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

Summary of monitoring activities

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Executive summary

There is a considerable body of environmental research on Te Awarua-o-Porirua Harbour and catchment (Porirua Harbour), reflecting the high cultural, recreational and ecological values of the estuary and its catchment streams and wetlands.

Key stressors affecting ecosystem health and water quality in Te Awarua-o-Porirua Harbour's waters include sedimentation, stormwater and wastewater discharges, and loss of habitat (e.g., seagrass and saltmarsh habitat).

The number of indicators measured in the Harbour and catchment has risen considerably over time, reflecting the diversity of issues and the wide range of indicators available. However, routine "state of the environment" monitoring is restricted to the main stem of Porirua, Pāuatahanui and Horokiri streams, with less regular monitoring of most smaller tributaries. Benthic ecological monitoring in the Harbour is extensive but is limited to five-yearly measurements for most attributes (e.g., invertebrates).

First released in 2012, Te Awarua-o-Porirua Harbour and Catchment Strategy and Action Plan (the Strategy) recognised that cleaning up the Harbour and its catchment is very much a community issue. Key principles of the Strategy include promoting community involvement in decision-making processes and restoration activities and developing and maintaining active partnerships between agencies and with the community. Developing a citizen science monitoring strategy for Te Awarua-o-Porirua will be important for meeting the objectives of the Strategy, as well as the recently released Te Awarua-o-Porirua Whaitua Implementation Programme (WIP), and also allows for expanding the coverage of existing monitoring networks and early warning detection of eutrophication issues in the Harbour.

In this report, we summarise existing monitoring activities in the Harbour and catchment, identify gaps in terms of the types of data collected and identify indicators that can be monitored by volunteers and could form the basis of a citizen science programme in Te Awarua-o-Porirua. However, volunteer water monitoring is more than just filling in gaps. Volunteer monitoring can also encourage innovation by aiding in the developing of new indicators (particularly around narrative ecosystem health objectives included in the Strategy and WIP), monitoring the success of restoration projects, providing a path for adaptive management, and identifying important hotspots of contamination or biodiversity.

1 Introduction

In 2012, the Porirua Harbour and Catchment Strategy and Action Plan (the Strategy) was launched in an effort to improve the health of the Te Awarua-o-Porirua Harbour (Porirua Harbour) and its waterways. However, community care and restoration groups, landowners and individuals have been working throughout the catchment to restore the streams, wetlands and coastal habitat long before the development of the Strategy. This is particularly the case for the Pāuatahanui Arm of the Harbour, reflecting the active involvement of long-established groups such as Guardians of Pāuatahanui Inlet (GOPI).

In April 2019, the Te Awarua-o-Porirua Whaitua Implementation Programme (WIP) was released, the culmination of a five-year collaborative discussion with various organisations and the community on the future management of the Porirua Harbour and catchment. The WIP, which will ultimately form part of the Greater Wellington Regional Council's Natural Resources Plan, recommends that restoration of the Harbour involve awareness-raising, encouraging innovation, encouraging citizen science and the establishment of additional catchment care groups.

NIWA was engaged by Porirua City Council (PCC) to summarise existing environmental monitoring activities in the Porirua Harbour catchment for the purpose of identifying opportunities for greater involvement of the community in these activities. Monitoring in the Harbour and catchment has been carried out for more than 30 years and has grown considerably in scope since around 2004 when Greater Wellington Regional Council (GWRC) implemented a new regionwide coastal monitoring programme. As well as routine monitoring, a range of research and targeted investigations has been carried out.

This report briefly summarises significant reviews of existing monitoring and investigations reported by Boffa Miskell Ltd (2000), Blaschke et al. (2010) and Oliver and Milne (2016) and includes more recent studies up until March 2020. The focus is primarily on longer-term monitoring and significant research/investigations (rather than small one-off research projects) in order to identify gaps that could be filled by community-led monitoring.

