relatively small changes from baseline conditions should be evaluated for ongoing monitoring and management. Volunteers could, for example, contribute to annual monitoring of intertidal invertebrates, redox depth potential and macroalgal cover. Faecal indicator bacteria are typically measured in the harbour during the summer months only (corresponding with the summer recreation season) but volunteer monitoring throughout the rest of the year could help increase understanding of faecal contaminants within the Harbour.

In the freshwater environment, volunteers can probably best contribute by expanding the existing monitoring network to cover more sites, particularly in the Pāuatahanui and Taupo subcatchments. Primary contaminants to monitor include sediment, faecal indicator bacteria and nutrients.

Extension of professional monitoring is most suited to volunteers willing to undertake training and evaluation in monitoring techniques and commit to regular monitoring. However, for some methods (e.g., the current community cockle count), inexperienced volunteers can be paired with experienced volunteers to provide greater opportunity for participation from a wider cross section of the community.

5.2.2 Evaluating restoration efforts

Community groups often form around a desire to restore degraded habitats and want to know that their efforts are having a positive impact on the environment. Similarly, resource managers and scientists require evidence of how/when on-the-ground actions lead to improved ecological outcomes. Working with community groups to evaluate restoration monitoring efforts, particularly within a before-after-control-impact (BACI) design framework is essential for identifying the causal links between restoration actions and ecological responses.

In the marine environment, restoration of seagrass and saltmarsh habitats are undertaken by volunteers overseas, including the translocation of seagrass to new sites and monitoring for successful establishment. Seagrass translocations including volunteer have been carried out in Porirua Harbour previously and, if more translocations are planned volunteers could once again be involved in both the translocation and evaluation of successful establishment.

In the freshwater environment, riparian plantings could be monitored to determine their impact on stream quality. Other restoration activities that would require monitoring include in-stream modifications to improve habitat complexity (e.g., in channelised stream sections) and modifications or removal of barriers to improve fish passage. MTSW work with communities to assess fish passage and in the United Kingdom, the citizen science group Action for the River Kennet (ARK) is involved in monitoring the effectiveness of their various restoration efforts[24].

Volunteers already engaged with restoration efforts in the Porirua Harbour catchment would be the group most likely to undertake this type of monitoring but it may also help attract younger volunteers to restoration activities by providing an opportunity to connect activities on the land with processes within the stream and/or Harbour.

5.2.3 Targeting species and ecological processes not otherwise monitored

Volunteer monitoring also provides an opportunity to collect data on attributes left out of professional monitoring, often because they require a lot of time to measure (e.g., plant, fish or bird community monitoring). However, these indicators are often ones in which the community may hold specialist knowledge. In the marine environment, this can include measures of saltmarsh and seagrass health. Community members may have specialised plant and bird knowledge and a strong interest in these areas. In the upstream freshwater environment, fish community composition and measures of riparian health (e.g., flying invertebrates, bird diversity, soil health, microclimate measurements and invasive species) are seldom monitored. Ecological processes, such as ecosystem metabolism, litter movement and microplastic formation, could be measured by volunteers.

This type of monitoring is suited for volunteers who already have a keen interest in an area and for students (primary and secondary) who would like to learn about specific environmental processes or phenomenon in addition to monitoring. These activities could be conducted over shorter time frames (e.g., leaf litter decomposition experiments) which is useful for volunteers who only want to be involved for a short period of time or who want more immediate engagement with the results.

5.2.4 Contributing to the development of new indicators

Volunteers can improve resource management by co-developing indicators. For example, New Zealand's Biological Heritage National Science Challenge is working with public and private sector organisations to develop novel measures of human and environmental health and better enable land managers to know if their work is creating positive change for biodiversity.

Volunteers could assist in the co-design of indicators for monitoring saltmarsh health in Porirua Harbour as well as develop indicators to assess ecosystem services (e.g., the provision of recreational opportunities, aesthetic value of landscapes).

In the freshwater environment, the Whaitua Implementation Plan (WIP) prepared for Te Awarua-o-Porirua as part of Greater Wellington Regional Council’s Proposed Natural Resources Plan, expressed stream habitat objectives in narrative form rather than numeric attribute states. These narratives include statements such as restoring habitat and natural character of the streams and providing habitat to support aquatic life. Indicators could be developed and trialled to measure progress in restoration efforts that give effect to these statements.

A wide variety of volunteers should be encouraged to participate in indicator development, particularly around assessing ecosystem services and understanding how the public interacts with and perceives the health of the environment. Volunteers can opt to monitor indicators that are meaningful to them.