This is the first of two initial reports to inform the development of a proposed citizen science monitoring programme for the Porirua Harbour catchment. The second report (Valois 2020) reviews relevant citizen science monitoring initiatives and methods from New Zealand and overseas. As well as summarising current coastal (i.e., harbour) and freshwater (i.e., catchment) monitoring activities (Sections 2 and 3 respectively), current litter monitoring undertaken by Sustainable Coastlines is also outlined (Section 4), along with examples of indicators that could be monitored as part of a citizen science programme for the Porirua Harbour catchment (Section 5).

2 Existing coastal monitoring

Numerous scientific investigations have been carried out in Porirua Harbour since the 1970s, coinciding with the appearance of public health warnings advising against swimming and shellfish harvesting (Calder 2015). In terms of routine monitoring, water samples have been collected in the Harbour for the faecal indicator bacteria as part of recreational water quality monitoring since around the early 1990s. Currently, four sites in the Harbour are jointly monitored by GWRC and PCC for microbial water quality, two in the Onepoto Arm and two in the Pāuatahanui Arm. Two further monitoring sites are located at Plimmerton Beach. Water samples are collected weekly over the summer bathing period (December to March) and monthly at some sites over the winter.

In 2015 a microbial water quality forecast model was developed for seven sites in Porirua Harbour; three sites within each arm and one site at South Beach at Plimmerton. This model was initially an action under the Porirua Harbour and Catchment Strategy and Action Plan. Further development of the forecast model was put on hold in 2018 pending further operational-related considerations.

Many of the earlier scientific studies focussed on the Pāuatahanui Arm. A comprehensive three-year study of physical and biological indicators, in response to concerns of increasing sediment loads from urban development, was carried out between 1975 and 1977 as part of the Pāuatahanui Environmental Programme (Healy 1980). In the late 1980s, 72 sediment sites were assessed across both arms of the Harbour for heavy metal pollution (Glasby et al. 1990). Pāuatahanui Inlet hosted the inaugural Community Cockle count in 1992, led by the GOPI. The cockle count remains ongoing to this day, held every three years, representing the longest running citizen science project in New Zealand. There have also been periodic assessments of faecal and toxic contaminants in shellfish flesh, beginning in 1997, with the last assessment undertaken in 2006 (Milne 2006).

Monitoring of harbour ecosystem health was ramped up in 2004 when GWRC implemented an expanded coastal monitoring programme across the Wellington region. Initial monitoring focussed on subtidal basins as sinks for both fine sediment and stormwater-derived toxicants, with monitoring of benthic sediment quality and macrofauna carried out once every three to five years. In 2008, an ecosystem health programme was introduced for the intertidal flats (Robertson and Stevens 2009), following an inaugural broad scale survey of the entire substrate and vegetation types across the entire Harbour (Stevens and Robertson 2008). The fine scale intertidal programme was carried out annually at two sites in each arm to measure a range of sediment properties (oxygen depth, grain size, organic content, nutrients and toxic contaminants) and biological indicators (epifauna and infauna). After annual surveys for three years, monitoring of most indicators was reduced to five-yearly intervals, with macroalgal cover continuing to be monitored annually until 2016. Sedimentation rates continued to be monitored annually; a total of 18 sedimentation plates are now located throughout the harbour and measured in January each year. Harbour-wide bathymetric surveys have also been carried out (e.g., Discovery Marine 2009), and ecological monitoring has been performed at various intertidal locations throughout the harbour by Boffa Miskell Ltd as a requirement of NZTA's consents to construct the Transmission Gully Motorway.

For a two-year period from January 2011, monthly water sampling was carried out at six locations in the harbour to provide information on nutrient, chlorophyll *a* and suspended sediment concentrations that would assist with understanding conditions for potential seagrass restoration; two sites in the Onepoto Arm, three in the Pāuatahanui Arm and one at the harbour entrance (Oliver and Milne 2012).

In 2015, NIWA and Ngāti Toa estimated the distribution and density of shellfish species within the Onepoto Arm, representing the first systematic survey of shellfish across the entire intertidal habitat (Lyon and Michael 2015). A total of 13 different species or species groups were found, with cockles the dominant shellfish species, as is the case in the Pāuatahanui Arm.

Birds have been documented by the Ornithological Society of New Zealand with a focus on the Department of Conservation (DOC)-managed Pāuatahanui Wildlife Reserve. The Bird Atlas of New Zealand (Robertson et al. 2007) provides a current summary of this information. In 2016, a Spotless crake survey was carried out across a number of wildlife reserves in the Pāuatahanui Arm.

The Porirua Harbour is widely recognised as an important feeding ground and nursery area for many species of fish. Fish surveys have been undertaken since the 1970s (Healy 1980, Jones and Hadfield 1985, Francis et al. 2012) and more recently heavy metal accumulation was assessed in benthic fish from eight sites across the Harbour (Cook-Auckram 2018).

3 Existing freshwater monitoring

Stream water quality has been routinely monitored across the Porirua Harbour catchment since 1987. The number of sites regularly measured has changed over time as has the number and suite of variables measured (Cameron 1988, Mitchell and Heath 2019). Currently, GWRC monitors water quality and deposited fine sediment monthly at three sites as part of its Regional Water Quality and Ecology (RWQE or State of the Environment) monitoring programme; Horokiri Stream (at Snodgrass), Pāuatahanui Stream (at Elmwood bridge) and Porirua Stream (below the Mitchell Stream confluence) Benthic macroinvertebrates, periphyton cover and habitat quality are also assessed at these sites annually, with periphyton cover and biomass now also assessed monthly at the Horokiri and Porirua Stream sites. An additional site, a tributary of the Horokiri Stream, was sampled for habitat quality, benthic macroinvertebrates and fish community composition as part of an ecological monitoring trial in 2017/18. Ecological monitoring is also carried out at various stream locations throughout the harbour catchment by Boffa Miskell Ltd as a requirement of NZTA's consents to construct the Transmission Gully Motorway.

Wellington City Council and PCC both monitored water quality at various stream and stormwater locations across the wider harbour catchment for a number of years. Most of this monitoring was limited to microbial water quality and was designed to detect faults associated with stormwater and sewerage infrastructure. This monitoring is now carried out by Wellington Water Limited (WWL) as part of its global resource consent for stormwater discharges across metropolitan Wellington. WWL's Stormwater Monitoring Plan also includes two autosampler sites in the Porirua Stream catchment to measure a range of stormwater contaminants. At this stage, it is proposed that the autosamplers are used to monitor contaminants from 5-6 storms over two years (WWL 2019). Stream sediment quality monitoring will also be undertaken in four streams and water quality in Taupō Stream will monitored monthly for two years to improve information on the effects of stormwater inputs on this stream (WWL 2019).

Various other stormwater-related stream investigations have been carried out over the past 15 years. Sampling to assess metals and organic compounds was undertaken in Browns Stream and Duck Creek (Pāuatahanui Arm) and the Semple Street stormwater drain (Onepoto Arm) between 2002-04 (Kingett Mitchell 2005). Monitoring of stream sediment contaminants and the quality of wet-weather stream flows occurred between 2005-07 and 2009 (Milne and Watts 2008, Sorensen and Milne 2009). Between 2011 and 2014, wet weather water quality sampling was carried out across the subcatchments and mainstem of Porirua Stream (Milne and Morar 2016).

In terms of hydrology, rainfall is monitored by GWRC at a number of locations, including Whenua Tapu (Taupō catchment) and Battle Hill (Horokiri catchment). WWL monitors rainfall at James Cook Reservoir (Duck Creek catchment) and at the RNZ transmitter (Titahi Bay). Metservice, in conjunction with GWRC and PCC, also maintains a rainfall and weather station in Elsdon and NIWA currently maintains a rainfall station at Te Puka in relation to the Transmission Gully Motorway construction. Stream flow is routinely measured by GWRC in Taupō Stream (at Flax Swamp), Horokiri Stream (at Snodgrass), Pāuatahanui Stream at Gorge) – Pāuatahanui and Porirua Stream (at Town centre).

To establish baselines for sediment loads entering Porirua Harbour, GWRC installed continuous turbidity monitoring stations from 2012/13 onwards in the lower reaches of Porirua, Pāuatahanui and Horokiri streams. These streams drain the three largest subcatchments of Porirua Harbour and were identified via CLUES modelling as the greatest contributors of sediment to the harbour. The data gathered from monitoring to date allowed for the calculation of sediment loads and yields between 2012 and 2018 (Morar and Alberto 2019). Sediment loads entering the Harbour as part of the construction of the Transmission Gully Motorway are also monitored.