[24] http://www.riverkennet.org/

6 Conclusion

There are a number of citizen science methodologies available, both in New Zealand and overseas, that can contribute to the development of a catchment-wide, citizen science monitoring programme for Te Awarua-o-Porirua Harbour and catchment.

Many of the indicators outlined in the Porirua Harbour Catchment Strategy and the Te Awarua-o-Porirua WIP can be measured by volunteers with appropriate training and support. However, interviews should be undertaken with current volunteer groups to assess their ability and desire to incorporate new indicators and methods into their existing work, and how these indicators and methods reflect their current goals or involvement in restoration and/or monitoring.

The approach outlined in Section 5, along with information obtained from community discussions, should be used to create a monitoring programme that both contributes to filling in monitoring gaps while also allowing for a diverse array of participation and learning outcomes and opportunities for the community to contribute their unique skills and local knowledge. This will require offering different options in terms of monitoring timeframes (e.g., opportunities for both one-off and long-term monitoring) and method complexity, as well as the opportunity to incorporate scientific discovery into traditional monitoring (e.g., Litter Trackers project, the Stroud Research Centre's Leaf Pack network).

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8 References

Ceccaroni, L., Piera, J., Wernand, M.R., Zielinski, O., Busch, J.A., Van Der Woerd, H.J., et al. (2020) Citclops: A next-generation sensor system for the monitoring of natural waters and a citizens' observatory for the assessment of ecosystems' status. *PLoS ONE,* 15(3): e0230084.

Conrad, C.C., Hilchey, K.G. (2011) A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environmental Monitoring and Assessment,* 176: 273-291.

Dykman, M., Prahalad, V. (2018) Tamar Saltmarsh Monitoring Program: citizen science monitoring of the tidal treasures of the Tamar River estuary, Tasmania, Australia. *Australian Journal of Maritime & Ocean Affairs*, 10(4): 222-240.

Forrest, B., Stevens, L. (2019) Synoptic overview of the Marlborough District Council estuarine State of the Environment monitoring programme. Salt Ecology. *Salt Ecology Report,* 010. Prepared for Marlborough District Council, April 2019: 32.

Jones, B.L., Unsworth, R.K.F., McKenzie, L.J., Yoshida, R.L., Cullen-Unsworth, L.C. (2018) Crowdsourcing conservation: the role of citizen science in securing a future for seagrass. *Marine Pollution Bulletin,* 134: 210–215.

Keep New Zealand Beautiful (KNZB) (2019) *National Litter Audit.* September 2019. Auckland, New Zealand: 256.

Michael, K., Wells, J. (2017) Community survey of cockles (*Austrovenus stutchburyi*) in Pauatahanui Inlet, Wellington, December 2016. Prepared for the Guardians of Pauatahanui Inlet. *NIWA Client Report* 2017077WN: 151.

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 measuring the ecological success of stream restoration. *National Institute of Water and Atmospheric Research*, Hamilton, New Zealand: 138.

Porirua City Council (PCC) (2012) *Porirua Harbour and Catchment Strategy and Action Plan*. March 2012. Porirua, New Zealand: 22.

Porirua City Council (PCC) (2015) *Te Awarua-o-Porirua Harbour and Catchment Strategy and Action Plan*. June 2015 Revision: 24.

Porirua City Council (PCC) (2018) *Te Awarua-o-Porirua Harbour and Catchment Strategy and Action Plan*. Annual Report 2017/18. September 2018. Porirua, New Zealand: 23.

Robertson, G., Peters, M. (2006) *Turning the Tide: An Estuaries Toolkit for New Zealand Communities, Taeiri Trust*.

Schwarz, A., Parker, S., Grose, M. (2005) Estuary Monitoring by Communities; Mangrove habitats a case study. *NIWA information series*, No. 56. Wellington: 8.

Smith, A., Pritchard, D., Carson, S., Desmond, M. (2017) Sediments and Seashores: Looking Deeper 2017. *Otago Marine Studies Programme.* With contribution from: Abbotsford School, Broad Bay School, Otago Girls High School, Portobello School, Sawyers Bay School, St Brigid's School, St Leonards School: 28.

Stepenuck, K., Green, L.T. (2015) Individual- and community-level impacts of volunteer environmental monitoring: a synthesis of peer-reviewed literature. *Ecology and Society*, 20(3): 19.

Thiel, M., Penna-Díaz, M.A., Luna-Jorquera, G., Sala, S., Sellanes, J., Stotz, W. (2014) Citizen scientists and marine research: volunteer participants, their contributions and projection for the future. *Oceanography and Marine Biology: An Annual Review*, 52: 257–314.

Valois, A. (2020) Developing a citizen science monitoring programme for Te Awarua-o-Porirua Harbour and catchment: Summary of monitoring activities. *NIWA Client Report* 2020185WN.