There are ten natural freshwater wetlands remaining in the Porirua Harbour catchment. Most of these wetlands are less than two hectares in size, but Taupō Swamp, at 36 hectares, is one of the largest wetlands in the Wellington region. Queen Elizabeth II National Trust (QEII) owns the majority of Taupō Swamp and have monitored wetland bird species, lizard species and carried out vegetation mapping (including aquatic weeds). There is a consultation process underway to redevelop the Plimmerton Farm into houses; this development has the potential to impact Taupō Swamp and may warrant further monitoring.

A widescale fish passage barrier assessment was undertaken by students (funded by GWRC) in the summer of 2018/19 using the Fish Passage Assessment Tool developed by NIWA. The students assessed 100 structures in the catchment of the Onepoto Arm. No assessments were performed in the Pāuatahanui catchment but a barrier to fish passage (weir) was identified in Taupō Stream (GWRC 2019). A survey of available habitat for inanga spawning was completed in April 2001 (Taylor and Kelly 2001), with a more recent survey completed in 2016 (Taylor and Marshall 2016).

4 Existing litter monitoring

Litter has been identified as a significant issue, in both Porirua Harbour and throughout the catchment (PCC 2012), with excessive accumulation in the southern portion of the Onepoto Arm removed on several occasions to date. However, litter is an issue throughout the entire Harbour and catchment. For example, in 2016 during a survey of spotless crakes in the Pāuatahanui Arm, extensive rubbish was observed along the shoreline and in the reserves upstream in Ration Creek and Horokiri Stream (Cotter 2016). Litter management was identified as a key objective in the Porirua Harbour and Catchment Strategy and Action Plan, with the focus on identifying and stopping litter at its source.

Litter clean ups have been conducted by businesses and community groups across the catchment but only recently has standardised litter monitoring been undertaken following the development of standardised marine litter monitoring methods by Sustainable Coastlines (in collaboration with DOC and Statistics NZ).

Marine litter is currently monitored at three sites in the Onepoto Arm; along Wi Neera Drive, at the mouth of Porirua Stream, and near the Paramata bridge. Litter is also monitored at Onehunga Bay in Whitireia Park and at Hongoeka Beach in Hongoeka Bay (near Plimmerton). Mountains to Sea Wellington (MTSW) has also conducted litter monitoring with Natone Park School in Waitangirua.

The highest density of litter was collected at the Paramata bridge site, with over 6,000 pieces per 1,000 m^2 collected during an event in November 2019 (almost triple the average litter levels across New Zealand). The other sites in the Onepoto arm also yielded a high amount of litter (~700-2,000 pieces per 1,000 m^2). Very little litter was collected from Onehunga Bay and Hongoeka Bay.

Litter items are overwhelmingly plastic; primarily food wrappers and unidentifiable plastic films and fragments. The large amounts of plastic fragments suggest that plastic is being broken down in the Harbour. No microplastic studies have been conducted to understand how much plastic is being retained in the Harbour and entering the sediment or food chain.

5 Current status of Te Awarua-o-Porirua Harbour and catchment

The most significant issues throughout Te Awarua-o-Porirua Harbour and catchment that have been identified from recent monitoring activities and outlined in the updated Te Awarua-o-Porirua Harbour and Catchment Strategy and Action Plan (PCC 2015) and Te Awarua-o-Porirua Whaitua Implementation Plan are described below. A more detailed summary of these issues is given in Table 5-1.

- Faecal contamination resulting from inadequately performing stormwater and wastewater networks and poor farm management practices.
- Sediment from eroding stream banks, urban development, motorway construction, forestry harvest, and run-off from pastures.
- Contamination from stormwater runoff (e.g., heavy metals, PAHs, sediment, nutrients).
- Nutrient inputs from agricultural runoff as well as stormwater and wastewater inputs.
- Impaired invertebrate communities (in the intertidal areas of the Harbour and throughout the streams) which reflect a wide variety of stressors.
- Habitat loss, including losses of seagrass and saltmarsh habitat in the Harbour and vegetation along the Harbour edge and loss of riparian and catchment vegetation along tributary streams. Habitat loss also includes alterations of the stream channel and reclamation of parts of the Harbour.
- Biodiversity losses, including reductions in the number of birds using the Harbour and unknown impacts on riparian diversity.
- Climate change poses a significant risk to the health of the Harbour and surrounding catchment but the potential impacts of sea level rise are difficult to assess.
- Extensive litter accumulating in the Onepoto Arm with a lack of catchment monitoring of litter inputs.

Table 5-1: Summary of the key findings from marine and freshwater monitoring activities in Te Awarua-o-Porirua Harbour and catchment and what they reveal about current Harbour and waterway health. Note that the information summarised here is indicative only; monitoring data continue to be collected and new statistics (e.g., sedimentation rates) reports released.

	Marine Environment	Freshwater Environment
Faecal contamination	Enterococci concentrations > 280 per 100 mL indicate that a coastal site is not suitable for swimming. Up to 6,500 enterococci/100 mL have been recorded in the Onepoto Arm[1]. In contrast, the highest enterococci concentrations in the Pāuatahanui Inlet was 480 n/100 mL[2]. During dry periods, enterococci levels normally range between 4 and 40 per 100 mL in both arms, although sewerage infrastructure issues have resulted in dry weather inputs of faecal contaminants.	*E. coli* concentrations at GWRC's long-term stream monitoring sites show that some stream sites are unlikely to meet the National Policy Statement for Freshwater Management (NPS-FM) bottomline attribute state for contact recreation. These include Porirua Stream at Wall Park, the lower reaches of the Kenepuru Stream and the lower reaches of Browns Stream (Miller et al. 2015). The highest *E. coli* concentrations have been found in Porirua Stream (5-year median = 1,400 n/100 mL) where concentrations are increasing over time[3].
Sedimentation	Modelled annual sedimentation rates for the Pāuatahanui Arm and Onepoto Arm are 4.7 mm and 4.1 mm, respectively (compared to historical rates of 1-2 mm/year). The inability to find two out of the five sediment plates in Pāuatahanui Inlet (due to deep mud) suggests current sedimentation rates are underestimated, with Duck Creek and Kakaho sites recording significant accumulation of mud[4].	Erosion due to development, historical forest clearance and unsustainable farming practises has resulted in high sediment loads entering some streams. Stream banks and unstable soils need more vegetation cover (Morar and Alberto 2019). Trends in stream visual clarity are improving over time, most likely due to ther rapid flushing of fine sediment from some streams during storms (Milne and Watts 2008, Sorensen and Milne 2009).
Stormwater contaminants	Metal concentrations in the harbour sediments are rated 'moderate' but there are hotspot areas adjacent to the mouths of the Porirua, Onepoto and Browns streams and Duck Creek (Sorensen and Milne 2009). Subtidal areas are at most risk because this is where the fine sediments (with the highests metal concentrations) tend to accumulate. Investigations of contaminants in cockles and fish have detected trace metals (particularly zinc), although concentrations were below recommended guidelines (Milne 2006, Cook-Auckram 2019).	Stormwater contaminants, including heavy metals (particularly zinc) and polycyclic aromatic hydrocarbons are present in the streambed sediment, particularly in urban and industrial areas. However, most fine sediment (and the contaminants attached to them) are not retained in the streams for long but instead rapidly flushed into the harbour during storms (Sorensen and Milne 2009). Sources of chemical pollutants include roads, roofing, residential properties, and illegal discharges from business and industrial users (PCC 2015).

[1] https://www.lawa.org.nz/explore-data/wellington-region/swimming/porirua-harbour-at-wi-neera-drive-boat-ramp/swimsite
[2] https://www.lawa.org.nz/explore-data/wellington-region/swimming/pauatahanui-inlet-at-water-ski-club/swimsite
[3] https://www.lawa.org.nz/explore-data/wellington-region/river-quality/porirua-stream/porirua-stream-at-wall-park/
[4] https://www.gw.govt.nz/assets/council-publications/Porirua-Harbour-Sedimentation-plate-monitoring-2019.pdf

	Marine Environment	Freshwater Environment
Nutrient inputs	Nutrient inputs into the harbour are high enough to sustain elevated macroalgal growth but not at nuisance levels. Monitoring has not revealed any significant gross eutrophic zones but sediment oxygenation (an indicator of eutrophication) is shallow and requires further investigation (Stevens and Robertson 2016).	The median total nitrogen concentration in Porirua Stream is approximately three times higher than in Pāuatahanui Stream. Nutrient levels appear to be decreasing except in the lower Horokiri Stream where they are increasing. Nitrate is below levels likely to cause toxic effects but urban areas can have peak concentrations with the potential to affect sensitive species. Periphyton assessments have shown that nuisance or toxic algal growth is not an issue in the catchment due to frequent flushing events (Miller et al. 2015).
Invertebrate health	Reasonably diverse invertebrate communities exist but there is some evidence for a decline in richness and abundance in the southern Porirua Arm. The Pāuatahanui Inlet cockle count revealed a a 50% population decline from 1976 levels, however it is on the increase again (Michael and Wells 2017). There is a high diversity of other shellfish but surveys have not determined whether numbers are in decline (Lyon and Michael 2015).	Benthic macroinvertebrate sampling reveals a range of ecosystem health values from 'good' to 'poor'[5]. Streams with good health tend to be hill country streams while poor health sites are more common in urbanised catchments (e.g., Porirua and Kenepuru streams).
Habitat	Saltmarsh is largely absent from the Onepoto Arm but occupies extensive areas of Pāuatahanui Inlet. There have been considerable losses in saltmarsh cover but no changes since 2008, with restoration initiatives seeking to improve saltmarsh condition. Declines in seagrass beds from historical cover have been recorded, with more recent losses attributed to the stress of macroalgal smothering, increased sediment muddiness and elevated nitrate concentrations (Matheson and Wadhwa 2012).	Many of the streams have been extensively modified (piped and channelised), particularly in the lower reaches which has had major impacts on biodiversity, reducing available habitat for invertebrates and fish. There is limited riparian cover in many streams and some riparian habitats are overrun with weeds and pest animals (Miller et al 2015). In a survey of streams in Wellington City, greater riparian cover was associated with higher macroinvertebrate community health scores (Harrison 2019).

[5] https://www.gw.govt.nz/annual-monitoring-reports/2019/rivers-water-quality-and-ecology/ecology.html

	Marine Environment	Freshwater Environment
Biodiversity	Pāuatahanui Inlet is a nationally significant location for wetland bird species with surveys noting an increase in diversity but declines in the total number of birds using the Inlet. Twent-one fish species live in the harbour and it is an important nursery for rig but surveys and oral history accounts suggest large population decreases over historical numbers. The non-native kelp species *Undaria* has been detected in the harbour but its spread is unknown (Stevens and Robertson 2008).	Teh streams support a range of native fish species with Porirua, Pāuatahanui, Horokiri, Kakaho and Taupō streams and Duck Creek supporting six or more indigenous fish species and inanga spawning sites. Barriers to fish passage remain and there have been major losses of inanga spawning habitat (Taylor and Marshall 2016). Aquatic weeds are present throughout streams catchments. In Taupō Swamp, cape pond weed (*Aponogeton distachyos*), beggars tick (*Bidens frondosa*) and monkey musk (*Erythrante guttata*) have been recorded, although only cape pond weed was declared as having an ecological impact (GWRC 2016).
Climate change	Sea-level rise has been estimated at 1.95mm/year (Gibb and Cox 2009) yet its impact on the ecosystem is unknown. A storm tide of 0.72 m above normal high water was observed in Pauatahanui Inlet (Gibb 1978). The Pauatahanui Inlet is at risk of flooding, impacting sensitive saltmarsh and seagrass habitat (Stevens and Robertson 2008). Sediment monitoring has revealed a single large storm event (50-year return flood) can bring 6 Kt of sediment from Porirua Stream to the harbour (Morar and Alberto 2019).	Monitoring has not been undertaken to understand the impacts of climate change but weather extremes are expected to get worse with climate change. Increased flooding in the stream catchment will result in a greater potential for stormwater contaminants and wastewater overflows. Increasing drought can lead to loss of fish habitat and impacts on fish spawning. Higher water temperatures will likely impact native species (Lundquist et al. 2011, PCC 2015).

6 Citizen science programme indicators

The Porirua Harbour and Catchment Strategy and Action Plan (PCC 2015) established three key objectives:

1. Reduce sedimentation rates,
2. Reduce pollutant inputs, and
3. Restore ecological health.

The Strategy sets out a series of indicators related to each of these objectives. Each indicator also includes its current condition, target levels to meet, and a date by which the target could realistically be achieved.

Many of the indicators could be monitored by volunteers. In the coastal environment, these indicators include enterococci concentration, macroalgae cover, sedimentation rate and sediment mud content. However, it is important to note that it is difficult for volunteers to measure the sediment attributes and so these may not be suitable as indicators for a community-led monitoring programme. Other suitable indicators include those not monitored on a frequent basis by GWRC, such as saltmarsh and seagrass habitat, bird diversity and terrestrial buffer composition. These indicators have been shown to be an important component of harbour health and are often indicators that the public is excited to monitor or may displays= a particular skill in monitoring (e.g., bird or plant identification skills).

In the freshwater environment, indicators that could be monitored by volunteers include concentrations of *E. coli* and nitrate-nitrogen, native fish (fish passage barriers), periphyton coverage, and benthic macroinvertebrate health. The narrative expression of the stream habitat objectives in the Te Awarua-o-Porirua Whaitua Implementation Programme allows for considerable scope for developing indicators that break away from traditional monitoring activities. This could include measures of riparian diversity (terrestrial insects, birds), weeds and pest species, and riparian microclimate along stream corridors.

At the time of preparing the Porirua Harbour and Catchment Strategy and Action Plan no standardised litter monitoring protocol existed but a target was included for a significant reduction of litter accumulation in and around the Harbour for which future improvements could be measured. The collection of litter data under the Litter Intelligence monitoring framework beginning in 2019 has since provided the first estimates of litter accumulation rates for the Onepoto Arm and the ability to compare litter densities to other harbours across New Zealand. The ability to determine the source of the litter is lacking from existing monitoring activities as only certain litter types would be re-stranding along the Harbour margins, with much of the litter lost to subtidal areas or being broken down into smaller pieces. Overall, there is considerable potential for the community to work towards identifying priority litter items. By sampling stormwater and stream litter inputs to the Harbour, baseline estimates of litter inputs will allow the development of litter reduction targets.

7 Conclusion

There has been a significant amount of monitoring activity in the Porirua Harbour catchment over the past 30 years, but there remains a number of opportunities where community-led initiatives could be introduced.

In the marine environment, monitoring of saltmarsh and seagrass habitat will provide a clearer picture on whether these habitats are recovering in condition and extent. Bird monitoring could provide an inventory of the birds that use the Harbour, monitor status and trends in these birds, and assess the effectiveness of restoration actions (e.g., saltmarsh restoration).

In the freshwater environment, volunteers can monitor new indicators (e.g., stream and stormwater litter, riparian health indicators, ecosystem metabolism indicators) and expand the spatial and temporal coverage of existing indicators. For example, Farnham et al. (2016) demonstrated how a citizen science campaign could monitor waterways impacted by inputs of stormwater and untreated sewage during periods of rainfall in New York City. Volunteers could collect water samples for faecal bacteria analysis from smaller tributaries which are not routinely monitored or at specific times when council or WWL sampling may not be occurring.

Volunteers could also play an important role in contributing to research around restoration success. Significant improvements in inanga spawning habitat have already been documented in the Kakaho and Horokiri streams response to restoration activities (Taylor and Marshall 2016). Volunteers could contribute to the continued evaluation of other restoration efforts (e.g., stream plantings, fish barrier removals, in-stream habitat restoration).

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